# Green Startup's Eco-Innovation Strategy: A Lean Startup Approach

**Abstract:** Green startups are at the forefront of initiating a societal transition toward a greener and more competitive economic model by developing and spreading radical eco-innovations. This study explores green startups' eco-innovation activities through semi-structured interviews to describe and provide insights into their eco-innovation strategies. The results found that green startups follow a three-phase approach derived from the lean startup methodology to identify, build, and exploit green opportunities. A notable observation highlights that green startups address their environmental objectives sequentially through three iterative cycles, starting from the products' environmental benefits and ending with setting up sustainable operations. The success of green startups' environmental objectives is greatly influenced by industry stakeholders who provide essential information, resources, and capabilities (manufacturing, distribution, recovery), and engage in prototype evaluations. This study contributes to the growing eco-innovation literature through key findings and 6 propositions, and provides valuable insights to managers and policy-makers to engage and support eco-innovation development and adoption.

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# 1 Introduction

With the growing environmental challenges of the linear economic model, economies are increasingly pressured to transition toward a more sustainable model. Under the current linear economic model, natural ecosystems are depleted of resources and severely damaged by human activities. Consequently, natural ecosystems' capability to renew resources and recover externalities has been shrinking over the years, jeopardising environmental stability vital for economies, humans, and nature survival. Neglecting to address this issue will increase environmental disaster occurrence and stringency, severely impacting society prosperity, for example, by damaging infrastructure, disrupting supply chains, and diminishing population's health and well-bing (COACCH, 2021).

Shifting toward a circular economy is commonly understood as the best solution to reduce economies' environmental footprint and restore Earth's natural ecosystems. Through a circular economy model, 'stakeholders collaborate to maximise the value of products and materials, and as such contribute to minimising the depletion of natural resources and create positive societal and environmental impacts' (Kraaijenhagen et al., 2016, p. 15). To successfully transition toward this model, developing and adopting eco-innovation is essential (Hizarci-Payne et al., 2021). Broadly, eco-innovations are similar to standard innovations, except that they provide environmental externalities in addition to the knowledge ones (Cecere et al., 2015; De Marchi, 2012; Klewitz & Hansen, 2014). This particularity is known as the double externality effect and allows firms to simultaneously improve their economic and environmental performance (Hizarci-Payne et al., 2021). Namely, eco-innovators tend to adapt faster to industry and market changes (Hoogendoorn et al., 2020; Klewitz et al., 2012) and come up with harder to imitate solutions (Doran & Ryan, 2016), reduce operational costs by avoiding environmental regulation taxes (Ghisetti & Rennings, 2014; Hizarci-Payne et al., 2021) and using resources more efficiently (Ben Arfi et al., 2018; Klewitz & Hansen, 2014), or increase turnover by reaching new markets (Arroyave et al., 2020; Ben Arfi et al., 2018; Doran & Ryan, 2016; Klewitz et al., 2012), securing partnerships (Hizarci-Payne et al., 2021; Sáez-Martínez et al., 2016), and selling environmental features at a premium (Ben Arfi et al., 2018; Hockerts & Wüstenhagen, 2010; Klewitz et al., 2012).

Among all organisations, green startups are considered leading industries' and markets' sustainable transition by developing and diffusing radical eco-innovations (Hockerts & Wüstenhagen, 2010; Pakura, 2020). To begin with, eco-innovation's research and development activities differ from standard innovation, as they pursue a different purpose (Horbach et al., 2013; Wicki & Hansen, 2019). Led by sustainable entrepreneurs, green startups' decision making is influenced by environmental considerations, and their environmental objectives share an equal importance to economic ones (Klewitz & Hansen, 2014). Moreover, most incumbent firms are deeply locked into pollution-intensive knowledge, technologies, and activities leading to high sunken costs to adapt their offerings and activities (Cecere et al., 2015). Due to their young age, green startups have no set offerings and activities, reducing their chances of technological lock-in and avoiding sunken costs to change (Hockerts & Wüstenhagen, 2010). Finally, other firm-specific characteristics found in green startups, such as a lean mindset and a smaller and simpler organisational structure enable green startups to swiftly adapt to industry and market shifts and more easily cooperate among functions and with stakeholders (Bocken et al., 2014). For these reasons, green startups appear to drive industries and markets

environmental transition as they strive in existing market failures and continuously come up with radical eco-innovations.

Even though recent studies suggest green startups are green champions, an existing gap in eco-innovation literature fails to explain how they proceed (Tiemann et al., 2018). Moreover, eco-innovation literature is severely lacking (Aboelmaged & Hashem, 2019; Pinget et al., 2015), without clear definitions and understanding (Brown et al., 2019; Carrillo-Hermosilla et al., 2010; Hizarci-Payne et al., 2021). Currently, most studies rely on standard innovation literature (Cuerva et al., 2014) and are limited in understanding the similarities and differences between both eco-innovation and standard innovation. For example, Pinget et al. (2015) investigated eco-innovations' barriers using standard innovations' ones, Wicki & Hansen (2019) explored the innovation process used by non-eco-innovative firms, or the influence of collaborative or open-innovation activities in the eco-innovation context has been studied (Brown et al., 2019; Wicki & Hansen, 2019). While a broader understanding of eco-innovation is rapidly growing, literature about strategies applied by eco-innovators is relatively thin and essentially focuses on large incumbents (Bocken et al., 2018). Thus, the following research question is raised: How do green startups define and execute successful eco-innovation strategies that allow them to stay afloat and bring their product to the market?

The present research will provide several implications for eco-innovation literature, managers and policy-makers. First, the study will complement the eco-innovation and green startup literature with explorative and qualitative data about the activities performed and strategies followed by green startups in the Netherlands. Currently, most studies rely on the same quantitative data sets provided by the European Union which do not specifically target eco-innovators and only focus on drivers and challenges faced by European companies. While several recent studies follow a qualitative approach, providing greater details and exploring eco-innovation specifics, only a few studies, such as Bocken et al., (2018) and Buhl (2018), have particularly investigated firms' eco-innovation strategies. However, their studies have focused on bigger firms, which are generally less successful and active with respect to eco-innovations than green startups (Hockerts & Wüstenhagen, 2010). Therefore, the present study will complement the eco-innovation literature by suggesting a framework outlining green startups' eco-innovative strategy in the Netherlands. Next to the framework, the study will complement eco-innovation literature with more empirical evidence about drivers and barriers, as well as stakeholders' implications and roles in Dutch green startups eco-innovation activities. Next, managers can leverage the insights from this study to understand how other green startups eco-innovate. To be more precise, managers can adopt and modify the proposed framework to complement their current and future eco-innovative activities and strategies. Finally, policy-makers can also benefit from the present study to stimulate more companies to keep environmental considerations into account and to improve regulations supporting firms' eco-innovation efforts, which currently do not reach optimal effectiveness (Cecere et al., 2015; Pinget et al., 2015; Sáez-Martínez et al., 2016).

# 2 Theoretical Framework

## 2.1 Eco-innovation

Eco-innovations are innovations with the primary purpose of benefiting the environment, deliberately or not (Cecere et al., 2015; Cuerva et al., 2014). Also referred to as green, sustainable, or environmental innovations, eco-innovations consist of new or improved

products, processes, organisation, and marketing innovations developed and adopted at different societal levels, ranging from micro to macro (Cecere et al., 2015; Klewitz & Hansen, 2014). These innovations aim to reduce environmental degradation caused by human activities, to contribute to natural ecosystem regeneration and resilience, and to satisfy current needs while preserving the capacity of future generations to fulfil their own by providing positive environmental externalities (Cecere et al., 2015; Klewitz & Hansen, 2014). Therefore, eco-innovations perform environmentally better than alternative standard or 'brown' innovations by providing environmental benefits at any stage of a product life cycle, from its conception to disposal (Horbach et al., 2013). The particularity and interest behind eco-innovation consist in its double externality effect. While the primary purpose is environmental, eco-innovation also provides both non- and pecuniary economic advantages to eco-innovators. In other words, eco-innovations can simultaneously contribute to transitioning societies toward more sustainable models while improving their competitiveness.

Environmental benefits are commonly split into two groups. On the one hand, eco-innovations reduce the generation of negative or unwanted externalities, which comprise all pollution types. For example, air, water, soil, noise, harmful materials, and by-products generated during products' production, distribution, and consumption (Ghisetti & Rennings, 2014). Depending on the eco-innovation, the effectiveness ranges from improving firms' capability to manage externalities from avoiding their releases to fully ceasing their generation in the first place (Ghisetti & Rennings, 2014). Ultimately, such eco-innovations may enhance the environment's regeneration capability and resilience (Carrillo-Hermosilla et al., 2010). On the other hand, eco-innovations can improve resource, energy, and surface efficiency. In most cases, such eco-innovations aim to maximise resource usage by reducing the input required to produce, deliver, and consume the same product units. Alternatively, they enhance resources and energy efficiency by substituting currently used ones with renewable alternatives.

### 2.1.1 Type and Nature

The environmental benefits are achieved by developing or adopting different eco-innovation types. Similarly to standard innovation, there are four eco-innovation types, namely product, process, organisational and marketing (Hizarci-Payne et al., 2021; Horbach et al., 2012; Kiefer et al., 2019), which differ in their environmental benefits. Generally, only product and process eco-innovations provide environmental benefits (Klewitz & Hansen, 2014). In contrast, organisational and marketing eco-innovations promote and ease the development and adoption of the former within and outside the firm (Klewitz & Hansen, 2014). Additionally, the environmental benefits of products and marketing eco-innovations essentially occur outside firms' boundaries, while process and organisational eco-innovations tend to directly improve firms' internal environmental performance (Horbach et al., 2012). Moreover, the intensity of eco-innovations environmental benefits varies based on their level of novelty (Carrillo-Hermosilla et al., 2010; Triguero et al., 2013). Radical eco-innovations, which depart from existing systems, usually have a greater positive environmental impact than incremental eco-innovations, which complement existing systems (Carrillo-Hermosilla et al., 2010; Klewitz & Hansen, 2014). However, incremental eco-innovations are faster to develop and adopt, allowing companies to rapidly improve their environmental performance, even if marginal, while waiting for radical eco-innovations (Carrillo-Hermosilla et al., 2010).

Product and process eco-innovations pertain to the adaptation of existing or development of new goods and services and manufacturing and delivery processes. Whereas

cleaner production systems, including end-of-pipe technologies, and eco-efficiency processes are the dominant concepts defining process eco-innovations, eco-design dominates product eco-innovation literature (Hizarci-Payne et al., 2021; Klewitz & Hansen, 2014). Eco-design consists of incorporating environmental considerations in developing new and existing products to mitigate environmental harm throughout their life cycle (Hizarci-Payne et al., 2021; Klewitz & Hansen, 2014). In other words, eco-design consists of changes in a product design to use fewer and more sustainable resources, extend its longevity, and improve its repairability and recyclability (Cecere et al., 2015; Klewitz & Hansen, 2014). Cleaner production systems and end-of-pipe technologies enhance firms' handling of waste, with the former referring to technologies reducing or stopping the generation of negative externalities and the latter to innovations enhancing a firm's management after it was generated (Ghisetti & Rennings, 2014; Klewitz & Hansen, 2014). In contrast, eco-efficient processes focus on reducing the resources and energy input required to manufacture and deliver a product by reusing by-products and making production processes more efficient (Ghisetti & Rennings, 2014; Klewitz & Hansen, 2014).

Organisational and marketing eco-innovations consist of all practices to support the development and adoption of eco-innovations (Horbach et al., 2012; Klewitz & Hansen, 2014). On the one hand, organisational eco-innovations roughly refer to including environmental considerations in firms' decision-making, strategy and vision (Klewitz & Hansen, 2014; Rennings, 2000). In other words, organisational eco-innovations entail the adoption of new managerial tools, routines and organisational structure that promotes or supports the development and adoption of eco-innovations (Hizarci-Payne et al., 2021; Klewitz & Hansen, 2014; Rennings, 2000). As such, organisational eco-innovations entail the usage of environmental management systems (EMS) or other tools to assess firms' environmental impact, the adoption of environmental norms, engaging employees in eco-innovation activities and training, and introducing environmental concerns in stakeholder management activities. On the other hand, marketing eco-innovations essentially consist of corporate social responsibility (CSR) activities undertaken by the firm (Hizarci-Payne et al., 2021). Overall, organisational and marketing eco-innovations raise awareness within and outside organisational boundaries about environmental challenges, increasing the likelihood of developing and adopting eco-innovations or sustainable practices (Klewitz & Hansen, 2014).

### 2.1.2 Double Externality and Economic Benefits

In addition to the environmental benefits, eco-innovations also provide non-negligible competitive advantages to firms (Hizarci-Payne et al., 2021). Overall, eco-innovations enhance firms' competitiveness, efficiency, reputation, growth and profitability (Ghisetti, 2017; Hizarci-Payne et al., 2021; Klewitz & Hansen, 2014).

First, eco-innovative firms tend to be more competitive and efficient than their counterparts. Namely, eco-innovators, which are considered more innovative than non-eco-innovative organisations (Hoogendoorn et al., 2020; Klewitz et al., 2012), are usually capable of introducing new and more challenging to imitate products at a faster pace than their competitors (Doran & Ryan, 2016). They are also capable of rapidly reorganising current or establishing new processes and infrastructure (Klewitz & Hansen, 2014). Therefore, eco-innovators adapt to environmental changes, such as new regulations, market trends change, and partners' demands more quickly (Doran & Ryan, 2016; Klewitz & Hansen, 2014). Finally, eco-innovators also enjoy enhanced productivity as fewer resources are required to manufacture and

distribute the same units of goods and services, fewer externalities have to be handled, and eco-innovators' work environment is safer for its labour when fewer harmful materials and externalities are used and generated, reducing downturn risks or additional procedures (Doran & Ryan, 2016; Klewitz et al., 2012; Klewitz & Hansen, 2014).

Next, the addition of environmental features in firms' products and processes positively enhances eco-innovators' brand image toward different stakeholders (Hizarci-Payne et al., 2021). First, the induced increase in flexibility and innovativeness increases eco-innovators' reputation within their industry. Therefore, eco-innovators find suitable partners with greater ease (Hizarci-Payne et al., 2021; Sáez-Martínez et al., 2016). Second, the decrease in harmful usage and reduction of externalities enables firms to become more attractive to the labour market (Klewitz et al., 2012). Additionally, firms incorporating a sustainable orientation in their core vision also attract a younger, specialised workforce, which is more sensitive to environmental responsibility (Klewitz et al., 2012). Finally, with the increase in quality or the incorporation of environmental features in products, eco-innovators tend to have a greater perception toward consumers as an eco-responsible and trustable brand (Arroyave et al., 2020; Hockerts & Wüstenhagen, 2010; Klewitz et al., 2012)

Finally, eco-innovations' capability to use resources more efficiently increases brand image toward different stakeholders and enhances firms' capability to develop highly differentiated and qualitative products directly and positively impact eco-innovator profitability. On the one hand, eco-innovators can minimise their operational costs through more efficient usage of resources (Ben Arfi et al., 2018; Klewitz & Hansen, 2014) by avoiding current or future environmental-related taxes (Ghisetti & Rennings, 2014; Hizarci-Payne et al., 2021), and through shorter research and development cycles (Hoogendoorn et al., 2020; Melander, 2017). On the other hand, eco-innovators see their revenue increase as they can reach new markets and customers for whom environmental features are important, as well as strengthen their current market positions through better product differentiation and increased product quality (Arroyave et al., 2020; Ben Arfi et al., 2018; Doran & Ryan, 2016; Klewitz et al., 2012). Additionally, customers are willing to pay a markup for the environmental or increase quality features offered by eco-innovations, hence increasing eco-innovators' margin (Ben Arfi et al., 2018; Hockerts & Wüstenhagen, 2010; Klewitz et al., 2012). Finally, eco-innovators' greater capability to secure partnerships and attract specialised labour assures long-term revenues, reducing market uncertainty (Hizarci-Payne et al., 2021; Klewitz & Hansen, 2014).

### 2.1.3 Determinants

Eco-innovations are driven or hampered by the same set of factors as standard innovations (Marin et al., 2015; van Hemel & Cramer, 2002). Thus, technology-push, market-pull, and regulatory pull-push constitute eco-innovations' determinant groups (Horbach et al., 2012; Pinget et al., 2015). Alternatively, the more recent eco-innovation literature also refer these groups as the demand side, market side, and regulatory side factors (Horbach et al., 2013; Marin et al., 2015; Triguero et al., 2013). Additionally, factors related to a firm's characteristics and capabilities are split from the supply side factors and are aggregated under the same group: firm side. (Pinget et al., 2015; Triguero et al., 2013). This distinction highlights the more importance these internal factors play in the eco-innovation context as they are more affected by a firm's characteristics and capabilities. Thus, the determinants of eco-innovation relate to the dynamics and characteristics of the market, industry, firm, and regulatory landscape. Finally, they also englobe more factors than standard innovation determinants. A reason for this can be found in

the addition of environmental factors, such as environmental awareness from the government and customers (Melander, 2017).

**Table 1 – Eco-innovation determinant groups**

| *Group* | *Definition* |
|---|---|
| Demand side | • Expected increase in market share or penetration of new markets<br>• Market environmental awareness<br>• Market preference for green products and public procurement |
| Supply side | • Industry environmental appropriability conditions<br>• Availability of capabilities and resources.<br>• Industry collaboration, supply chain pressure, networking activities |
| Firm side | • Firm characteristics (size, age, structure)<br>• Technological, managerial, and social capabilities<br>• Availability of resources within the company |
| Regulatory side | • Stringency and flexibility of existing and expected (environmental regulations)<br>• Availability to subsidies and fiscal incentives |

*Source: Horbach et al., 2013; Pinget et al., 2015; Triguero et al., 2013*

## 2.2 Differences with Standard Innovation

Identifying and addressing environmental problems complexifies innovation and operational activities. Environmental problems are difficult to analyse because of several reasons. First, environmental problems are highly dependent on the context as they are bound to the micro, meso, and macro characteristics, such as economic activities, available resources, and capabilities within a company or region (Marin et al., 2015; Rinaldi & Cavicchi, 2016; Triguero et al., 2016). As such, environmental problems continuously change over time due to industry, market, and societal changes. The adoption of eco-innovations as well as the improvement of tools to analyse environmental problem changes the focus toward other existing or previously undiscovered environmental problems to tackles (Klewitz & Hansen, 2014). Next, environmental problems can occur at any stage of a product's life cycle (Cecere et al., 2015; Klewitz & Hansen, 2014; Rennings, 2000). Thus, most of them will occur outside of eco-innovators' boundaries at the various stakeholders along the products' value chain (Hizarci-Payne et al., 2021). This means it is important to investigate the environmental performance throughout the full product value chain (Ben Arfi et al., 2018). Finally, in addition to technical and market knowledge, environmental knowledge is required to develop eco-innovation (Aboelmaged & Hashem, 2019; Bocken et al., 2014; Horbach et al., 2013). Additionally, assessing environmental problems requires knowledge, expertise, and tools that most firms or industries do not usually have, as such resources and competencies are distant from the ones they have (Pinget et al., 2015). Thus, overall, eco-innovation also requires more external knowledge sources than standard innovations (Arroyave et al., 2020; Horbach et al., 2013; Kiefer et al., 2019).

Finding a solution to an environmental problem is also not easy. For one environmental problem, multiple solutions are possible, however, with different environmental and economic impacts (Cecere et al., 2015; Ghisetti, 2017; Rennings, 2000; Rinaldi & Cavicchi, 2016). To be more precise, different eco-innovation types adopted within a company or by different external

stakeholders have the potential to address the same environmental problem (Arroyave et al., 2020). However, the different possible solutions provide different levels of environmental and economic performance, whether they are positive or negative (Ghisetti & Rennings, 2014). On the environmental side, one eco-innovation can be more effective in solving the environmental problem; however, it can generate a new environmental burden (Rinaldi & Cavicchi, 2016). Similarly, one solution may provide a competitive advantage to the eco-innovators, while another one with a greater and positive environmental impact may provide no or negative economic gains (Garcia et al., 2019). Radical eco-innovations make this even harder since they contribute the most to society's sustainable development goals; however, their environmental benefits are drastically more challenging to forecast, making the development of radical eco-innovation riskier (Brown et al., 2019; Carrillo-Hermosilla et al., 2010; Sáez-Martínez et al., 2016). Furthermore, the implementation of different eco-innovations at different stages of a product life cycle can have the same environmental benefits (Cecere et al., 2015). It is also hard to find a solution that maximises both environmental and economic performance (Garcia et al., 2019; Ghisetti & Rennings, 2014). The environmental benefits usually have no economic value (Ghisetti, 2017); only the society and other stakeholders in the value chain benefit from the environmental externalities, not the firm that is adopting the eco-innovation (Hamburg et al., 2017). This is especially the case for eco-innovations that focus on reducing negative externalities, which tend to only increase the number of tasks the firm needs to execute and operational costs (Ghisetti & Rennings, 2014). Environmental eco-innovations also require more testing in general, including in real conditions. During these tests, the environmental side needs to be tested thoroughly to make sure it works in all situations (Rinaldi & Cavicchi, 2016).

Additionally, implementing solutions for environmental problems is difficult as well. It happens quite often that the existing non-green infrastructure should be adjusted or undone to make place for a greener version. This is especially the case when a firm adopts an eco-innovation. For example, when replacing fossil fuels with solar panels, batteries are also required to balance the energy usage throughout the day since sunlight fluctuates during the day, resulting in more or less energy at a given moment. This is not only the case for the eco-innovator but also potentially for its industry partners (Rennings, 2000). Cooperation with specific stakeholders can become difficult as existing relationships may be incompatible with sustainable development (Ben Arfi et al., 2018; Melander, 2017). In other words, changing long-term partners might be necessary due to their unwillingness to adapt or their activities incompatible with a green model. Moreover, incumbent firms face the challenge that introducing green alternative products would directly compete with their existing non-green products (Hockerts & Wüstenhagen, 2010). Therefore, the firms must either create a different product that does not compete in the same market directly, or they must abandon the green alternative because it makes no sense to have both. Finally, to understand whether a solution is successfully implemented and provides the expected environmental benefits, measuring the environmental impact is lengthy as the environmental assessment can only be completed after the product reaches its end-of-life state (Rinaldi & Cavicchi, 2016).

### 2.2.1 Consequences of the Environmental Dimension on Eco-Innovation Activities

Based on the problems that firms face when analysing, finding, and implementing solutions for environmental problems, the firms can also face some additional drawbacks. First, the total effort for being sustainable is increased from development to exploitation of eco-innovation (Marin et al., 2015). Eco-innovating is more operationally intensive. From an internal perspective, firms need to take environmental considerations into account when making

decisions, collaborating with others, training collaborators and personnel, testing during and after development. The company's supply chain should also be taken into consideration since eco-innovators are likely to cooperate with more stakeholders to fulfil new activities related to the environmental dimension, such as assessing the firm's environmental performance or taking care of its product in its end-of-life stage. Sustainable development also increases the number of operational activities in general since new activities should be performed that non-green companies do not have to think about, like end-of-life recycling of eco-innovations, for example. For instance, (Ghisetti & Rennings, 2014) found that end-of-pipe eco-innovations always negatively affect profits because they do not increase the production or efficiency of a company; they just make sure that the externalities are not released into the environment. This results in extra activities that need to be performed.

Second, eco-innovations are developed with multiple purposes in mind, namely providing environmental and economic benefits simultaneously; hence, more knowledge is required to succeed in this endeavour and understand both sides (Arroyave et al., 2020; Cecere et al., 2015). Knowledge specialists, such as universities, can play an important role in synthesising and providing this knowledge to companies (Arroyave et al., 2020; Melander, 2017). This does not substitute technical and market knowledge but supplements. Furthermore, if the firm does not yet have these resources, it needs to attain them from outside or even outsource the activities. This is an issue since this is a continuous effort that keeps adding up and cannot be stopped (Klewitz & Hansen, 2014; Rinaldi & Cavicchi, 2016).

Third, the business model usually must be updated when firms start with eco-innovations. The eco-innovator should turn down the return on investment because of the extra activities, as the product or service will cost more for the firm and will take longer to pay back. Furthermore, in a context where stakeholders put an emphasis on competitive advantages, eco-innovations must be technically and functionally superior to non-green alternatives. Thus, technical development must be equally prioritised as the environmental aspect of firms' products and operations. Additionally, eco-innovators cannot simply adopt competitors' solutions as they must fit them to their own situation. Firms must also be fully committed in the long term when engaging in eco-innovation activities to gain significant competitive advantages (Ghisetti & Rennings, 2014). Both environmental and economic benefits are only attained with the continuous adoption of multiple and diverse eco-innovations. This effect is amplified through the adoption of radical eco-innovations, while incremental eco-innovation only provides marginal and short-term benefits. Therefore, eco-innovators must establish a strong, sustainable orientation and a long-term development plan to reach and maintain eco-innovations' competitive advantages (Rinaldi & Cavicchi, 2016). Moreover, the multitude of potential solutions and the need to investigate their environmental and economic outcomes increases the chance of failure. To be more precise, an eco-innovator is more likely to abandon a path because one eco-innovation does not provide the expected environmental benefits, and the negative economic impact is too big.

Finally, these extra activities and resources end up costing the eco-innovator lots of money, especially if there are no regulations in place. Firms must collaborate with more and different stakeholders, not only to cover tasks but also to analyse the environmental problems in the value chain to help each other identify issues and share the costs of eco-innovations (Melander, 2017). Garcia et al. (2019) and Carrillo-Hermosilla et al. (2010) even suggest that eco-innovative firms must cooperate with stakeholders outside the value chain to maximise

environmental and economic benefits. This means that cooperation with different stakeholders, not only the traditional industry partners such as suppliers and distributors but also policy-makers and academic institutions, is essential. Stakeholders present in the value chain cannot only help identify the root cause of an environmental problem but also come up with and implement fitting solutions (Melander, 2017). Involving different stakeholders and aligning sustainable goals improves the analysis of environmental performance as they can share information about issues they encounter themselves, limiting imprecision and reducing the amount of work required to identify environmental problems. Additionally, the involvement of stakeholders eases the identification and implementation of solutions that maximise environmental and economic benefits (De Marchi, 2012). When collaborating with stakeholders, the cost related to eco-innovation activities can also be brought down because they are shared among the different parties. Similarly, the need for additional environmental knowledge or expertise can be shared in the same way, reducing the complexity of eco-innovation activities (Acebo et al., 2021; Pakura, 2020). Collaboration is also important to develop more radical eco-innovations (Brown et al., 2019). All in all, eco-innovation must be developed and adopted collectively to minimise the additional burdens while maximising the outcomes for all participating stakeholders and society (Acebo et al., 2021).

### 2.2.2 Society Situation and Consequence on Eco-Innovation Activities

Even though collaboration is critical for eco-innovation activities, society is stuck in system failure, blocking the transition toward a circular economy even more. This section discusses the main challenges eco-innovators face from a societal perspective.

A market failure situation is created because social, institutional and technological realms are often pollution-intensive (Cecere et al., 2015). This domination of such technologies and human activities comes from historical events which favour some innovations over others. However, this situation has created an environment in which eco-innovation cannot thrive due to externalities that brown innovations enjoy (Cecere et al., 2015, 2020). First and foremost, eco-innovations often rely on technologies and resources that are in their early development stages (Cecere et al., 2015; Pinget et al., 2015; Wicki & Hansen, 2019). As a result, they suffer from scarcity and a lack of economies of scale, making them hard to find and costly compared to brown alternatives (Cecere et al., 2015). This scarcity is affecting not only the industry side but also the market, as most eco-innovations are only present in new or emerging markets (Hockerts & Wüstenhagen, 2010). Therefore, with the absence of proper infrastructure and the small market present, the adoption of such technologies and resources considerably increases eco-innovators' operational costs without guarantees of higher market returns (Cecere et al., 2015, 2020). All in all, with the current society situation, firms engaging in eco-innovative activities will depart from the current linear system based on polluting technologies and activities, hence losing all networking externalities it provides (Cecere et al., 2015). Secondly, knowledge asymmetry further undermines eco-innovation development and adoption (García-Quevedo et al., 2020). Because companies do not have the right knowledge, it is difficult to ascertain what they should do (García-Quevedo et al., 2020), making it more difficult to ask for help from others since they cannot explain their needs and convince others to do the same. It is difficult to search for information on environmental problems since firms either do not analyse their environmental performance or do not have the correct tools to do so (Hockerts & Wüstenhagen, 2010). If other firms found a good solution, they also might not want to share this information since it can bring them a competitive advantage over their competitors (Ben Arfi et al., 2018). Furthermore, because of the lack of environmental information, firms in the

value chain have different visions of what the environmental problem is or what should be prioritised. This makes it more difficult to agree on one solution and cooperate from an environmental perspective.

However, this cooperation is of utmost importance, and a lack of cooperation between stakeholders can even prevent the required changes from occurring (Moreno-Mondéjar et al., 2020). Firms can have multiple motivations to develop and adopt eco-innovations, whether the motivation comes from the market side, such as the potential market opportunities or cost reduction, or improve market position, from the technological side, firms motivated to participate in the technological advancement, or environmental reasons (Bocken et al., 2014; Horbach et al., 2013). Especially economic motivations can complexify the collaboration because it is usually the other firms that benefit from eco-innovations and not the ones adopting them (Rennings, 2000). Furthermore, the longer development time and risk of failure can also hurt collaborating businesses, so eco-innovators usually prefer to collaborate with long-term partners and can be more reluctant to engage in such activities with new and existing partners (Cecere et al., 2020; Melander, 2017). Finally, environmental awareness in markets and industries is not strong enough to drive firms to eco-innovate (Melander, 2017). When looking at environmental awareness from a customer's perspective, there are several types of customers (Cecere et al., 2015). Some customers are not interested in environmental features, which means that they will not adopt the green product unless they provide economic incentives. It can also be hard to convince customers who are interested in environmental features since they lack environmental and industry knowledge to fully understand how green products can be better for society, next to a lack of trust for the new solution. Similarly, some companies, especially incumbent firms, can act against eco-innovators to protect their current business activities for similar reasons (Pinget et al., 2015). This means they can engage in anti-competitive activities such as lobbies to counter progress or acquire technologies and make them unavailable to the public.

Because of the current market failure, compared to standard innovation, regulatory factors play a more important role in eco-innovations (De Marchi, 2012; Horbach, 2008; Pinget et al., 2015; Triguero et al., 2013) not only to provide economic benefits to environmental benefits (Cecere et al., 2015; Horbach, 2008) but also to make sure that people cooperate (Fabrizi et al., 2018; Melander, 2017) and that the market understands the environmental features (Hamburg et al., 2017). The only way to solve market failure is to get the government involved in promoting eco-innovations (Pinget et al., 2015; Sáez-Martínez et al., 2016) and collaboration between stakeholders and industries (Acebo et al., 2021; Arroyave et al., 2020; Ghisetti, 2017), raising market interest and demand toward eco-innovation (Cecere et al., 2015; Melander, 2017), and building the missing green infrastructure (Cecere et al., 2015). However, the current regulations are not effective, leading to system failure where the regulations act against the promotion of eco-innovations. First, environmental benefits and environmental harm do not have an economic value (Horbach, 2008; Kobarg et al., 2020; Pinget et al., 2015). This means that non-sustainable behaviours are not penalised, while sustainable ones are not rewarded (Cecere et al., 2015, 2020). Subsidies are needed for eco-innovation development. However, subsidies are usually not equally distributed among firms, leading to most companies not having proper financial support (García-Quevedo et al., 2020; Pinget et al., 2015). Next, when regulations are used as guiding sources for eco-innovation development, the focus is usually on specific technologies (Kiefer et al., 2019), such as electric cars. This helps industries and markets to invest in such technologies because these have the support of policy-makers.

However, policies are often too focused on specific solutions, which is not compatible with eco-innovations, as solutions must fit the regional and firm context (Cecere et al., 2015; Kiefer et al., 2019). This tunnel vision prevents the development of a wider variety of solutions that provide greater environmental and economic benefits (Carrillo-Hermosilla et al., 2010; Cecere et al., 2015). Third, regulations change too often and much faster than the development time required for eco-innovations (Wicki & Hansen, 2019). This means that companies do not eco-innovate because they will either not be able to finish development in time or the time needed for adoption is so long that the eco-innovation is not considered sustainable anymore (Pinget et al., 2015; Triguero et al., 2013). Additionally, there is a lack of cooperation between different bodies of government, leading to confusion about the regulations adopted (Marin et al., 2015). On the one hand, it creates confusion between regulations that are adopted since they cancel each other out. On the other hand, the lack of cooperation between policy agents prevents the establishment of common environmental goals for different industries that companies can focus on and ease up collaboration. Finally, the influence of strong lobbies can also slow down the adoption of regulations supporting green initiatives as well as make these regulations weaker because incumbent firms want to preserve their current operation (Cecere et al., 2015).

## 2.3 Green Startup

Green startups play a central role in initiating industries and markets' transition toward more sustainable patterns (Hockerts & Wüstenhagen, 2010; Klewitz & Hansen, 2014; Pakura, 2020). Green startups are almost identical to standard ones. Namely, they are ventures in early stages of their existence, they are challenged by multiple resource constraints (Bergset, 2015; Hockerts & Wüstenhagen, 2010; Pakura, 2020), and they emerge from market failures with radical innovations driven by business opportunities (Pakura, 2020). What sets them apart is that green startups are founded and led by sustainable entrepreneurs, who intend to contribute to societies' sustainable development objectives. While traditional startups only strive to exploit business opportunities, green startups only pursue a business opportunity if it also provides a significant and positive environmental benefit to society. As such, green startups tend to come up with radical solutions as they ignore traditional market and industry demands and focus on reshaping all dimensions of businesses and integrate environmental considerations in the decision-making process (Klewitz & Hansen, 2014; Pakura, 2020), while other organisations tend to focus on incremental eco-innovations (Triguero et al., 2016). They also usually focus on product eco-innovations (Pakura, 2020), while incumbents focus on process eco-innovations (Hockerts & Wüstenhagen, 2010). Finally, green startups first focus on new and niche markets before eventually expanding to the mass market (Hockerts & Wüstenhagen, 2010; Klewitz & Hansen, 2014). Therefore, their presence is essential to initiate industries and markets sustainable transition (Bergset, 2015; Klewitz & Hansen, 2014) as they continuously go beyond regulation expectations in terms of environmental performance, setting the market and industry norms (Hockerts & Wüstenhagen, 2010; Sáez-Martínez et al., 2016). In essence, green startups endorse the explicit objective of contributing to building a more sustainable society through the exploitation of green business opportunities and the diffusion of radical eco-innovation (Bergset, 2015; Pakura, 2020).

### 2.3.1 Green Startup Advantage

Green startups' newness and smallness contribute to their success. To begin with, green startups leverage their smaller, simpler and more flexible organisational structure to ease eco-innovation development and adoption. In detail, their structure reduces bureaucratic burdens and promotes better communication and cooperation between individuals and functions within the firm

(Bergset, 2015; Klewitz & Hansen, 2014). Together with green startups' lean mindset and capability to absorb new knowledge favours the creation of radically new solutions. Likewise, their flexibility, green startups can be more reactive to industry and market changes and adapt accordingly with more ease (Klewitz & Hansen, 2014). Last but not least, small firms are influenced by the vision of the owners' environmental considerations and interest in coming up with environmentally superior offerings and business models than the competition (Bergset, 2015; Klewitz & Hansen, 2014). Furthermore, green startup's newness also provides several benefits to eco-innovation activities. Compared to established firms, green startups usually have not yet made any investments. Thus, they are less prone to a technological lock-in, leading to fewer technological and financial hurdles to dismantle previous investments and adapt to new settings. Additionally, they are less likely to cannibalise their existing offering or market as new ventures usually have no products yet (Hockerts & Wüstenhagen, 2010). Besides, green startups are more likely to cooperate in eco-innovation activities with stakeholders to overcome their resource shortcomings (Pakura, 2020; van Hemel & Cramer, 2002). Moreover, they enjoy a better image than their competitors as customers tend not to assimilate green startups responsible for current environmental problems but rather as the troubleshooter (Hockerts & Wüstenhagen, 2010). As a result, startups have greater chances to attract customers in niche markets that value environmental features. Evolving in niche markets testing in real conditions with smaller and more engaged customers or users samples (Cecere et al., 2015). Overall, green startups' characteristics provide the best conditions to develop and diffuse eco-innovations.

### 2.3.2 Paradox of Green Startups: which Challenges Do They Encounter?

Although green startups are considered as essential agents to initiate industry and market sustainable transition, they are also the most challenged when eco-innovating. As highlighted previously, eco-innovation activities demand a considerable amount of resources and time, as well as broader and deeper cooperation with stakeholders to succeed, which smaller and newer firms usually lack (Klewitz et al., 2012; Pinget et al., 2015). Thus, they are less likely to engage in eco-innovative activities (Sáez-Martínez et al., 2016; Triguero et al., 2016) and rather adopt eco-innovations as a reaction to new environmental policies (van Hemel & Cramer, 2002). However, they are not less motivated than other firms to eco-innovate (Marin et al., 2015; Triguero et al., 2013) as most new ventures that successfully develop or adopt one eco-innovation tend to undergo new eco-innovation activities (Triguero et al., 2013). This lack of participation can be explained by eco-innovation complexity and novelty (Ghisetti et al., 2015; Horbach et al., 2013; Klewitz & Hansen, 2014; Wicki & Hansen, 2019), and the current system failure combined with their shortcomings in resources and capabilities (Cecere et al., 2020; Klewitz & Hansen, 2014; Pinget et al., 2015; Triguero et al., 2013). Even if green startups come up with radical innovations that change the industry, cooperation with incumbents is a necessity as they will reform the processes and provide the means to bring eco-innovations to the mass market (Hockerts & Wüstenhagen, 2010; Pakura, 2020). The latter part of this section focuses on the challenges green startups face, split into internal and external challenges.

To start with, firm-side factors hamper green startups' eco-innovation activities for several reasons. First, green startups lack specialised employees or departments solely committed to working on eco-innovations or with environmental-related knowledge (García-Quevedo et al., 2020; Pinget et al., 2015). Additionally, only a few have implemented relevant tools, such as an EMS, to monitor their environmental performance (Hockerts & Wüstenhagen, 2010; Klewitz & Hansen, 2014). Their absence prevent green startups from effectively identifying their environmental footprint and their products' environmental benefits, hindering

their capabilities to establish an action plan. Moreover, such tools are critical for new companies, which lack years of operational insights, to estimate the potential environmental impact of their future offerings and operations. Next, sustainable entrepreneurs lack business-related skills to build a company, especially when environmental objectives are more important than economic ones (Bergset, 2015). In particular, green startups have poor managerial, communication and collaboration capabilities, and the lack of a reputation preventing them from finding relevant and necessary resources and partners to successfully eco-innovate (Ben Arfi et al., 2018; Bergset, 2015; Melander, 2017). Finally, some sustainable entrepreneurs fear teaming up with stakeholders, moving out from niche markets because their environmental objectives might not be fulfilled anymore, or resort to only address one environmental problem (Bergset, 2015; Klewitz & Hansen, 2014).

Moving beyond internal factors, challenges from the demand, supply, and regulatory side also hinder green startups' eco-innovation activities. The following external factors greatly influence green startups' eco-innovation capabilities (Bergset, 2015). First, many industry and market stakeholders are not interested in the environmental aspect of green solutions. Thus, green startups must make their offerings technically and economically interesting to these stakeholders as well. Moreover, the needs and expectation greatly varies between stakeholders that value or disregard environmental features. As such green products have more requirements than their non-green counterparts. However, green startups lack the necessary internal resources and capabilities to fully address or implement all demands and expectations, especially compared to incumbent firms (Ben Arfi et al., 2018; Sáez-Martínez et al., 2016). Additionally, stakeholders are reluctant to adopt eco-innovation as green markets suffer from high rivalry and business failure rates (Cecere et al., 2015; Marin et al., 2015). Combined with the potential greenwashing from some agents, industry and market stakeholders generally do not trust green products (Cecere et al., 2015). As a consequence, incumbent firms think twice before engaging with green startups while customers simply avoid green products due to mistrust (Cecere et al., 2015). Additionally, green startups also encounter issues to establish a sustainable supply chain as green industries lack of maturity (Cecere et al., 2015; Pinget et al., 2015). Thus, they encounter challenges in finding partners to source sustainable materials or access green production, distribution, and recovery capabilities. On top of that, investors and industry partners are less interested in working with green startups due to the longer and smaller return on investment as they usually focus on radical eco-innovations, which require more time and resources to develop (Bergset, 2015; Cuerva et al., 2014). Finally, regulations do not effectively support green startups as most of the subsidies are given to startups in later development stages. Likewise, governments' focus on specific green technologies deters industry stakeholders from supporting alternatives that might provide even greater environmental benefits.

This paradox of how green startups successfully manage to survive and bring eco-innovations to the market despite all the challenges results in the following research question:

*Q1 How do green startups define and execute successful eco-innovation strategies?*

# 3 Methodology

## 3.1 Research Approach

The study applied an explorative and qualitative research approach. In the context of theory building, an exploratory approach is more appropriate due to its high degree of flexibility, which is imperative for identifying expected and unexpected phenomena that arise in empirical

observation (Jebb et al., 2017). Additionally, case studies allow the repetitive observation of particular instances of a phenomenon to build theory inductively (Eisenhardt & Graebner, 2007). Building on Eisenhardt & Graebner, (2007) recommendations, a theoretical sampling approach was used to select cases representing green startups.

Several criteria were defined in the selection of green startups. First, the EU definition of a startup was used to identify cases. Namely, a startup is at most ten years old, has at most one product finalised, and is still building its business model (pre-revenue). Second, to be considered as a "green" startup, their environmental objectives were assessed. To be more precise, their websites and LinkedIn pages were investigated to identify clear mention of the environmental problems they target and what environmental benefits their product will provide. Product and business environmental performance goals were also taken into account, however, weighed less in the assessment as these aspects of a green startup's environmental objectives are addressed in later development stages or after product commercialisation. Finally, the stage of green startups was investigated. Only startups that have already started their product development have been selected because the study focuses on the development part after they have been seeded; pre-seed startups have been disqualified. Furthermore, the startups must have completed the ideation phase and already started developing their solutions. A final but optional criterion was the assessment of environmentally oriented impact funds and investors supporting the green startups.

### 3.2 Data Collection

Data was collected through individual semi-structured interviews involving founders or managers of Dutch green startups in spring 2023. In total, ten green startups participated in the study. One respondent per participating green startup. Due to the scarcity of eco-innovation literature, cases were selected based on multiple criteria using a theory sampling method. A semi-structured interview grid with open-ended questions divided into four sections was prepared prior to the interviews. First, an introduction section served to collect information about the respondent and the green startup. The following section investigated the activities undertaken by green startups to develop eco-innovations. In addition to the activities, the potential implications of stakeholders and encountered challenges were discussed. The third section adopted similar questions but mainly focused on the commercialisation activities performed by green startups to promote and sell eco-innovations. The last section focused on the environmental performance of the startups. To be more precise, the questions investigated how environmental considerations influence green startups' strategy and activities, as well as understanding their environmental awareness. An overview of the interview grid can be seen in Appendix x. Finally, additional probe questions were prepared to clarify respondents' answers or further investigate topics. All interviews were carried out and recorded through online conference calls and lasted, on average, 60 minutes, ranging from 30 to 90 minutes. Audio recordings were transcribed, and the transcriptions served as the foundation for the data analysis.

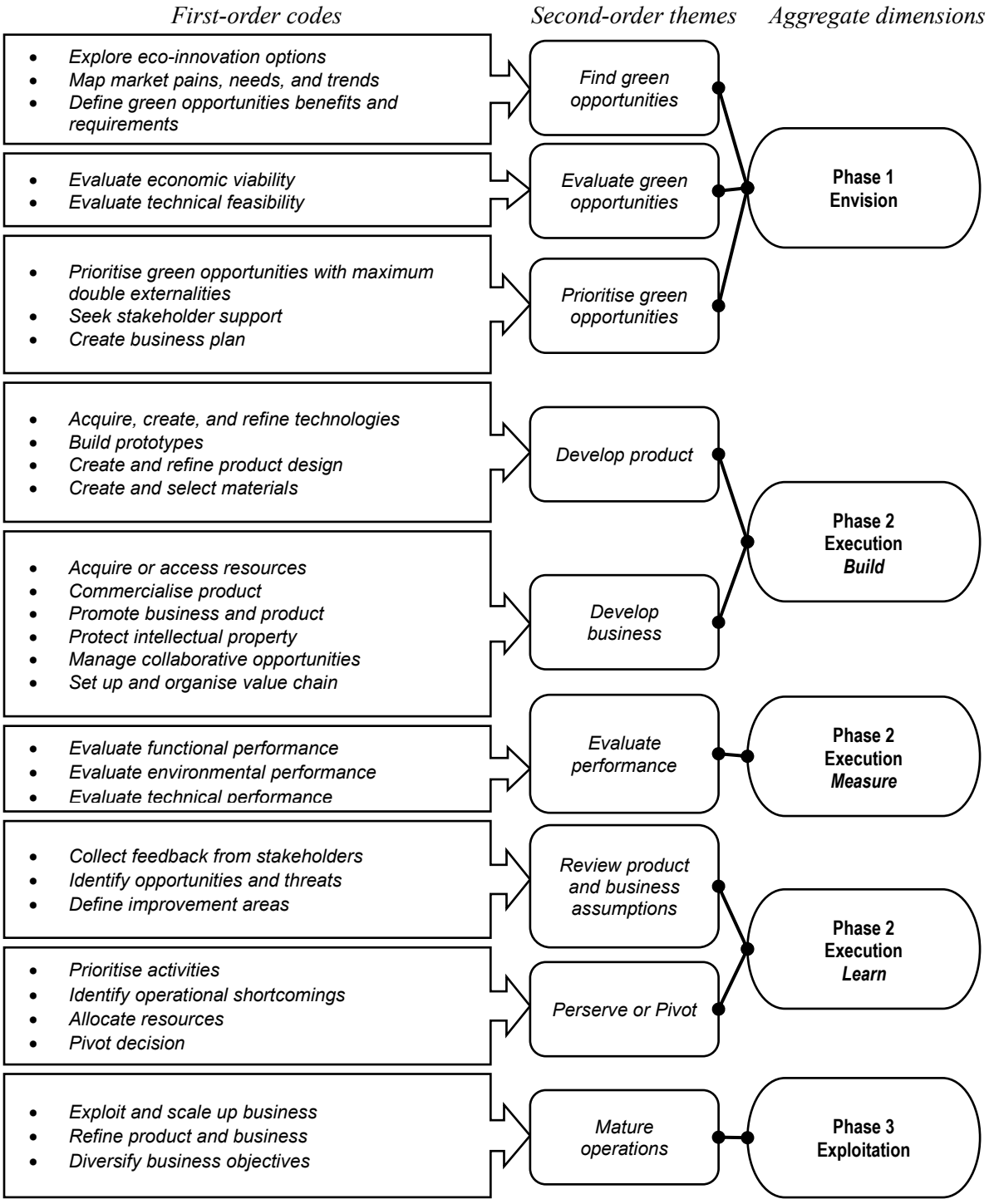
**Table 2 – Interviewed green startups description**

| *Case* | *Interview duration* | *Interviewee position* | *Founding year* | *Size* | *Product type* | *Industry* |
|---|---|---|---|---|---|---|
| GSU1 | 62:47 min | CEO and founder | 2022 | Micro <10 | Hardware | Real estate |
| GSU2 | 51:13 min | CEO and founder | 2019 | Micro <10 | Hardware | Real estate |
| GSU3 | 62:09 min | CEO and founder | 2019 | Small <50 | Hardware | Food |
| GSU4 | 94:01 min | CTO and founder | 2018 | Small <50 | Hardware | Energy |
| GSU5 | 54:32 min | CTO and co-founder | 2019 | Small <50 | Hardware | Automotive |
| GSU6 | 52:31 min | CTO and co-founder | 2016 | Small <50 | Hardware | Energy |
| GSU7 | 52:47 min | Cofounder | 2020 | Micro <10 | Software | Waste management |
| GSU8 | 65:39 min | CEO | 2019 | Small <50 | Hardware | Real estate |
| GSU9 | 97:09 min | CEO | 2014 | Small <50 | Hardware | IT Hardware |
| GSU10 | 28:52 min | CPO | 2016 | Small <50 | Software | Energy |

### 3.3 Data Analysis

A thematic analysis using the method proposed by Gioia et al. (2013) was performed. The data analysis was performed in several stages. First, transcriptions were analysed to identify dominant themes. Because the focus of the study was on green startups' green activities to successfully eco-innovate, the identification of themes focused on patterns of activities. Because each interviewee clearly expressed the different milestones of their product and business development, these could be used as the basis for the coding. Once the main pattern was defined, relevant quotes pertaining to the main questions were investigated, saved, and given a first order code. At this stage, the first order code essentially consisted of a summarised idea of the interviewee's quote, to retain the details of the responses. Next, these summarised quotes were reviewed to refine actual first order codes. The goal consisted of aggregating quotes carrying similar ideas and reduce the number of first order codes. Subsequently, first order codes were grouped into similar topics resulting in second order codes based on existing literature. Finally, these second order codes were combined again into aggregates to define the framework.

*Figure 1 – Data structure*



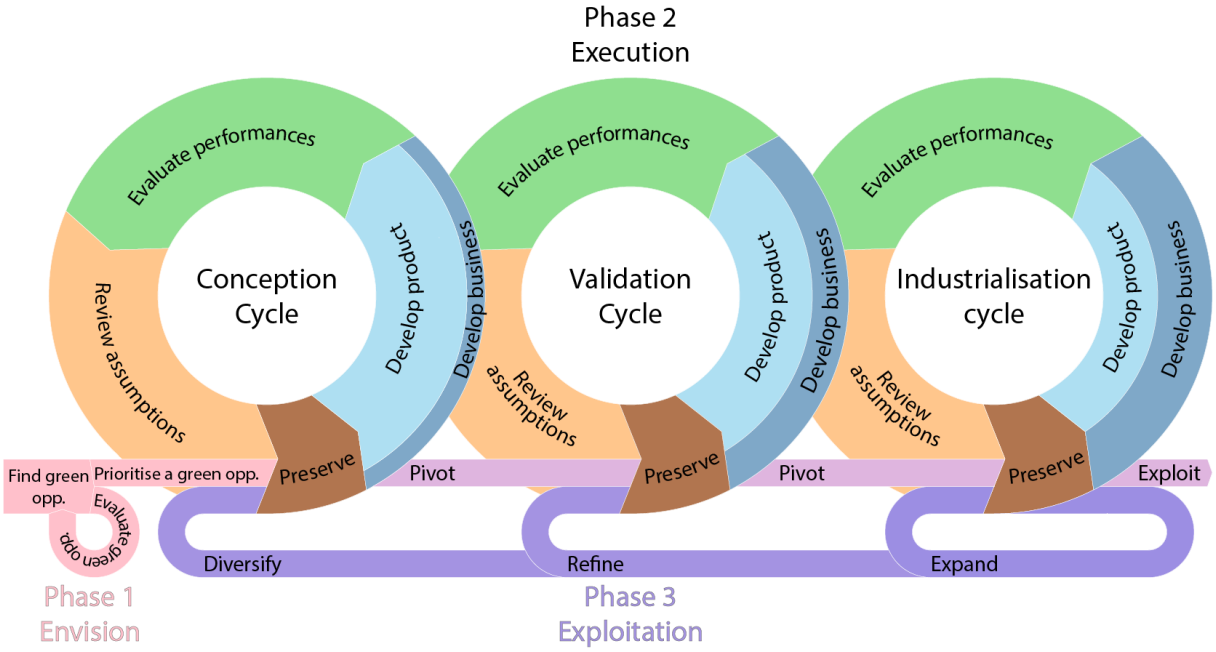

# 4 Results

The findings indicate that green startups engage in a three-phase development process grounded on the lean startup methodology to develop and adopt eco-innovations. Green startups' eco-innovation journey starts with finding and evaluating a portfolio of green opportunities before prioritising one. Next, the concept is transformed into a marketable product following an agile product development process. By and large, green startups progress through three successive iterative cycles in which they validate the concept, product, and business model. Upon

completing all development cycles, green startups are now confronted with a range of options, which are repeated indefinitely, to exploit, mature, and diversify their business model.

> *"At the beginning, we simply tested the functionality. So, laboratory scale prototypes were produced, tested, measured, so that we knew what level of performance was coming from the devices that we created. Once we had done that, there is a refinement cycle that then goes into that, you produce the first prototypes, you measure them, you evaluate them, and you do a due diligence as it was on those prototypes, and you look for (...) any obvious areas where you can improve upon them. Once you have got something that you are happy with, then you can move on to a viability stage where you look at the manufacturability." GSU8 7:13*

*Figure 2 – Green startups' eco-innovation framework*




## 4.1 Phase 1 – Envision

The interviewed green startups' eco-innovation endeavour begins with *finding green opportunities*. On the condition that a technology is present at the start of the identification process, entrepreneurs explore eco-innovation options using either a technology-push or market-pull strategy.

Granted that entrepreneurs initiate the green opportunity exploration process with a specific technology in mind, they follow a technology-push strategy. Here, entrepreneurs either encounter a new technology and deem it interesting to acquire and commercialise, or seek to utilise a new technology stemming from their research and development initiatives. In both cases, the technology is related to their previous professional career and expertise. When a technology is preselected, entrepreneurs examine the technology's fit in different markets by exploring its potential applications. Entrepreneurs then confirm the presence of a green opportunity by interviewing and evaluating potential customers or investors' interest.

> *"[Company] was founded (...) by my CTO. At that moment, he was basically alone together with a few people with a technical background.*

*They looked at the technology and came up with I do not know how many different potential applications, all being quite technical. They all focused on the technical feasibility of all the different projects that they had in mind." GSU3 3:12*

Alternatively, they follow a market-pull strategy if no specific technology is present when *finding green opportunities*. Here, entrepreneurs scrutinise and interview markets to *identify pains, needs, and trends*. Likewise, the orientation of market research is correlated with entrepreneurs' professional career and interests. Then, entrepreneurs aggregate all collected information to ideate concepts that address the identified market failures. Entrepreneurs then pitch their product ideas to potential customers to verify their hypotheses and gauge their interest. Until they receive strong interest from the market, entrepreneurs refine the concept based on the received feedback.

*"(...) before we made its first sketches, we already tried to commercialise our product. So, it is not a deep tech thing that we developed a technology and then try to fit it into the market. Initially, we already tried to commercialise it. (...) This is something we have been doing by talking to a lot of customers, or potential customers, and see what their requirements or wishes are, what their pains are (...)" GSU2 2:43*

**Table 3 – Initial strategy followed**

| *Case* | *Strategy followed* |
|---|---|
| GSU1 | Technology push |
| GSU2 | Market pull |
| GSU3 | Technology push |
| GSU4 | Technology push |
| GSU5 | Technology push |
| GSU6 | Technology push |
| GSU7 | Market pull |
| GSU8 | Technology push |
| GSU9 | Technology push |
| GSU10 | Market pull |

Whichever strategy is pursed to *find green opportunities*, entrepreneurs undertake similar tasks before prioritising one. To begin with, they *define each green opportunities' benefits and requirements*. Concurrently, they *evaluate each opportunity's economic viability and technical feasibility*. Ultimately, entrepreneurs *define business model assumptions, eliminate unfeasible or unviable opportunities,* and *prioritise the green opportunity* that *maximises environmental and economic benefits*.

Entrepreneurs specify green opportunities' value proposition by *defining their environmental and economic benefits*. To begin with, entrepreneurs detail the environmental problems and benefits of each green opportunity address and provide compared to brown alternatives. To be more precise, they define why one opportunity is considered green (externality reduction or resource efficiency), when it provides the benefits (before, during, or

after product use), and how much it contributes to the natural environment (reduction to a positive impact). However, entrepreneurs only limit on defining the environmental benefits and the environmental performance of each green opportunity. Concurrently, entrepreneurs define the economic value each green opportunity provides to the market. In all cases, entrepreneurs emphasised the importance to come up with solutions that are economically superior to brown alternatives. Thus, they define the economic value, whether it consists of competitive advantages or economic incentives, each opportunity provides to the customerbased on the end application or by translating environmental benefits into economic ones.

**Table 4 – Example of green opportunity environmental benefits classification**

| *Case* | *Why* | *When* | *How much* | *Detail* |
|---|---|---|---|---|
| GSU3 | Energy | During use | Less negative impact | The tool uses less energy than existing alternatives |
| | Material | During use | Zero impacts | Does not use the toxic material during usage compared to existing alternatives |
| | Pollution | After use | Zero impacts | The absence of toxic material avoid its release in the nature after use |

*"First of all, we look at the contribution the technology makes to the end application in terms of its environmental performance, what its savings are and what benefits it brings up." GSU8, 7:63*

*Defining the benefits* facilitates entrepreneurs grasping all prerequisites inherent to each green opportunity. First, entrepreneurs translate the different *economic benefits* into *functional requirements*. Second, all *environmental requirements* are investigated and converted into *technical requirements*. Depending on the context, products my be subjected to harsh conditions which require specific design and material choices. Third, additional *industry requirements* and *regulatory obligations* are considered to guarantee it can fit in the existing system. Fourth, *market requirements*, which consists of customers' habits and preferences, are considered. Finally, entrepreneurs express *natural environment requirements*, which represent entrepreneurs environmental objectives in most cases. Thus, *natural environment requirements* greatly varied from one green startup to another, from simply providing the defined environmental benefits to adopting a fully circular business model. However, environmental performance targets are only aspirational at this stage. To define green opportunity's *requirements*, entrepreneurs extensively interact with industry stakeholders to apprehend industries' current available capabilities and resources, regulatory obligation, industry dynamics, and market structure. All in all, entrepreneurs investigate all *requirements* green opportunity must address to be manufactured and adopted in the current society situation.

*"For a long time and still up to date, we have had to do some market and technical feasibility research. So, how many houses can handle a green panel, which regions, which plant, what the best and most sustainable materials are, how to attach the green panels; it is really technical." GSU1, 1:17*

Brining together all the gathered information, entrepreneurs then evaluate green opportunities' *technical feasibility* and *economic viability* before *prioritising one.* Regarding the first dimension, entrepreneurs evaluate whether the industry situation is favourable to transform the concept into a marketable product. For example, by investigating the presence of relevant expertise, information, (green) manufacturing and distribution capabilities, and the availability of sustainable resources. Concerning the other dimension, entrepreneurs define each green opportunity profitability prospects. While motivations may stand on technical or environmental sides, entrepreneurs stress the importance of pursuing economically viable green opportunity to provide lasting environmental benefits to society and natural environments. As such, entrepreneurs evaluate their competitiveness by analysing the market situation. For example, they investigate their competitive advantages, the rivalry intensity, market demand or interest toward green products, market size, material costs, or existing and future regulatory opportunities. In summary, entrepreneurs investigated the market, industry, and regulatory situations to evaluate their chances to succeed economically and sustain in the long term.

> *"Whenever you see a new project, the first thought will always be, 'Can we do it?' then you should ask yourself, 'Should we do it?', and then 'Why should we do it? Is it because it is going to make us a lot of money or is it because it is going to make a big impact on the environment?' With [Company], what we aim for is we should always have a yes to both of these." GSU3, 3:94*

Once green opportunities are *found*, *defined*, and *evaluated*, entrepreneurs *prioritise one green opportunity* to develop. To begin with, entrepreneurs aggregate all collected information to *define business model assumptions* by drafting the value proposition, creation, delivery, and capture for each green opportunity. This includes which party could be responsible for the development and operational activities required to bring the green opportunity to the market. Generally, incubators and accelerators aided entrepreneurs in laying out the initial business plan.

Next, entrepreneurs decide on which opportunity to focus one based on internal and external factors. Starting with internal factors, entrepreneurs always select the green opportunity that *maximises the double externality effect* based on the previous assessments. Even though contributing to society's sustainable development goals remains a priority for entrepreneurs, they are also aware of the importance of building a competitive and economically viable business. From the economic perspective, entrepreneurs compared the potential revenue against the potential costs to develop and commercialise the product. Additionally, they consider their advantages against relevant competitors, resources and capabilities availability within the industry, and market trends. On the environmental side, entrepreneurs compare the potential positive impact the different opportunities would provide to natural environments. Combined, entrepreneurs prioritise a green opportunity that maximises the economic and environmental outcomes with the lowest failure risk.

> *"Whenever you see a new project, the first thought will always be, 'Can we do it?' then you should ask yourself, 'Should we do it?', and then 'Why should we do it? Is it because it is going to make us a lot of money or is it because it is going to make a big impact on the environment?' With*

*[Company], what we aim for is we should always have "yes" to both of these". GSU3, 3:93*

In parallel to the internal considerations mentioned previously, entrepreneurs also *seek support from external stakeholders* to prioritise a green opportunity. Because green opportunities only stand a chance if they are considered commercially viable, entrepreneurs aimed to secure the interest of at least one stakeholder to support financially the first development cycle. On the whole, investors are the most important stakeholders group that entrepreneurs aim to gain support from, followed by potential customers, and, to a lesser extent, universities and policy-makers. Investors, such as investment funds, venture capital, and incumbent firms, are the priority as they provide the financial resources to support the development of a proof of concept. Whereas with other stakeholder groups entrepreneurs can leverage their interest to raise funds at investors. Only universities can provide sufficient funding if entrepreneurs manage to integrate public research, however, chances to join are low and mostly depend on regulatory opportunities to fund such research. Altogether, customers, universities, and policy agents mostly have an indirect role to support entrepreneurs to initiate product development. Pitching the green opportunity and business model was the most common method to gain support from these stakeholders. Again, incubators and accelerators played a significant role only helping entrepreneurs to prepare the pitch and expose them to their network.

*"[The parent company] was facilitating the concept of smaller startups within the company. So, you could pitch an idea and if it was considered as something that was worth pursuing, you could get some budget for that within a different department in the company (...). That is how, I think, the idea was converted into a first group of people that were working on this concept." GSU10, 9:12*

Once a *green opportunity has been prioritised*, entrepreneurs *draw the initial roadmap*. Broadly, entrepreneurs outline the development steps, potential risks, and the required resources to develop and commercialise the green opportunity. While they sketch the entire execution phase, the first cycle is defined with greater detail. The roadmap and business model assumptions only serve as a guideline for the short term and would be periodically assessed, refined, and validated throughout the subsequent development cycles. Additionally, once entrepreneurs have sufficient assurance that the selected green opportunity could be developed, they found the green startup to initiate the development.

All in all, entrepreneurs find, evaluate, and prioritise a green opportunity throughout the envision phase, which ends after securing market interest.

### 4.2 Phase 2 – Execution

Once a green opportunity is *prioritised*, green startups initiate the product and business development. A noteworthy finding is the division of the second phase into three distinct iterative development cycles: *conception*, *validation*, and *industrialisation*. Each cycle follows a lean startup approach in which green startups iteratively *build* their products and business, *evaluate* their respective performance, and *learn* from reviewing the results before deciding on the next steps.

*"The first step is very much about whether the concept worked and, if it worked, how well it worked. Secondly, given that the concept worked, how manufacturable it is and what manufacturing processes would be required to reproduce the technology at a suitable scale for the target markets."*
*GSU8, 7:10*

### 4.2.1 Conception Cycle

Green startups initiate the execution phase by *designing and building a functional laboratory prototype* to prove the concept is functioning. Thus, most resources are allocated to *product development activities* to come up with a prototype that provides sufficient performance in a controlled environment. In parallel, *business development activities* are kept at a minimum; however, they remain essential to support product development efforts.

*"We started first developing the technology and then building a lab version that was at least able of showcasing to the experts that it would work."*
*GSU 3, 3:26*

Detailing, iterating, and testing the technologies, product design, and components are the main *product development activities*. First, green startups further specify all product's technical, environmental, and functional requirements to incorporate in design, which influences technology, and material choices. Essentially, green startups keep collecting external knowledge, such as industry reports and stakeholder feedback, and combine it with internal expertise. Once the product design is specified, they start *iterating different product designs* that implement all functional requirements. To be more precise, the *required technologies are adopted and further developed*, while *candidate materials were identified and assessed*. While in all green startups further develop the technology they use, it is not always the case with the material. In cases where the material is part of the technology, green startups are also further developing it to enhance its capabilities. Otherwise, green startups are only evaluating different materials available. Overall, materials' environmental and technical performance are a priority in the selection process, which, in most cases, both criterion work in pairs. However, material choice is not definitive as the *conception cycle* focuses on validating a product design that provides sufficient enough functional performance. Therefore, material selection only completes in the *validation cycle*.

*"It is a completely new design compared to [existing alternative energy production systems in the field]. It has been developed and operated in the past. (...) We developed a concept where we think that we can mitigate the major challenges with this technology."GSU4, 4:5*

*"The first selection process is that the material itself is fit for purpose. (...) Then, of course, they need to be fit for purpose in our application. (...) they will not only be robust but they will also perform within a dynamic system and return the right level of performance. (...) The sustainability comes in at quite an early stage, but we would evaluate the sustainability of various materials anyway if they were of particular interest to us in terms of usage."*
*GSU8, 7:25*

Despite green startups allocating most of their effort toward *product development*, *business development activities* remain important. To begin with, green startups perform

complementary environment research to better understand the targeted market's needs, interests, and size as well as the industry's capabilities are solely supporting green startups' product development activities. All collected information is used to further specify the product requirements and design. Additionally, the industry research activities help green startups *to search for collaborative opportunities* for the current and upcoming product development cycles. For the current cycle, green startups essentially team-up with partners that can assist in developing and testing prototypes. Thus, universities, public research institutions, and specialist firms are the most common active stakeholders participating in this current stage. In all cases, green startups onboard partners to overcome their shortcomings, such as lack of manufacturing and testing equipment, or legal and technical expertise. However, collaboration strategies greatly vary between green startups based on their characteristics. The more sensitive and unique a product or its technology is, the more likely a green startup will internalise product development activities. For these reasons, green startups stress the importance of a strong intellectual property protection strategy and only engage in collaborative activities through formal frameworks. However, no changes have been observed in externalising testing activities; all green startups are eager to multiply prototype testing with several stakeholders to gather valuable information about its performance. Similarly, more financially constrained green startups are less likely to engage in multiple collaborative activities. All in all, involving stakeholders to product development activities speeds up product development as green startups focalise on core product development activities while partners assist in or fully take over other product and business development and testing activities.

*"We have a professional company we work together with for the concept and the development phase of our product. (...) There are three of these kinds of partners that help us to develop a certain system or subsystem of our product."GSU2, 2:26*

In parallel, green startups debut *promoting their business* to the market. They essentially promote their vision and missions while omitting to disclose detailed information about their product. Promotional activities are necessary to gain market traction helping them to *acquire additional resources*, such as securing additional funds, expanding their network, and hiring skilled labour. However, providing too much information about their product design and technologies can be used by incumbent competitors that have the capability to out develop green startups. Therefore, this strategy allows green startups to gain market traction, build trust and credibility, and create brand awareness without awakening potential incumbent competitors.

*"All the activities in those first two years were more toward public relations, getting your name out, and creating awareness about our technology, the company in general, and our potential. That was more meant toward getting some subsidies in and getting some market traction." GSU3, 3:51*

*"When we started the company, we probably spent 12 months in what we call the stealth mode. Part of that was because (...) we intended to develop the technology based on existing manufacturing processes. If we had given too much away too soon, that could have been copied by those manufacturing people. So, we stayed stealthy and secret for the first 12*

*months, which has paid enormous dividends because we have a very robust IP portfolio now." GSU8, 7:39*

*Product evaluation activities* essentially focus on *functional performance* in the *conception cycle*. In all cases, each product design is first tested and iterated through simulations before a physical copy is built and assessed in controlled conditions. Therefore, physical prototypes are only built if simulations provide satisfactory results. Additionally, testing activities are mostly limited to controlled or laboratory conditions during the *conception cycle*. All green startups test the prototypes internally and with external stakeholders. However, the type and level of implication of the stakeholders vary from one green startup to another. Product development partners and universities are the most common stakeholders participating in product testing activities. In fewer cases, a limited number of trusted users or customers may also test the prototypes. Involving external stakeholders to evaluate the prototype allows green startups to gather direct feedback from potential customers and industry experts, and access to specialised testing equipment and facilities. On the whole, A/B testing is the preferred method to test the different product iterations against each other or existing alternatives. Next to A/B testing, green startups also perform pilots and usability testing to ensure the prototypes functions as expected. Through these testing methods, green startups set predefined key performance indicators that the prototypes must reach or simply evaluate the performance an iteration can deliver.

Depending on green startups' objectives and product requirements, green startups also *test the product's technical and environmental performance*. Focusing on *technical performance evaluation*, green startups only perform related testing if the product must meet specific market or regulatory requirements, such as fire safety norms. Thus, technical requirements are treated as functional ones more extensive testing is performed. Expanding on *measuring the environmental performance*, a similar pattern is observed, namely, industry norms or market expectations for green products pushed green startups to perform more rigorous *environmental performance evaluations*. For example, green startups evaluate different materials toxicity during usage, recyclability, or availability through sustainable sources. Additionally, and crucially, green startups with stronger environmental orientation are likely to undertake more rigorous environmental performance evaluations. Therefore, and at this stage, *technical and environmental performance evaluation activities* consist of material performance and environmental impact analysis relying on available industry information and stakeholder feedback. In the case either aspect is critical to the product's value, the green startup may already assess the different materials in laboratory conditions.

*"The test will mainly show that the system can be operated safely and that our models are describing the system correctly. It has to do with demonstrating safety because if the system is not safe, we will never be able to get it licensed and operating."GSU4, 4:39*

*"First of all, you need to show that the concept itself provides adequate performance. Then you really have a roadmap stretching out into the future where you are making improvements to the technology in terms of its environmental robustness." GSU8, 7:17*

Regardless of the development cycle, each development and evaluation activities ends with green startups first *reviewing the business model assumptions* before deciding on *persevering* in the current or *pivoting* to the next cycle or phase.

First, green startups aggregate all the *feedback they collect* through their development and testing activities and interaction with external stakeholders. The feedback relates to any product and business aspect, such as material suggestion, disclosure of unique selling points, or guidance to establish commercial or collaborative strategies. Information is acquired both passively and actively through the various activities and interactions with stakeholders.

> *"It is really gathering a lot of insights and feedback from different sectors. How do we do it? Having a lot of meetings and brainstorms to develop ideas and see how we can test them."GSU1, 1:22*

> *"Whenever we are approaching a new phase in the company, or we run into any difficulties, whatsoever being technical, commercial, or supply chain management, (…) [the venture capital] would be one of the first [stakeholders] to go to (…). They were sort of the sparring partner on it, 'Would this business model make sense?', 'Would you think this would be an interest for the market?', and (…) they could give us some feedback." GSU3, 3:59*

Next, green startups *identify opportunities and threats* to their development and operations. By and large, green startups consider any demand, supply, and regulatory side factors that may affect the product and business development. Predominantly, supply side factors have the greatest influence on green startups activities. Their impact considerably varies depending on green startups' industry, while some sectors are largely supportive others are predominantly challenging. To illustrate, some green startups evolve in an industry that foster cooperation and innovation, and have a high availability of material and service at a low cost, others experience the exact opposite drastically hindering their development.

> *"There is a lot of influence lately of the inflation. For example, we initially chose stainless steel for a specific material, let us say, to develop our products to be even more durable and sustainable. But with the rise of the material cost, it was three times as more expensive than plain steel." GSU2, 2:38*

> *"We wanted to make sure that things were manufactured with a minimal carbon footprint. But then comes the reality, (…). When you need to have something manufactured, you cannot really afford to go to 20 different manufacturers and do an assessment of their carbon footprints or different manufacturing methods. (…). You are just stuck with a supply chain that you have or can access. When you already have such a huge sustainability impact with the core technology that partially justifies that thought process." GSU9, 8:52*

To a lesser extent, demand and regulatory side factors mostly support green startups' product and business development. Starting with demand side factors, green startups reported that customers display an interest for green products and, even if not interested in environmental

features, are willing to pay a premium for the product as long as it performed better than existing alternatives. Similarly, competitors are willing to collaborate to elevate markets' environmental standards. However, green startups noted that customers tend to lack of industry and environmental knowledge to understand the product's environmental features and their importance, increasing market resistance toward green products. To overcome that issue, green startup promotional activities also consisted in explaining the existing environmental problems industries are facing and how their product address them.

*"I think one of the main challenges is that the whole concepts of electricity markets are very hard to grasp for electric vehicle drivers. (...). The whole concept of what is happening behind your electricity socket, all the energy trading and the grid balancing, is not known to a lot of people. There is very little available information about it." GSU10, 9:22*

Continuing with regulatory side factors, green startups draw a more nuance outlook. On the one hand, public subsidies and research public research programs play a detrimental role in providing a long-lasting financial support, create sources of environmental-related knowledge by s fundamental research, and draw attention to green products and technologies. Additionally, various regulatory tools geared toward industries and markets are forcing firms and customers to transition toward more sustainable practices and products, effectively supporting eco-innovation development and adoption. On the other hand, regulation unpredictability and inconsistency deter industry stakeholders from investing in green products and technologies. Moreover, strong lobby from industry leaders against environmental regulations, policy-makers bias toward some green technologies and products, and policy-makers excluding green startups from regulatory talks push green startups to tune down their environmental objectives to survive economically.

*"We are facing changing [environmental] reporting standards regularly." GSU5, 5:66*

*"Small companies are not really being taken that seriously by legislators" GSU7, 6:30*

Aggregating all information, green startups decide on *persevering* in the current or *pivoting* to the next cycle or phase. Each iterative cycle has a predefined product and business development target to complete before moving to the next step. First, green startups must validate a product design with sufficient functionality and performance. Next, they aim to replicate the results in the real world. Finally, green startups set up the supply chain and initiate the product sales. Therefore, until a green startup reaches the current cycle targets, it will *persever* in the current cycle.

*"Based on the first operation, you will learn a lot about the system. This will also show you where you can further optimise and make it more economically attractive. That means that in the first instance you are relatively conservative. So, you do not care a lot about the efficiency of the system, you are mainly focused about how I can get it to operate."GSU4, 4:41*

In both cases, the process to *decide on the next steps* to take is similar. First and foremost, green startups *prioritise the next activities to perform* based on the knowledge acquired from the *development and evaluation activities*, the *stakeholders feedback*, and the *identified opportunities and threats*. Following this, green startups *identify their shortcomings* in expertise, resources, equipment, before *allocating the resources* to perform the next activities. To begin with, they determine the resources and capabilities required to execute upcoming tasks. Next, they perform an internal introspection to ascertain if they process them. Finally, green startups rank their shortcomings based on their importance to achieve the next activities.

*"If you want to take that on to, let us say, a higher level, I would say it is knowing in which phase you are and knowing in which phase you miss specific either technical, management, or commercial expertise."GSU3, 3:44*

Building on this, green startups *allocate resources* to future activities. They determine how resources would the best used between internalising activities or delegating tasks to external partners. Essentially, green startups internalise activities that relate to their core competencies or are sensitive to their business model. Therefore, green startups would utilise financial and human resources in bolstering internal development, evaluation, and manufacturing capabilities, for example by onboarding specialised employees, acquiring equipment, and building manufacturing or testing facilities. On the other hand, peripheral and out of their core competencies tasks would be delegated to external stakeholders. To illustrate, green startups would work with legal experts to oversee the administrative tasks to secure patents and protect their intellectual property. In some cases, green startups also delegate core activities to third parties, either to overcome their shortcomings, or to get an independent review of their internal results from an industry expert. Therefore, green startups *allocate* more *resources* to *stakeholders management* over *resources acquisition* and *development activities*.

*"We initially outsourced part of our back-end. That had more to do with the capabilities of the functions that were available within [parent company]. Within the team that we had gathered, there were no particular product developers or back-end developers. So, we had to outsource that in the beginning."GSU10, 9:20*

Green startups *pivot* toward the *validation cycle* after successfully developing and validating a functional laboratory prototype that provides sufficient performance to prove the concept and secure additional funding to finalise the product development.

### 4.2.2 Validation Cycle

Through the *validation cycle*, green startups transform the proof of concept into a minimum viable product. Thus, *product development activities* remain the priority over *business development ones* as they concentrate on finalising the product design. However, *business development activities* increase in importance as green startups explore supply chain options to prepare their product's market debut.

Green startups pursue similar *product development activities*; however, the focus shifted from *product development* to *refinement*. After validating a proof of concept in controlled conditions, green startups aim to replicate the success in uncontrolled conditions. Therefore,

they focus on improving their prototype technical performance to operate flawlessly and reliably in the fields. In parallel, they also ensure that the product design achieves the highest environmental performance possible within their current capabilities. On the whole, green startups meticulously evaluate the different candidate materials and components environmental performance, such as toxicity, renewability, recyclability. Depending on their environmental objectives, and industry and market constraints, green startups may have to tune down their product's environmental performance to ensure it remains affordable, manufacturable in mass, and reliable. Finally, green startups remain open to add new or adapting existing product functionalities based on relevant market and industry factors, such as high material costs, customer feedback, or regulatory landscape changes requiring drastic design changes. However, such changes are only performed if they provide high economic gains or avoid stringent barriers. To summarise, *product development activities* remain similar to the *conception cycle*, although concentrate on refining the product's technical performance until it meets customers' expectations and industry norms. To a lesser extent, improvements in products' environmental and functional performance depends on green startups' objectives and society factors.

> *"We are currently (...) working with one of our shareholders to see whether we can build such a [production system], and the interesting thing about their technology is that one [production system] can be made representative of a whole [production system]. This is not what we had in mind originally and there is no budget for it now. But our stakeholder indicates that we should make a plan to attract additional investments to make that happen. That would accelerate our program significantly." GSU4, 4:36*

*Business development activities* expand to explore supply chain options, however, remain mostly supportive to *product development activities*. To finalise the product design, additional *resources and capabilities* are necessary to develop and evaluate the product at larger scales. They are *acquired* by *intensifying promotional activities* and *expanding collaborative opportunities*. In parallel, green startups begin to explore supply chain options to manufacture, distribute, and recover their product.

To begin with, green startup secure additional funds by *promoting their product* alongside their business. Expanding upon their previous promotional activities, green startups begin to share information about and showcase their product. In most cases, they directly contact potential customers, attend fairs to display their prototypes, and share performance results from the various fields and pilot testing to the market.

> *"With that prototype, we could go to specific fairs, so we went to the Hanover Messe as an example, where we could showcase our technology in a live environment for the first time." GSU3, 3:54*

Next, green startups *expand their collaborative opportunities* with existing and new stakeholders to strengthen their product development and evaluation capabilities. Universally, green startups favour deepening existing partnerships over onboarding new stakeholders, including hiring labour, as the process is time and resources-consuming. However, green startups shifting from building prototypes with off-the-shelf to minimum viable products inherently leads to the need for additional resources, capabilities, and expertise, necessitating new partners to fill the shortcomings. Frequently, additional stakeholders bolster green startups' product evaluation and manufacturing capabilities. Beginning with testing capabilities, green

startups multiply partnerships with universities and public research institutions to access specialised equipment or larger testing and facilities. Additionally, early adopters also provide testing facilities and financial resources by purchasing and evaluating prototypes in pilot projects.

> *"One of the first steps (...) was to go to an institute in another European country with the idea (...) to verify the results on all materials. Additionally, we went to the institute with the thought that the development at the University was always limited to a laboratory scale. (...) So, they can upscale [products] and they have the facility to make a large performance [test]. (...) At that point, we wanted to widen our cooperation base (...) [but] we still work with both institutes today." GSU5, 5:22*

Continuing with manufacturing capabilities, green startups being to explore their supply chain options, such as material and equipment suppliers, manufacturers, and distributors. They prioritise potential partners' capability to provide a qualitative and reliable service, such as capability to manufacture at the desired scale and supply high-quality materials. In addition, green startups also explore their option to set up a sustainable supply chain are evaluated, however, they are examined with less depth due to a combination of internal and external constraints. Internally, green startups lack specific environmental knowledge and tools. Externally, green startups stress the difficulty to find transparent and cooperative stakeholders willing to share information about their environmental and willing to adopt green practices. Among all cases, only one green startup is cooperating with its supply chain partner to reaching high business environmental performance. Combined, these constraints hinder green startups' capability to effectively explore and set up a green supply chain, thereby stifling their efforts to achieving a high business environmental performance. While they might work with some partners during the validation cycle, their integration is not final and can change in the upcoming cycle depending on the partner's capabilities. For example, a green startup may work with a manufacturer specialised in manufacturing one prototype, however, cannot mass-produce for the future phases. While the search for product evaluation partners is essentially performed alone by the green startups, shareholders play a crucial advisory role and open their network when exploring supply chain options.

> *"What we do for commercialisation now is trying to connect to (...) suppliers that can supply our materials and components. That is very important if you want to establish your products. We could potentially assemble our own facilities, or it could also be done at another company. But we look at these supply chain options because (...) you need to scale up so incredibly quickly that we think it will not be possible for this small organisation. We think we will need to have partners and a supply chain in place to be able to do that." GSU4, 4:59*

Similarly, green startups maintain, however, adapt previous *evaluation activities* in line with the *validation cycle* objectives. On the whole, three key differences are observed. First, green startups conduct more tests using physical prototypes and rely less on simulations. Second, prototypes are tested in larger and uncontrolled conditions to evaluate their technical performance. Third, third parties, especially early adopters and specialised public research entities, play a more important role in evaluating the products' functional and technical

performance. Given these differences, previous *product evaluation activities* are adapted accordingly. Namely, A/B testing evaluates which material or product design provides the highest technical performance, pilot testing is performed in larger settings, usually at early adopters to identify flaws occurring in a real world usage, and laboratory experimentation concentrate on assessing material and product design durability. Additionally, green startups also perform usability through field-testing by observing how customers or users operate the product with the intention to identify and correct shortcomings in functionalities. Altogether, *evaluation activities* essentially focalise on assessing the product's technical performance as well as functionality shortcomings when it operates in real condition. The gathered feedback helps green startups finalise the product's design to meet market and industry expectations.

> *"In the bigger field test, we actually rolled it out to the [parent company]'s customers. There, obviously, we also got a lot of feedback." GSU10, 9:17*

> *"I think that the main stakeholder would always be the [users] due to all the feedback that we get from them. But then in larger parts, it is also feedback coming from our business-to-business customers, (...) which are asking things on behalf of their [users]." GSU10, 9:18*

Green startups *pivot* toward the *industrialisation cycle* after successfully refining their prototype into a minimum viable product that operates reliably and flawlessly in uncontrolled situations and secure additional funding to set up a supply chain.

#### 4.2.3 Industrialisation Cycle

Throughout of the *industrialisation cycle*, green startups prepare to *commercialise the product*. Thus, *product and business development activities* share an equal importance in green startups activities compared to previous cycles. Additionally, only green startups developing a hardware product perform the industrialisation cycle because they have to set up a supply chain. However, promotional and commercial activities are also performed by green startups developing a software product.

Almost no change is applied to the product's design during the *industrialisation cycle*. Considering green startups have validated an MVP in the previous cycle, green startups divert their product development resources toward business development activities, especially if they aim to build their own manufacturing capabilities. In some cases, green startups further develop the product, however, changes were decided on during the previous cycle. Therefore, product design changes are not decided based on product evaluation activities performed during the current cycle. Deferring product development activities to the industrialisation cycle allows green startups to simultaneously prepare the supply chain and initiate the product commercialisation while minor design changes are addressed, effectively reducing the time to market. Except this situation, green startups do not actively improve the product's overall performance, however, implement design changes to fit in the existing supply chain.

> *"The tech team is (...) the biggest team within the entire company; they still need to develop the last few steps of the machine. We need to outsource the production of that specific machine with all the requirements in it to the production company. They need to build it, which will take some time." GSU3, 3:85*

*Business development activities* peak in the third cycle as green startups set up their operations. Until now, they mainly produced one-off prototypes for testing purposes in the previous cycles. Thus, setting up a supply chain to manufacture, distribute and recover the products is an important activity during the *industrialisation cycle*. Depending on the green startup and the supply chain partners involved since the *validation cycle*, they either deepen their collaboration or find new partners if they cannot match the desired quantity or quality. In the case green startups decide to partially or fully manufacture their product themselves, they would instead acquire the required equipment and facilities to build their manufacturing capabilities. In this process, green startups also address their product's end-of-life strategy. Interestingly, none of the interviewed startups plan to manage the end-of-life activities internally. At most, they will only deal with by-products created during internal manufacturing processes. Green startups expressed two reasons behind this situation. First, most green startups sell products to business customers, which recover themselves from their products. Second, recycling activities are out of their core competencies. As such, green startups *establish partnerships* to recover and recycle products once they reach end-of-life.

> *"Because our technology will essentially be embedded into to a larger assembly, we basically need to (...) supply a window manufacturer with sustainability data and potentially also sustainability instructions on how you recycle certain materials, etc. But it is very unlikely that [Company] itself will recycle the end product. But we do need to pay attention to recycle unused materials." GSU8, 7:75*

Next, green startups expand their business development workforce to intensify *marketing activities*. Compared to the previous cycles, green startups are now actively promoting their products with the intent to sell it. In addition to their existing communication channels, green startups also expand marketing activities by presenting their product to the public instead of potential customers only. Most commonly, they would interact with potential customers through fairs, workshops, or any event in which they can showcase the product and its functionalities in action. At last, green startups validate the final business model assumption, value capture, by interacting with customers and investors to estimate the value of their product.

> *"I could argue we should sell it for the highest possible price because we want to make money. But that is not the main goal of the company. The main goal would be to eliminate [negative externality], that is also why we saw this leasing model as the option because you will get a much quicker, faster and higher market penetration. But the return on investment for us as a company would be a lot longer." GSU3, 3:64*

Given that *product development activities* are at a minimum, fewer *product evaluation activities* are performed. Throughout the *industrialisation cycle*, green startups focus on pilot, compatibility, and certification testing. To begin with, they continue to conduct pilot testing, however, with promotional intentions. For example, green startups share the results to the market or let customers first try the product before purchasing. Next, compatibility and certification testing are performed to prepare the product's market debut. Referring to compatibility testing, green startups evaluate with supply chain partners whether the product can be produced at scale with their production lines. The outcomes help them to identify product design changes to make it easier to manufacture. Continuing with certification testing, they are

performed to pass the different industry norms and customers qualifications. In both cases, these evaluations are performed by third parties, such as public research institutions, regulatory bodies, industry experts, or customers. Ultimately, *product evaluations activities* support its commercialisation rather development.

> *"We work together with a company that does the LCA analysis (…) once every 1 or 1.5 years (…). That is also required by our investors today. Our investors are impact funds, they have the objective to be as sustainable as possible. (…) At some point, we will report our environmental impact because of the European Sustainability Reporting Standards regulations that have come up in Europe." GSU5, 5:62*

Green startups *pivot* toward the *exploitation phase* after successfully certifying the product and setting up a supply chain to introduce the product to the market, effectively completing the *execution phase*.

### 4.3 Phase 3 – Exploitation

Following the successful market introduction, green startups decide between to *maturing*, *refining*, and *diversifying* their business model. On the whole, the third phase parallels the first one as green startups decide on the next opportunities to follow, however, differs on the depth of exploration, evaluation, and prioritisation activities. Unlike the first phase, green startups primarily focus on the conclusions drawn during the learning activities throughout the execution phase to decide which path to pursue. In addition, each path links back to one of the iterative cycles, from which green startups repeat the same steps. Finally, there are not predefined order and more than one path can be pursued simultaneously. Thus, green startups freely decide which paths to follow after completing the execution phase.

All green startups that reached the third phase undertake the *maturing path*. At minimum, green startups decide to capitalise on the product market debut, focusing on strengthening their financial and market position. To *exploit* their business model, green startups increase promotional activities, such as attending fairs, communicating through various channels, and multiplying pilot programs with customers. A notable finding reveal green startups' role in reforming industry norms and regulations to promote more sustainable industry and market activities. For example, they contribute by sharing some of their product's environmental features with industry clusters to define new norms or work with associations to reform existing regulations with policy-makers. Apart from *exploiting* their product, green startups may decide to *scale up* their operations geographically and manufacturing capability. Ultimately, green startups repeat the activities performed in the *industrialisation cycle* when pursuing the *maturing path* to secure the necessary resources and capabilities to follow other paths.

> *"We are (…) participating in all kinds of pilots and demonstration projects, co-writing some of these new standards, etc. But typically, there are also some associations that try to convince policy-makers of those changes, like SmartEn." GSU10, 9:26*

Pursuing the *refinement path*, green startups decide on improving their products, processes, and operations. These enhancements aim to improve green startups' current economic and environmental objectives. Therefore, improvements are not limited to their

products but also processes and operations. Overall, these enhancements stem from customers and industry partners' feedback, previously postponed product and process improvements, or green startups' continuous improvement commitment. In this study, green startups primarily focus on improving their product and processes environmental performance, as most enhancements were postponed to focalise on the product launch and business survival. For example, green startups explore and set up processes to recover end-of-life products. In the case green startups decide to enhance their products, the *refinement path* sends them back to the *validation cycle*, otherwise, for all processes and operations improvements they repeat the *industrialisation cycle* activities.

> *"If we have [the energy production system] operating (...) then (...) the process of optimisation starts, relating to making the efficiency higher, trying to recycle waste streams after use, etc." GSU4, 4:71*

Through the final path, green startups *diversify* their business model by seizing new green opportunities. Typically, they decide to pursue an opportunity that was previously unprioritised during the envision phase or found during their activities and interactions with stakeholders throughout the execution phase. In either case, green startups expand their business objectives as they seek to address new economic and environmental challenges enctounred in industries or society. Therefore, the *diversifying path* brings green startups back to the *conception cycle* as they initiate the development of a new product, either from the ground up or by modifying an existing one to offer new functionalities and address new economic and environmental problems.

### 4.4 Observed Framework Variation Between Green Startups

All interviewed green startups followed the outlined framework; however, some variations were observed based on a green startup's *nature*, *internal* and *external factors*, and *origin*. To begin with, a noticeable framework difference was observed regarding the *nature of the green startups*: some created software products while others focused on hardware. Green startups developing software products have a shorter execution phase than hardware-focused ones. Both interviewed software oriented green startups seem to skip the *industrialisation cycle* and immediately initiate sales at the end of the validation cycle as no supply chain is needed to manufacture, distribute, and recover their product. Additionally, their *conception* and *validation cycles* appear to be shorter than their hardware focused counterparts because software oriented green startups have no physical product to develop. Therefore, they simply avoid most technical and environmental performance development and evaluation activities, saving time and resources. As a result, software oriented green startups complete their *execution phase* quicker and with fewer resources than their hardware oriented counterparts.

Next, the execution phase greatly varied between green startups due to *internal and external factors*. On the one hand, green startup objectives and business models can greatly influence the time spent on product and business development in the second phase. For instance, green startups for which intellectual property protection is critical end up spending more time and resources to develop their products internally. Likewise, when they have strong competitive advantages due to uniquely developed technologies and processes, they tend to protect themselves as much as possible, not only with patents but also by manufacturing sensitive parts. Therefore, these startups end up developing not only a product but also the entire manufacturing process. On the other hand, external environmental considerations and ambitions can also

impact the development time. For example, environmental objectives may be forced upon green startups with the need to meet specific environmental standards. However, in the presence sample, it seems that all green startups wilfully meet the minimum environmental standards because they strive to exceed environmental regulations or believe these standards will become important in the future.

Variations could also be observed regarding green startups' establishment. In most cases, entrepreneurs found their green startups when pivoting to the *conception cycle* after securing the first major funding at the end of the *envision phase*. However, when the green startup originates from intrapreneurship, entrepreneurs only founded their green startups when moving to the *validation cycle*. Among all cases, five green startups spun out of their mother organisation after validating a proof of concept. Interestingly, they all came from different organisation types, as shown in table 5. All green startups mentioned the need to grow at a faster pace and independently as the main reasons to spin out. Surprisingly, GSU3 originated from another green startup. Entrepreneurs pursued two green opportunities within the same organisation before separating them in two different entities for the same reasons.

**Table 5 – Green startup origin**

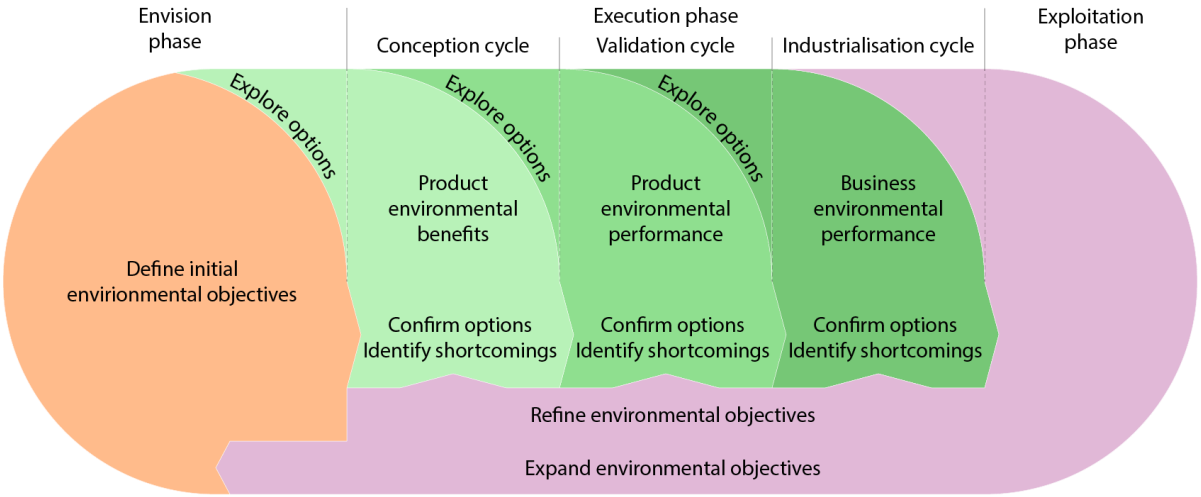
| *Case* | *Previous organisation* |
|---|---|
| GSU3 | Green startup |
| GSU4 | Public research institution (internal independent research group) |
| GSU6 | University |
| GSU8 | Incumbent firm |
| GSU10 | Large incumbent firm |

# 5 Discussion

Green startups followed a lean startup methodology to eco-innovate. On the whole, the strategy described by green startups shares multiple similarities with the lean startup framework (Bocken et al., 2018; Bortolini et al., 2021; Buhl, 2018; Shepherd & Gruber, 2021). To begin with, their strategy echoes the customer development model (Shepherd & Gruber, 2021). Green startups first find and prioritise one green opportunity with external stakeholders during the envision phase before developing it through the execution phase. The process is then repeated with the exploitation phase. Similarly, the execution phase resembles an agile product development approach (Shepherd & Gruber, 2021). On the whole, green startups perform three iterative product development cycles that conclude with the validation of a laboratory, field, and commercial prototype by relevant stakeholders (Shepherd & Gruber, 2021). Depending on the green startup's product type, hardware or software, the field or commercial prototypes represent their first MVP. The similitudes are not a surprise as eco-innovation and lean startup literature suggests that the methodology is suitable in a sustainable development context (Bocken et al., 2018; Buhl, 2018; Shepherd & Gruber, 2021). Indeed, the lean startup literature that the lean startup and sustainable development share the same environmental objectives (Buhl, 2018). Namely, providing high value to customers while minimising resources usage.

The usage of a lean startup framework offers several advantages in an eco-innovation context. To begin with, a lean startup framework strives to continuously improve a firm's value proposition, which is in line with the eco-innovation context. In particular, environmental problems continuously evolve with the introduction of eco-innovations. Therefore, they are temporary solutions that only fit the present context, forcing firms to continuously eco-innovate to maintain and improve their environmental performance. Next, environmental problems are often described as "issues with innumerable and undefined causes, difficult to frame and understand" (Rinaldi & Cavicchi, 2016, p. 213). Moreover, the current system failure and knowledge asymmetry further aggravate the situation (Cecere et al., 2015). Thus, eco-innovators often must proceed with limited information and inadequate options. To cope with this issue, green startups build and test prototypes in real condition and interact with multiple stakeholders in order to acquire the missing data, evaluate the different available options, and identify alternatives, as suggested in the lean startup framework (Bortolini et al., 2021; Shepherd & Gruber, 2021). Moreover, the continuous involvement of stakeholders in product development and evaluation provides additional non-pecuniary advantages such as strengthening green startup credibility, while customers involvement raises interest in the product (Pakura, 2020). Last but not least, the iterative development cycles and continuous interaction with stakeholders are essential to reach the defined environmental objectives. Green startups address one aspect of their environmental objectives in each iterative cycle during the execution phase. Namely, they first validate the environmental benefits the product generates, before addressing its environmental performance and finally setting up a sustainable supply chain and operations. While in most cases, green startups could not fully guarantee a high environmental performance on all aspects, the explorative and iterative process helps to find relevant options and identify the shortcomings. Despite not all environmental problems are addressed during the development of their first product, this process allows for understanding the barriers hindering green startups in reaching their environmental objectives during the exploitation phase.

*Figure 3 – Environmental objectives completion order*




*Proposition 1: By continuously evaluating and reviewing assumptions through prototypes, the lean startup framework is suitable for green startups to deal with the high risks and degree of uncertainty related to the general lack of environmental knowledge.*

*Proposition 2: By continuously involving stakeholders in the development process, the lean startup framework is suitable for green startups to build a high level of trust and credibility within industries and markets that green products can provide a higher value to stakeholders.*

*Proposition 3: Through the lean startup's iterative development process, green startups gradually address their environmental objectives, starting with the product's environmental benefits and ending with the business's environmental performance.*

*Proposition 4: Through the lean startup's iterative development process, green startups explore the current possibility of building a sustainable business model while uncovering the existing limitations to be addressed after the product launch.*

One notable difference between the lean startup in the eco-innovation and standard innovation context consists of the environmental externalities. While in both context improving resource efficiency and reducing unwanted externalities is a shared goal (Buhl, 2018), the initial motivation differs. In a standard eco-innovation context, environmental gains are essentially a side effect and only occur if they provide economic value to the firm (Bortolini et al., 2021). Whereas in the eco-innovation context, positive environmental externalities occur even if they negatively impact firms' economic outcomes. This variation can be observed in the envision phase as green startups categorise the environmental problems they will address following the method described by Buhl (2018), to determine green opportunities' value. Namely, they all have clarified "why, when, and to what extent" the green opportunity is green. This classification was later used to prioritise which opportunity to follow. Thus, environmental objectives are part of the eco-innovator's business value, even if they do not economic value.

*Proposition 5: In the eco-innovation context, lean startup's environmental externalities are a principal motivation and not a side effect of innovation activities.*

Answering Shepherd & Gruber (2021) inquiry, it appears that the lean startup framework used in an eco-innovation context is not significantly different to the one used in for standard innovations. The only notable variation consists in environmental externalities being part of the objectives and not a consequence of economic actions.

### 5.1 Open Eco-Innovation

Consistent with the literature, interacting and cooperating with external stakeholders is detrimental to green startups to define and reach their environmental objectives. The type, nature, and timeline of interaction as well as the contribution to green startups' environmental objectives greatly, varied between the stakeholder (Pakura, 2020). Contrary to the literature, green startups faced no issue in setting up and managing multiple relationships with external stakeholders (Bergset, 2015). Additionally they played an essential validating role to pivot toward the different steps (Bocken et al., 2018; Shepherd & Gruber, 2021).

To begin with the environmental benefits, potential customers, incubators, and accelerators played the largest role. The potential customers mainly play a passive role when green startups are exploring green opportunity options. By disclosing their pains and needs, green startups identify existing environmental problems. Similarly and to a lower extent, industry and academic reports can guide green startups on similar paths; however, green startups confirm the presence of environmental problems through interaction with potential customers. Alongside, incubators and accelerators have a more active role in the process as they help green startups to formulate the environmental problem, assist in the elaboration of a

business model, and expose green startups to industry stakeholders to validate the present of a green opportunity (Bris et al., 2019).

Next, product development and evaluation partners contributed the most in addressing the product's environmental performance. Expert firms, such as engineering firms, as well as regulatory bodies provide valuable environmental information that influences material and product design choices. In the first case, they share the knowledge, whereas in the second case regulatory bodies relay materials' environmental performance data within industries, for example through the REACH certification. Regarding the evaluation of the product's environmental performance, potential customers, through qualification testing, and universities through public research contributed the most. In most cases, these stakeholders test against other relevant alternatives and provide green startups with environmental performance shortcomings.

Finally, supply chain partners and investors influence the most of the business's environmental performance. Similarly to specialised firms, supply chain partners provide green startups with information about on the environmental performance of their activities, helping green startups to better understand the available options to sustainably source materials and manufacture, distribute, and recover the products. To a lower extent, investors also contributed to the effect by connecting green startups with sustainable industry partners.

### 5.2 Eco-Innovation Determinants

Surprisingly, the system failure was not as prevalent as expected. By and large, barriers encountered by green startups mostly originated from the supply side rather than the regulatory and the demand sides. Moreover, the latter two groups of factors seem equally supportive than not. One possible explanation is that the green startup sample can be considered as green champions, thus, essentially perceive financial constraints as deterring barriers (Marin et al., 2015; Triguero et al., 2016).

Unpredictable and inconsistent regulations are the main barriers in the regulatory side. Without a foreseeable regulatory framework, green startups end up wasting resources to adapt to the change (Pinget et al., 2015). Additionally, the lack of consistency deters incumbent firms to adopt green startups' product as they may not be considered as green products. Moreover, green startups often complain about being excluded from regulation creation and policy frameworks. An exclusion of green startups to the government long-term planning leads to the same results. Despite these barriers, regulatory side factors are increasingly becoming drivers for green startups. While public subsidies remain somewhat challenging to find, most green startups encountered no difficulties to secure multiple ones as policy-makers increasingly introduce environmental requirements to acquire them. Likewise, policy-makers more often use the different regulatory tools, such as subsidies, fines, and public procurement, to raise environmental awareness and interest toward green products in industries and markets.

The same conclusion could be drawn with demand side factors. In most cases, market barriers were essentially limited to customers not able to identify and understand the environmental features (Cecere et al., 2015), or are simply no interested in the products' environmental features (De Marchi, 2012; Pinget et al., 2015). However, customers appear to understand them when provided with the relevant information, leading to acceptance of the eco-innovation. Additionally, multiple green startups have noted that customers are not only

environmentally aware (Doran & Ryan, 2016), but are also more willing to pay a green premium (Pinget et al., 2015), even if they are not interested in the environmental features.

Although regulatory and demand side factors appear more supportive than expected (Cecere et al., 2015), supply side factors mostly hinder eco-innovation development and adoption. To begin with, there is a general lack of sustainable resources and capabilities, driving preventing green startups to reach all their environmental objectives. In the case green alternatives exist, they are often out of reach financially to green startups or not available in sufficient quantity. Regarding to end-of-life activities, they are simply underdeveloped; however, multiple green startups noted participating industry-wide projects to address this shortcoming. Next, most industries lack of environmental appropriation (Cecere et al., 2015; Marin et al., 2015). Thus, incumbent firms appear to protect their existing business model regardless of the environmental harm it may cause, while small and medium enterprises do not assess their environmental performance. Considering green startups mostly outsource most of their activities (Hockerts & Wüstenhagen, 2010), they have difficulties to evaluate their business's environmental performance. Moreover, industry stakeholders often pressure green startups to maximise economic gains at the expense of environmental ones (Bergset, 2015). As a result, they had to postpone the completion of or abandon some environmental objectives. Another reason to postpone environmental objectives is related to the fast pace environment that green startups operate. Industry pressured green startups to reach economic benefits first or maximise them, especially investors (Bergset, 2015). As a result, software green startups are often favoured over hardware ones. Additionally, green startups must postpone environmental objectives to the third phase. Finally, green startups may lose ownership through shareholders, further reducing its capability to reach initially set environmental objectives as industry stakeholders are less environmentally motivated. Last but not least, industry dynamics are not prone to the cooperation to develop and adopt eco-innovation, which is critical in this context (De Marchi, 2012). However, industry side factors are highly dependent on the industry in which the green startup operates. In rare cases, strong regulatory and demand side drivers were sufficient to dismiss the industry side barriers as they provided the incentive to develop and adopt eco-innovations.

*Proposition 6: System failure is not the main issue for green startups to eco-innovate; conservative industries and the lack of environmental appropriability among industry stakeholders constitute the stringent barriers to eco-innovation development and diffusion.*

# 6 Conclusion

To date, few studies have investigated strategies applied by firms to successfully eco-innovate. For the most part, research focused on large incumbents and, more recently, small and medium enterprises (Bocken et al., 2018), while less attention is given to startups despite their critical role to initiate industry and market sustainable transition (Hockerts & Wüstenhagen, 2010). Therefore, a research gap exists due to the inherent difference in eco-innovation exploration and development paths compared to standard innovation (Bocken et al., 2018; Shepherd & Gruber, 2021), primarily due to the addition of the environmental dimension in activities and operations and the existing system failure hindering eco-innovation development and adoption. This study addressed this gap by exploring eco-innovation strategies followed by green startups in the Netherlands and provides several contributions to literature, managers, and policy markets. Finally, limitations and future research conclude the study.

## 6.1 Theoretical Implication

The present study contributes to the eco-innovation, green startup, and lean startup literature streams. To begin with, the research completes the eco-innovation literature by providing empirical data about drivers and barriers as well as stakeholders implication and importance by examining green startups eco-innovation strategies and activities. A notable contribution consists in the observed system failure improvement (Cecere et al., 2015).

Next, the findings emphasise green startups' pivotal role in leading industry and market sustainable transition (Hockerts & Wüstenhagen, 2010). Contrary to other startups, sustainable entrepreneurs not only fully support environmental objectives but strive to continuously improve after reaching them (Bergset, 2015). Additionally, the absence of a knowledge base and previous investments, a simpler and flatter organisational structure, and strong absorptive capabilities allow green startups to avoid any form of lock-in and come up with creative solutions to overcome issues imposed by the ongoing system failure (Klewitz & Hansen, 2014; Pakura, 2020). Finally, contrary to the literature, the findings suggest that green startups are capable of managing multiple relationships simultaneously (Ben Arfi et al., 2018).

Finally, the study highlights the advantages of the lean startup's iterative process in the eco-innovation context (Bocken et al., 2018; Buhl, 2018). Addressing the environmental objectives sequentially by first focusing on the product's environmental benefits and end with the business environmental performance enable firms to deal with the environmental dimension's challenges. In particular, the continuous evaluation of product and business improvements permit firms to understand their environmental performance, both positive and negative, as well as their competitiveness against relevant alternatives. This practice allows firms to overcome the existing shortcoming regarding environmental-related knowledge while ensuring the business model remains competitive.

## 6.2 Managerial Implications

Manage can leverage the findings to bolster their eco-innovation strategies. First, they should adopt a lean startup framework considering the advantages it offers multiple advantage to cope with the uncertainty and risks bound with eco-innovation development and adoption. Additionally, managers should spread their environmental objectives throughout the different iterative cycles and phases and always beginning with ensuring that the product provides the expected environmental benefits before addressing the products and the business environmental performance. Moreover, green startups should not hesitate to postpone certain aspects of their product and business environmental performance to the exploitation phase if there are currently no sustainable and affordable alternatives available.

Next, entrepreneurs should only prioritise and develop one green opportunity at the time. Despite a product could be used in different scenarios, its requirements and functionalities will drastically differ from one to another. Additionally, all industries are not equal as they progress at different paces and have a distinct set of factors. Therefore, neither opportunity will progress at the same pace and would require more resources than if they were pursued individually. In a large firm, managers should resort to intrapreneurship to ensure the green opportunity can develop independently.

Finally, managers should consider cooperating with universities and customers the earliest possible (Acebo et al., 2021; Pakura, 2020). Regarding academic institutions offer several non-negligible opportunities, such as access to public funding, specialised equipment

and workforce, large scale and real condition testing facilities (Acebo et al., 2021; Arroyave et al., 2020). Additionally, cooperating with universities help green startups to gain in visibility and credibility toward industry stakeholders (Bris et al., 2019). Continuing with customers, their involvement not only helps green startups to capture unique selling points, but also increases market penetration. Indeed, eco-innovation lacks of successful business cases (Cecere et al., 2015), therefore, multiplying successful pilot testing with customers increasing market interest and trust toward the green startups and its products (Shepherd & Gruber, 2021).

### 6.3 Public Policy Implications

Although regulations seem to have an impact on the current system failure situation, multiple recommendations for policy-makers can be drawn. To begin with, policy-makers must adopt an objective and fair support on eco-innovations. The favouritism of some and the exclusion of other eco-innovations limits the diffusion of diverse eco-innovations. As environmental problems are highly bound to the context, one solution cannot fit all situations (Carrillo-Hermosilla et al., 2010).

Next, policy-makers should include green startups in industry and environmental regulation drafting discussions. Unanimously, green starts agreed they were overlooked by policy-makers during the creation of new regulations. Only giving voice to large incumbents essentially diminish the impact of these regulations and slow down society's sustainable economy transition as their protect their existing business models (Marin et al., 2015). However, green startups' inputs were crucial to uplift industry environmental norms when supported by industry clusters.

Additionally, policy-makers must intensify industry and academic cooperation via public exploratory research to promote industry-wide collaboration (Moreno-Mondéjar et al., 2020). Several participating green startups have benefited from such research as they draw attention toward their solutions, because they came with environmental conditions that green startups' products matched. As such, firms and academic institutions included green startups to industry-wide research and development projects, speeding their development and raising their credibility. However, not all industry seems to have the same degree of attention. Therefore, policy-makers should not only intensity such projects, but also equally spread them in different sectors.

Last but not least, policy-makers should ensure a more predictable and stable environmental regulatory framework (Cecere et al., 2020). Currently, the rapid and erratic environmental regulations and framework changes not only costs resources to green startups to continuously adapt to them, but also decrease incumbents' interest in green startups and eco-innovations (Wicki & Hansen, 2019). A more predictable and stable framework should not only be implemented at the national level, but at the European one. In some cases, drastic variation in regulation between European countries pushed green startups move in more favourable countries or simply slow down their development if they cannot afford to relocate. Additionally, cooperating with neighbouring countries could help to investigate in which scenario one eco-innovation is more suitable than others. Thus, eco-innovation that may not be relevant to the Netherland could still exist in other countries if policy makers intensify cross country testing.

### 6.4 Limitations and Future Research

As with any study, the findings come with several limitations. First and foremost, no distinction was made between the type of green startups. Whether a green startup develops a software or

hardware product greatly affect the number, intensity and type of activities performed. Therefore, future research should investigate these two types of green startups separately or take into account the potential variation. Additionally, green startups operating in different industries and at different development stages were interviewed with the intention to explore similarities in activities and strategies pursued. Future research should proceed with more homogenous green startups grasp the specificities bound to a phase, cycle, industry, or green startup type, such as the activities performed, determinants encountered, or the interaction and cooperation with stakeholders. On the whole, subsequent quantitative studies with a broader sample of green startups are necessary to validate the proposition. Second, only two green startups in the present sample have pivoted away from their initial green opportunity toward a new one due to negatively changing industry and market factors. While in both cases, the green startups managed to repurpose the initial project in another industry, it would be interesting to investigate the reasons push green startups to abandon a green opportunity for development in the first place. Third, only green startups founded and operating in the Netherlands participated in the study. Compared to other European regions, Dutch firms are considered to be green champions as they are more motivated to develop and adopt sustainable business models and perceive fewer barriers than their European counterparts (Marin et al., 2015). Therefore, it would be interesting to investigate possible changes in strategies applied by green startups from other European countries. Last but not least, software products developed by green startups provide valuable information about the environmental performance of the stakeholders using them. However, the data generated and collected is currently not used for various reasons, according to the green startups. Therefore, it would be relevant to investigate investigating the potential role and usage of the data generated by their products to accelerate society's sustainable transition.

# 7 Appendix

## 7.1 Interview grid

**Introduction**

1) Could you tell me something about yourself?
2) Could you briefly introduce [company]?
    a. Why was [company] founded?
        *i. What ware [company]'s objectives?*
            *1. Does [company] have any specific environmental objective?*
            *2. Could you describe [company]'s environmental objectives?*
        *ii. Why did [company] chose these objectives?*
    b. What is [company]'s product and/or service?
        *i. What is [company]'s main selling point?*
        *ii. How did [company] come up with this product and/or service idea?*
    c. In which industry is [company] operating?
    d. Which customer group is [company] targeting?

The EU defines 4 phases in a startup life cycle: seed, startup, steady, and growth. The first ends with the development of a concept. The second ends with the development of a minimum valuable product. The third starts with the commercialisation of its products and/or services while not experiencing rapid growth. The last begins when the startup experience a rapid growth in terms of workforce, sales, market share, etc.

e. In which startup phase would you place [company]?
    i. *If I understand well, [company] is currently developing its product and/or service and has not started the commercialisation of its products and/or services?*
    ii. *If I understand well, [company] has completed the development of its product and/or service and has started the commercialisation of its products and/or services?*

**Development activities**

3) Could you describe which steps or activities has [company] taken in its development process to date?
    a. How long has [company] been in the development process to date?
        i. *How long does [company] expect the development process to take?*
    b. To what extent does the current products and/or services differ from the initial concept?
        i. *What are the differences?*
        ii. *Was [company] expecting these differences?*
        iii. *What reasons enabled these differences?*
4) Could you describe which stakeholders have played an important role in [company]'s development process to date?
    a. How do stakeholders contribute to [company]'s development process?
        i. *With which stakeholders is [company] interacting the most closely to achieve its objectives?*
    b. Could you describe how important are stakeholders to [company]'s development process?
        i. *What benefits or challenges have arisen from stakeholders' involvement in [company]'s development process?*
        ii. *Has [company] experienced any unexpected benefits or challenges that have arisen from stakeholders' involvement in [company]'s development process?*
        iii. *Overall, how would you rate the benefits versus the challenges?*
            1. Do the benefits outweigh the challenges?
            2. To what extent is collaboration required for [company]'s development process success?
5) Could you describe how [company]'s environmental considerations – concerns influence its development process?
    a. How does it affect:
        i. *[Company]'s decision making?*
        ii. *The selection and involvement of stakeholders?*
        iii. *[Company]'s concept – product – business model design?*
6) Could you describe the biggest challenges that [company] has faced in its development process to date?
    a. How did [company] overcome these challenges?
    b. What challenges remain?
        i. *How does [company] plan to overcome these challenges?*

ii. *How does [company] manage competing priorities between environmental objectives and commercial success/survival?*

**Commercialisation activities**

7) Could you describe which steps or activities has [company] taken in its commercialisation process to date?
    a. How long has [company] been preparing the commercialisation process prior starting to commercialise its product?
        i. *How long does [company] expect the commercialisation preparation to take?*
8) Could you describe which stakeholders have played an important role in [company]'s commercialisation process to date?
    a. How do stakeholders contribute to [company]'s commercialisation process?
        i. *With which stakeholders is [company] interacting the most closely to achieve its objectives?*
    b. How important are stakeholders to [company]'s commercialisation process?
        i. *What benefits or challenges have arisen from stakeholders' involvement in [company]'s commercialisation process?*
        ii. *Has [company] experienced any unexpected benefits or challenges that have arisen from stakeholders' involvement in [company]'s commercialisation process?*
        iii. *Overall, how would you rate the benefits versus the challenges?*
            1. Do the benefits outweigh the challenges?
            2. To what extent is collaboration required for [company]'s commercialisation process success?
9) Could you describe how [company]'s environmental considerations – concerns influence its commercialisation process?
    a. How does it affect:
        i. *[Company]'s decision making?*
        ii. *The selection and involvement of stakeholders?*
        iii. *[Company]'s promotion of its organisation and/or products?*
            1. [Company]'s supply chain design?
10) Could you describe the biggest challenges that [company] has faced in its commercialisation process to date?
    a. How did [company] overcome these challenges?
    b. What challenges remain?
        i. *How does [company] plan to overcome these challenges?*
            1. How does [company] manage competing priorities between environmental objectives and commercial success/survival.

**Environmental dimension**

Using a scale of 1 to 10 where 1 represents no action taken to reduce [company]'s operations and products negative environmental impact and 10 represents complete environmental neutrality across all stages of [company]'s operations and product life cycle.

11) How would you rate [company]'s environmental performance?

a. Could you elaborate how does [company] assesses its environmental performance?
    i. *How does [company] assess whether its product addresses [company]'s environmental objectives or the environmental problems that [company] targets?*
    ii. *What factors does [company] considers when assessing its environmental performance?*
    iii. *If any, which stakeholders are assisting [company] to assess its environmental performance?*
        1. How do stakeholders contribute to the process?
    iv. *What are the biggest challenges [company] faces when assessing its environmental performance or footprint?*
b. Based on your assessment of [company]'s environmental performance, is there room for [company] to improve it?
    i. *Which areas of [company] can be improved?*
        1. How does [company] identify potential areas for improvement in [company]'s environmental performance?
        2. How could [company] further improve the sustainability of its products and/or operations?
    ii. *Is [company] planning to improve these areas in the near future?*
        1. YES: Could you explain how is [company] planning to improve these areas?
        2. NO: Could you explain why is [company] not planning to improve these areas?
    iii. Are there any specific obstacles or challenges that prevent [company] from improving its products and/or operations environmental performance?

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