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## Article

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# Readiness for Innovation of Emerging Grass-Based Businesses

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**Abstract:** New business opportunities based on grassland and green fodder present a promising avenue to realize the transition towards a circular and sustainable bio-based economy. Yet, such potential remains largely untapped and grass-based products and businesses remain a small niche in the global economy. To understand this phenomenon, this paper introduces and operationalizes a model to assess innovation readiness built around seven focus areas: technology, manufacturing, business, IPR, customer, team, and funding readiness with their own detailed “progress scales.” We employ necessary condition analysis (NCA) to identify limiting factors and bottlenecks in actual business situations. Our results reveal that lack of consumer awareness, infant conversion technologies and paucity of long-term investments that support emerging bio-based businesses are the most limiting conditions for the growth of emerging grass-based markets. The present study advances our understanding of the factors that limit complex innovations in grassland systems. Focusing on necessary conditions in a coordinated way between practitioners and policy makers by giving priority to fostering positive awareness of bioeconomy businesses, developing conversion technologies, and improving access to capital is a recommended approach to foster emerging grass-based innovations.

**Keywords:** bioeconomy; business; readiness; innovation; grasslands

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## 1. Introduction

The bioeconomy can be defined as the production, utilization, conservation, and regeneration of biological resources to provide sustainable solutions (information, products, processes and services) within and across all economic sectors and enable a transformation to a sustainable economy [1]. One of the most discussed aspects of the bioeconomy is the replacement of fossil-based products by renewable and plant derived resources [2]. Bioeconomy transitions have major implications for the structures and outcomes of the economy and offer a new dawn, in particular for rural regions, as new bio-based products and services enable a new take on skills, jobs, and provide mutual benefits for local economies and the environment [3,4]. This has been the main rationale for the political interest with strong focus on innovation through research and technology development represented in the European Green Deal, national bioeconomy strategies and global climate agreements, among others.

In the EU, approximately 17.5% of the surface area is covered by grasslands and green shrubs [5]. Grasslands not only provide food and income for herders, but also provide essential ecological services such as climate regulation, wind prevention, biodiversity conservation and carbon fixation [6] as well as cultural services such as aesthetics and recreation [7]. A large fraction of this area has traditionally been utilized as pasture for livestock. However, this practice has been declining substantially in the passing years [8]. Today these resources remain underutilized, being left to decay after mowing and thus causing costs and lost benefits for individuals and society. Utilizing the surplus material

of otherwise unused grasslands can help valorize and maintain the biodiversity and ecosystem value of grasslands [6]. In the last few decades, varied technologies to enhance the treatment and valorization of grass biomass into high value-added products for emerging markets have been studied and developed [9–12]. However, the transfer of technologies and therewith commercialization of grass-based products into the market remains a difficult endeavor [13,14]. Despite the urgent need for harnessing local resources and developing innovative bio-based products, the full potential of grass biomass remains widely unlocked and alternative grass-based products remain relatively unknown and underused in Europe's economy [15]. To fill this gap, this study addresses the question of which conditions limit the upscaling of emerging grass-based businesses? Further, we aim to assess if and to what degree these different conditions are of importance?

The intricacy of the bioeconomy starts at the system level by interfacing biotechnology and economy and involving industries, civil societies, governments, educational institutions, political and public organizations [16]. Emerging businesses are now dealing with systemic innovations [17,18] which encompass certain particularities into the larger transition towards a bio-based economy in a more dynamic context [19]. Firms in emerging markets typically suffer from the absence of an institutional infrastructure which includes access to capital and legal frameworks that would facilitate their business transactions [20]. Unlike other businesses, innovative bio-based businesses, have to deal with more and very specific legislative constraints, as well as the challenges posed by infant and non-adapted technology [21]. The unclear values and perceptions of consumers, ambiguous market signals and an embryonic competitive structure pose further difficulties [22]. As such, it has been recognized that grand societal challenges such as the depletion of natural resources cannot be solved by means of technological solutions alone [23,24]. To address the sustainability of future agriculture in this context, a holistic approach that considers the multidisciplinary nature of innovation processes is a fundamental milestone.

Literature on innovation indicates that transformation is a consequence of the interplay of activities at multiple levels [25,26]. The innovation process has been defined as the sum of all activities needed to develop, disseminate and commercially apply the innovative idea [27,28]. Organizations increasingly understand that meeting sustainability ambitions does not only require new and improved technologies, but innovation on the business model level [29]. In this context, several frameworks such as the Technology Innovation System (TIS) [30], the Business Model Canvas [31] and the Business Environment Framework [22] have helped with the conceptualization of a wide range of business models and business environments. Yet, methodologies for business and innovation research are complex and multifaceted, and unfortunately not as well developed as its conceptual aspects [32]. Contemporary methodological challenges for business and innovation research include, *inter alia*, deficient measures [33] and insufficient evidence about causal relations [34,35]. Despite considerable efforts, the current body of literature is still lacking a practically useful framework which enables the measurement of the wide variety of business processes and which considers their intricate relationships within the business setting [36,37]. Particularly, for emerging innovations enabling Bioeconomy transition [14,38].

Against this background, and taking advantage of more recent methodological developments, this investigation aims to make at least three contributions. Firstly, we present a practical framework synthesized from a number of different approaches as an instrument to assess the innovation readiness of emerging businesses. Secondly, we prescribe Necessary Condition Analysis (NCA) as a practical method to identify bottlenecks and critical determinants that are essential for upscaling innovative businesses based on grass and green fodder. Thirdly, we empirically test the NCA approach across eight grass-based cases with different “maturity” levels to gain understanding on the limiting factors for the development of emerging bio-based businesses, and grass-based businesses in particular. The empirical evidence provides key recommendations which could support firms

and innovators to economize resources dedicated to the innovation process and translate into management tools for policy and planning.

## 2. Materials and Methods

### 2.1. Case Study Selection

We use case studies [39] due to the limited availability of businesses producing high value-added products from grass biomass. Limiting the study to one sector, namely the grass-based industry, allows in depth analysis of the conditions, ongoing activities and dynamics of sectors in transition towards more sustainability. Our sample comprises eight innovative grass-based businesses in Europe at different stages of the innovation process, i.e., from small-scale demonstration sites to more advanced self-sustaining businesses. The cases were selected using a combination of searches for innovative grass-based businesses in the web, expert's forum and EU project network databases. The sampling criterion was based on the potential of the business models in terms of the use of grass as raw input material, the key activities to make use of the grass resources, the value propositions, the products and services provided different from traditional livestock and grass-based products (i.e., not milk, meat, cheese), as well as the customer segments, business channels, and revenue streams.

### 2.2. Case Study Description

**Case 1:** Small scale grass-refinery developed and operated by Aarhus University Center for Circular Economy (CBIO) in cooperation with the Food and BioCluster Denmark. The focus is on extracting protein from grass-clover, lucerne, organic grasses, and paludiculture crops from intensively managed grassland situated in nitrate sensitive areas. The biorefining process fractionates freshly harvested grass into a juice and a fibrous pulp. The pulp is ensiled and used for ruminant forages, while the juice is heated, to precipitate protein, and subsequently centrifuged to separate the protein concentrate. The organics in the residual liquid fraction (brown juice) is used for biogas production and the nutrients are recycled back to the soil as fertilizer.

**Case 2:** Digestion and fermentation to produce paper and carton products from roadside grass or fauna grass developed in collaboration with the Application Centre for Renewable Resources of Wageningen University and Research (ACCRES), Nordlike Fryske Walden and Schut Papier in the Netherlands. The raw material grass used is harvested from nature reserve areas and roadside areas. The digestate is separated into an aqueous fraction that is used as fertilizer and a solid fraction. From the solid phase the fibers are extracted and further refined to a quality that fits the applications for use of paper products. The company SCHUT uses grass fibers to manufacture egg-cartons and egg-trays.

**Case 3:** The local production of biochar uses grassland-cuttings from periodically wet grasslands located in the National Park Unteres Odertal, Germany. The harvested grass is mostly strongly lignified and with lower nutritional quality for animal feed. A Hydrothermal Carbonization process (HTC) is developed by the Leibniz-Institute for Agricultural Engineering and Bioeconomy (ATB) in cooperation with the Naturparkverein Unteres Odertal e.V. to produce grass-based biochar as supplement for soil improvement.

**Case 4:** The production of climate-friendly animal bedding from reed canary grass that has been heat treated and pressed is a development by Research Institutes of Sweden (RISE) and other local partners such as Glommers Miljöenergi and Vastakra Gard located in Sweden. The main technology to be applied is briquetting at local and small scale. The briquetting technology needs to be put in context with the other steps to create a new production chain.

**Case 5:** Re-engineering of grass unto biodegradable materials such as pulp molding, paper and packaging and fiberboards. The processes developed by Zelfo Technology located in Germany revitalizes a wide range of cellulosic and ligno-cellulosic sources. The processes impart new application capabilities to these materials, giving value to resources

that had little to no value and encouraging the use of renewable and biodegradable materials as an alternative to plastic-based solutions. Current main applications are in pulp molding, paper and packaging and fiberboards.

Case 6: Sustainable use of resources in neglected or underutilized grasslands mainly through the production of biochar. The innovation is facilitated by the Hungarian Research Institute for Organic Agriculture (ÖMKI) to support organic agriculture production in Hungary. Building upon the experience of their nationwide on-farm experimentation network, ÖMKI aims to replicate grass-based business models in Hungary.

Case 7: Developing and replicating technical solutions and business models to valorize agricultural residues and grass material from marginal grasslands by the Romanian Association for Sustainable Agriculture (ARAD), a non-governmental organization focusing on the promotion of sustainable farming systems.

Case 8: Small scale circular systems based on grass and green fodder to provide new business opportunities for young entrepreneurs by the Galician Association of Agri-food Cooperatives (AGACA) in Spain. Drawing upon the practical experience of their 34,000 members, AGACA aims to replicate circular business models at a local level.

### 2.3. Variable Definition

To expedite an orderly and reproducible assessment of the innovation readiness process, a set of seven necessary conditions (or independent variables) for innovation were selected from the literature: Technology, Manufacturing, Business, IPR, Customer, Team and Funding Readiness. Our selection of the seven readiness areas was guided by the Innovation Readiness Level Framework (IRLF) developed by the Royal Institute of Technology in Stockholm, Sweden (KTH). The IRLF was inspired by the Technology Readiness Level (TRL) developed by the space industry in the 1970s. The other focus areas are not universally agreed. Yet, they have been included to support early-stage innovation development and have been empirically tested by KTH in multiple ventures for the past 20 years. Since our study targets the production of grass-based products, we extend the framework by including manufacturing readiness [40] and considering innovation readiness [41] as the outcome or dependent variable.

Within each focus area, a detailed readiness level scale from 1 to 9 is described with clear definitions of criteria, milestones, and activities that must be accomplished to move on to the next level (Appendix B). The scales provide a roadmap for guiding progress in every dimension of innovation development, from an idea unto its successful commercialization.

### 2.4. Data Collection

Data were gathered within the frame of the H2020 GO-GRASS project ([www.go-grass.eu](http://www.go-grass.eu)) between October 2019 and July 2022. Firstly, a questionnaire based on the Innovation Radar (Appendix A) was sent to eight business representatives of the cases to assess their current state and to understand their value propositions. These results were discussed in two stakeholder board meetings organized in the frame of the H2020 GO-GRASS project which took place in Denmark and Sweden in 2021. Focus group discussions [42] with entrepreneurs, researchers, technology developers, and agricultural producers took place with the aim of discussing opportunities and constraints for the upscaling processes of grass-based businesses.

The readiness levels of the business cases were assessed in an iterative process with experts, according to specific milestones and criteria (Appendix B). To evaluate the readiness levels for each case, we conducted self and external assessments [43]. Quality standards were ensured by assessing the diversity and the degree of consensus on the readiness levels in a series of dedicated meetings. Finally, based on the empirical findings, GO-GRASS project deliverables and consultations at project meetings, we derive upscaling strategies to accelerate the development of grass-based businesses.

### 2.5. Necessary Condition Analysis (NCA)

Conventional theories and methods generally operate on the logic that several factors contribute to the outcome and can compensate for each other (e.g., OLS and other types of multiple and multivariate regression, multilevel modeling and structural-equation modeling) [35]. Factors are usually interpreted as being sufficient causal factors that can help to produce the outcome. Yet, these methods are not able to identify necessary conditions in data sets [44].

In contrast to more traditional regression analysis that study variables in a probabilistic relation to each other, NCA is based on necessity causal logic and allows the study of variables which are necessary but do not guarantee a certain outcome [44]. For example, grass processing and conversion technologies are necessary but do not guarantee the success of businesses producing grass-based products. Indeed, a necessary condition will prevent an outcome from occurring. There will be “no Y without X” in the necessary condition logic. Thus, while a sufficient cause produces an outcome, without the necessary cause, the outcome will not exist despite other factors being present, at least to a necessary degree [45,46].

To spot critical determinants that constrain the upscaling of emerging grass-based businesses, we conducted a Necessary Condition Analysis (NCA) with the NCA package in R (Version 3.1.1). The advantage of using NCA is that the study and its theoretical reasoning can focus on single necessary concepts, which allows a clear storyline and an efficient data collection and analysis [47]. The method is developing rapidly and applied in a variety of research areas including business and management to provide effective decision support and managerial insights [48]. Examples of related studies that have used NCA include the role of contracts and trust in driving innovation [49], the link between specific firm capabilities and performance [50], and the necessity of top management support for successful implementation of lean manufacturing [51]. Identifying relationships of necessity is of key interest in the social sciences and beyond. It can provide actionable knowledge with “very powerful policy implications [52].” By understanding which variables are critical to what degree for a desired outcome, researchers and practitioners can gain a better understanding of the causal effects when examining a particular outcome.

The NCA analysis in R produces scatter plots in an XY plane and conducts a bivariate analysis. NCA draws borders lines called “ceiling lines” between the space without cases and the space with cases. NCA offers two default ceiling lines to choose from. The Ceiling Envelopment-Free Disposal Hull (CE-FDH) ceiling technique is a step function employed when using discrete (with few levels) necessary conditions. The Ceiling Regression-Free Disposal Hull (CR-FDH) ceiling technique is the default ceiling technique for discrete (with many levels) and continuous necessary conditions. In this study, we used nine levels for each condition; hence, we focus our analysis on the step function CE-FDH.

The size of the empty space above the ceiling line is an indication of the strength of the necessary condition (‘effect size’). In the following section, we report results of the NCA based on 10,000 permutations using the observed sample. The relative importance of the independent variables and the accuracy of the results were presented and discussed in two conferences among experts and practitioners.

## 3. Results

### 3.1. Readiness Levels

The results for the readiness levels of the cases in Table 1 show that the cases studied are very heterogeneous in terms of their readiness levels. Our sample comprises eight innovative grass-based businesses in different countries of Europe and at different stages of the innovation process, i.e., from small-scale demonstration sites to more advanced self-sustaining businesses.

**Table 1.** Readiness levels assessment of grass-based businesses cases.

Case ID	Country	TRL	BRL	CRL	IPR	FRL	TMRL	MRL	IRL
1	Denmark	7	7	7	5	9	8	8	8
2	Netherlands	7	4	6	2	5	5	5	6
3	Germany	5	3	4	1	3	4	5	4
4	Germany	9	9	8	9	9	8	9	9
5	Sweden	7	7	7	2	7	5	7	7
6	Hungary	2	1	2	1	1	2	2	2
7	Romania	4	3	5	1	3	3	2	3
8	Spain	2	2	5	1	1	3	2	3

### 3.2. Effect Sizes of the Seven Necessary Conditions

The results shown in Table 2 about the effects sizes for the seven conditions indicate that Customer Readiness has the biggest effect (0.619) for the development of the grass-based businesses tested. Thereafter, Technology Readiness (0.612), Funding Readiness and Team Readiness (0.571), Manufacturing Readiness (0.551), Business Readiness (0.518), and lastly IPR Readiness (0.268).

The effect size indicates to what extent a variable is necessary for an outcome. In other words, to what extent conditions constrain the outcome. The effect size  $d$  can range from 0 to 1. In applications of NCA, necessity effect sizes between 0 and 0.1 are usually considered small, from 0.1 to 0.3 medium, from 0.3 to 0.5 large and above 0.5 very large.[47]. Yet, these are highly dependent on the research context and should be assessed accordingly.

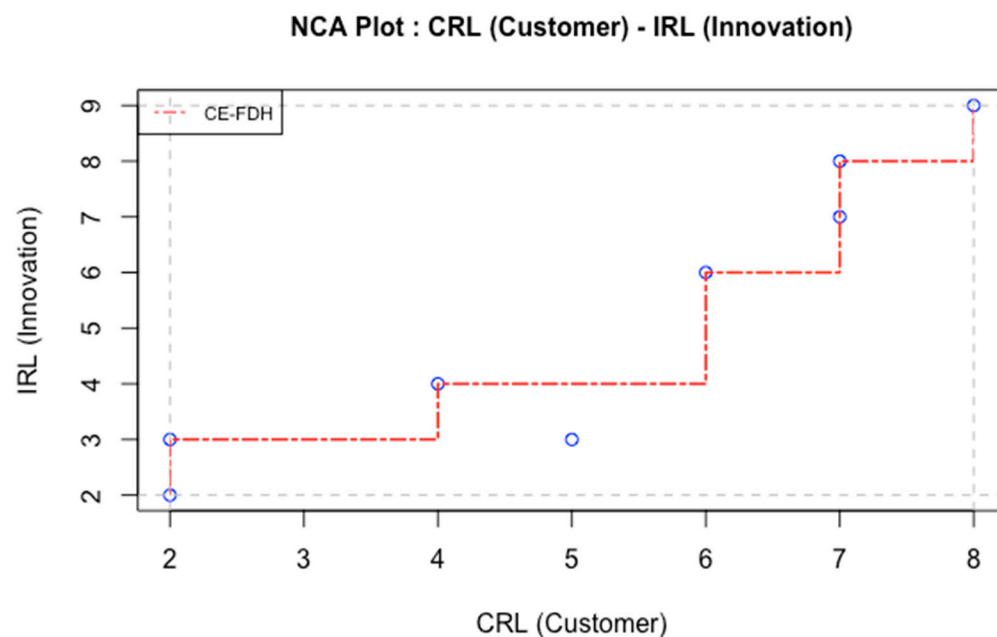
**Table 2.** NCA parameters of the seven necessary conditions for upscaling grass-based businesses.

Condition	Method	Effect Size ( $d$ )
Customer Readiness	CE-FDH	0.619
Technology Readiness	CE-FDH	0.612
Funding Readiness	CE-FDH	0.571
Team Readiness	CE-FDH	0.571
Manufacturing Readiness	CE-FDH	0.551
Business Readiness	CE-FDH	0.518
IPR Readiness	CE-FDH	0.268

### 3.3. Scatter Plots for Necessary Conditions

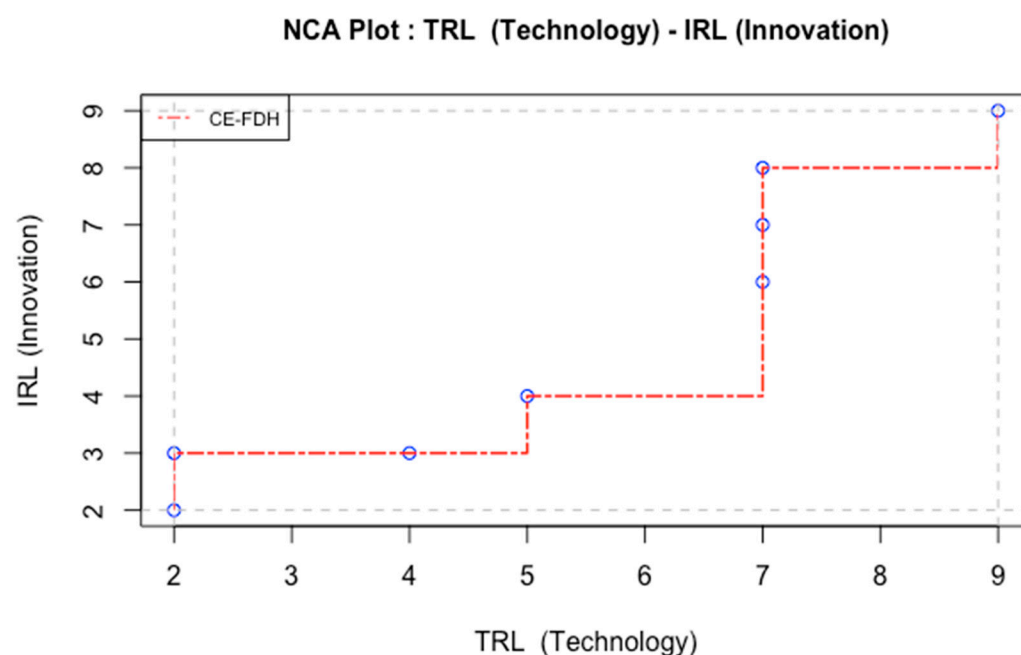
The NCA analysis in R produces x-y plots for each critical factor (X-axis) in relation to the levels of innovation readiness (Y-axis) with so called “ceiling lines”. Data analysis with NCA is always bivariate, meaning that each necessary condition is analyzed in isolation from the rest of the causal structure. Inspections of all figures (Figures 1–7) show an empty space in the upper-left corner, indicating that all seven conditions are necessary to some extent for innovation readiness. The ceiling line represents the level of Y that can be reached with a certain level of X, or in other words, the level of X that is necessary for reaching a certain level of Y.

Figure 1 exemplifies the necessity of customers for innovation readiness. By observing the empty space in the upper left corner, we can formulate the hypothesis that to achieve a desired level of IRL 6, a level of at least CRL 6 is required. This means that the benefits of the product must be confirmed through partnerships or first customer testing in order to support the development and design of the product with a market driven business team.

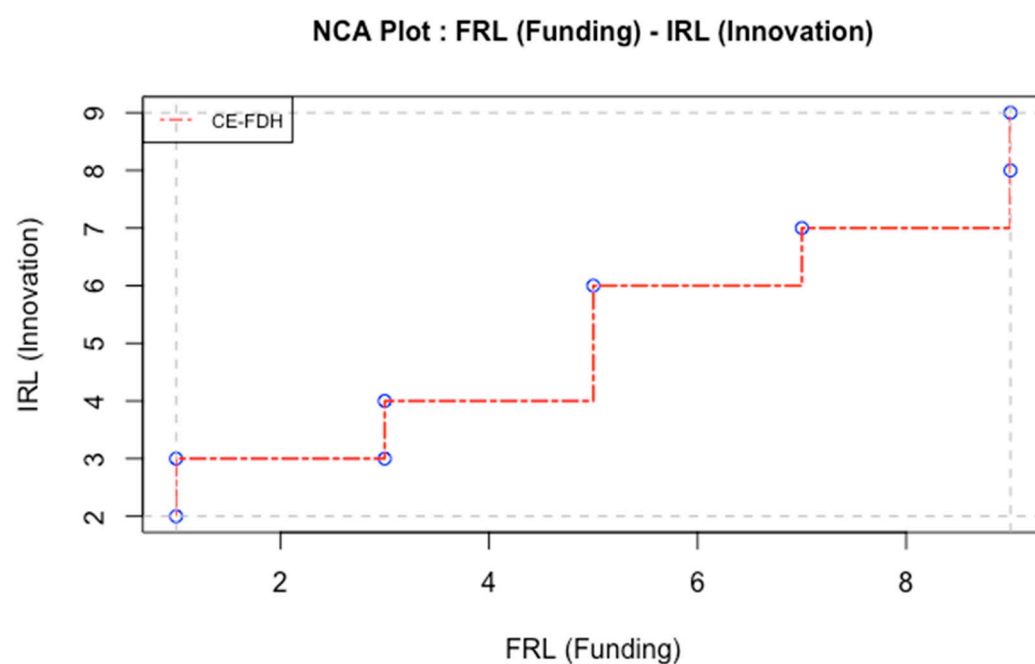
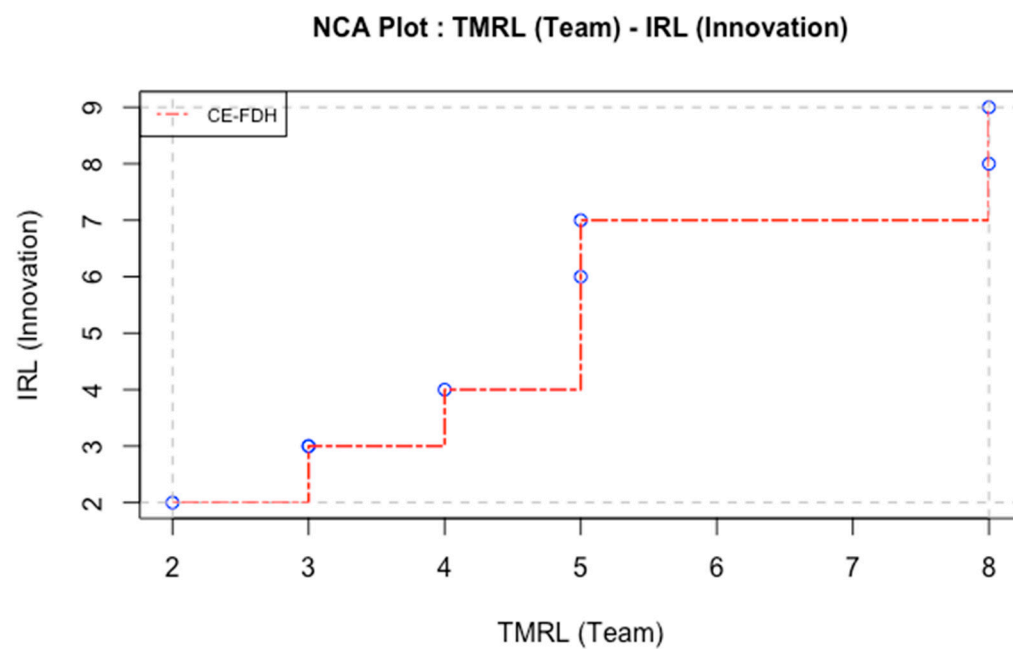


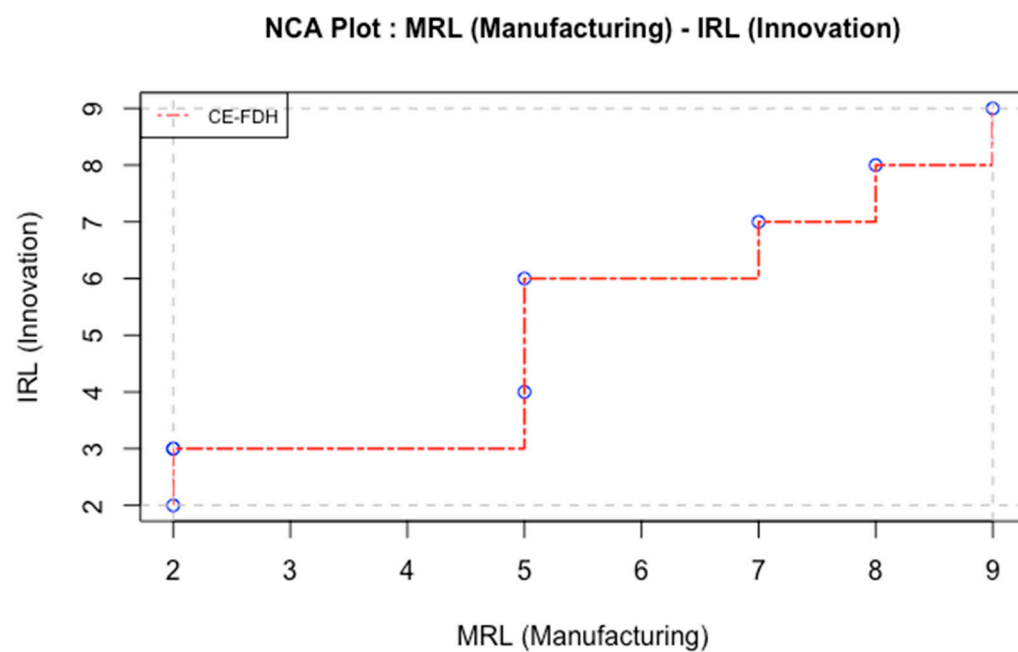
**Figure 1.** Scatter Plot for Customer and Innovation Readiness.

Figure 2 exemplifies the necessity of technology for innovation readiness. By observing the empty space in the upper left corner, we can formulate the hypothesis that to achieve a desired level of IRL 4, a level of at least TRL 5 is required. In other words, to support project engineering development and design, the technology must be scaled from the laboratory unto a prototype demonstrated in an operational environment. To achieve an innovation readiness of 8, in which the capability to transition to full production and distribution is confirmed, the actual technology system must be completed and qualified through test and demonstration (TRL7). All other plots can be analyzed in the same way by using the detailed scales and descriptions provided in Appendix B.

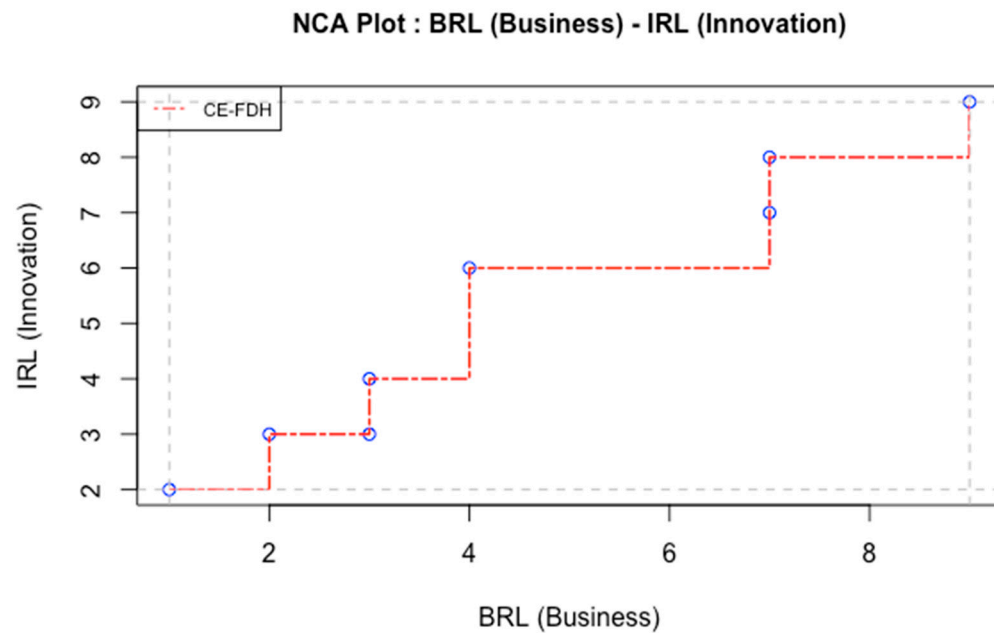




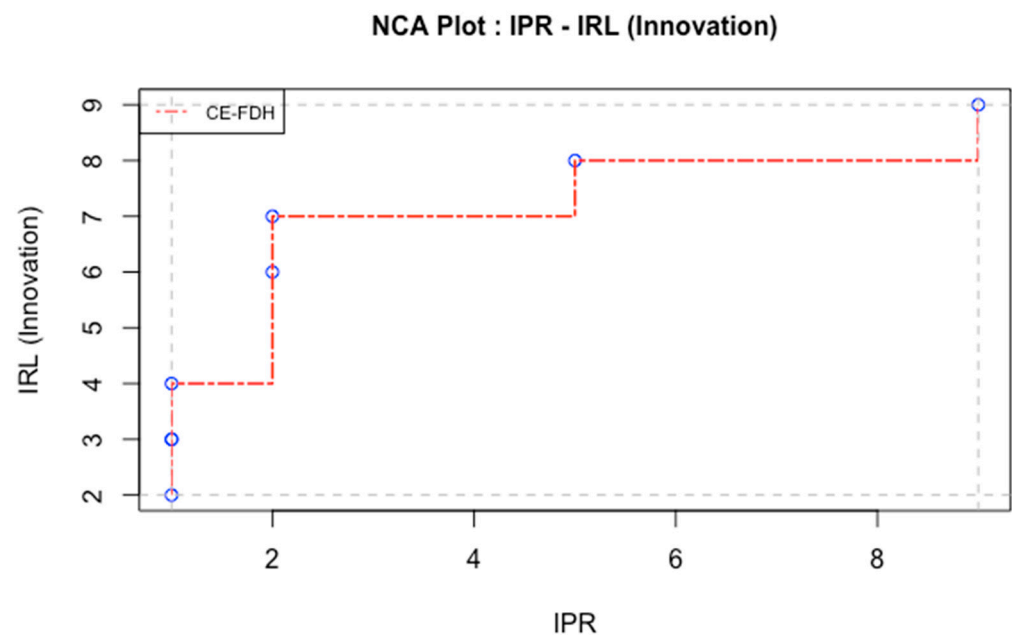
**Figure 2.** Scatter Plot for Technology and Innovation Readiness.**Figure 3.** Scatter Plot for Funding and Innovation Readiness.**Figure 4.** Scatter Plot for Team and Innovation Readiness.



**Figure 5.** Scatter Plot for Manufacturing and Innovation Readiness.



**Figure 6.** Scatter Plot for Business and Innovation Readiness.



**Figure 7.** Scatter Plot for IPR and Innovation Readiness.

## 4. Discussion

### 4.1. Customers

Our results indicate that customer readiness has the largest effect size or is the most critical condition for grass-based businesses to ascend the ladder of innovation. According to the expert group on R&D and innovation of the European Commission, enabling the market demand for innovative products is one of the key challenges for boosting productivity and competitiveness of Europe's economy [53]. Recent studies stress a dismally low percentage of consumer awareness for bio-based products in several European countries [54,55].

Consumer's purchasing preferences are essential for business as they signal the kind of products desired and enable companies to shape production decisions [56]. However, demand for bio-based products depends on the buyer's perception of the product's quality, usability and production method of the bio-based product [57]. This means that grass-based products must be perceived to be at least as good as their alternatives by the customers. Thus, a key challenge for entrepreneurs offering bio-based products is that potential customers often cannot make informed decisions related to the use of the offered new products and services provided by bioeconomy businesses [22]. In addition, geographically distant supply chains of resources have increased access to and human consumption of many goods, without consumers feeling accountable for or being aware of their environmental or social impacts [58].

The existence of strong environmental values in a certain region and the early formation of local markets for sustainable products and services may provide early testing grounds for wider development and diffusion [59]. At earlier stages, firms may enter an initial market with an early version of the product, learn from the experience, modify the product and marketing approach based on what has been learned [60]. Another recent study found that firms can nurture and manage customer relationships to acquire, share, and exploit customer knowledge for the benefit of the customers and the firm [61]. It should therefore be a top management priority to build and maintain the trust of consumers for bio-based products. Emerging grass-based businesses must identify the value proposition for its customers, which customers it tries to serve and identify the type of

relations they want to create with their customer segments in the early stages of innovation [31]. Since novel green innovations are often systemic in nature and require changes in consumption behavior, end-user integration along the innovation process may be particularly relevant for the success of such products and services [62]. Finally, businesses emphasize the need to foster positive awareness of bioeconomy businesses and their products and services among consumers and public agents. As stated in a recent study, unless coupled with responsible consumption patterns, sustainable production cannot contribute to the overall goals of sustainable development [63].

#### 4.2. Technology

Our results indicate that technology readiness is the second most critical condition for grass-based businesses. Biotechnology is a key enabling technology for the discovery, development and manufacture of new products and materials [16,64]. Grass-biomass must be converted and manufactured into a product through a meaningful combination of different methods and processes (physical, chemical, biological and thermal). It is therefore necessary that biorefinery-based technologies are developed [65]. New technologies not only provide cleaner solutions for the future, but also help in avoiding and overcoming problems caused by the current technologies [66]. Furthermore, technological developments may encourage companies towards more circular systems of production [67].

Varied technologies to enhance the treatment and valorization of grass biomass unto high-value-added products for emerging markets have been studied and developed [10,12]. Yet, currently most of the technologies for utilizing the grassland biomass are developing at the lab scale and the further development, optimization and integration of the technologies into the existing industries or sectors are needed. However, technological advances do not necessarily result into marketable innovations able to change economic systems [18]. On one hand, new technologies often bring disruptive changes in value and supply chains and business behavior [24,68]. On the other hand, lacking technical skills creates challenges for identifying, assessing and implementing more advanced technical solutions [69]. In line with previous research, we highlight that technological developments which are not aligned to the needs of the stakeholders or to local conditions bear the risk of placing public money in the death-valley of innovation [70]. Information sharing platforms may support cooperation with stakeholders and enable better information transparency. Involving various kinds of social actors as assessors and discussants can support the decision process towards the most feasible and sustainable technologies to valorize grass resources and to facilitate the cascading use of grassland biomass unto a variety of bio-based products and services.

#### 4.3. Funding

The agricultural economic literature on innovation clearly documents that innovations do not occur randomly, but rather that incentives and government policies affect the nature and the rate of innovation and adoption [28]. The public sector has played a major role in funding R&D activities that have led to new agricultural innovations. However, research has shown that emerging markets often suffer from the absence of access to capital [20]. This is especially true for emerging bio-based businesses which compete with the established economic system relying on fossil resources [15]. Such competition with the extant fossil-based industry is cost and risk intensive and thereby requires foresight and strategic management [2,71]. We found that attracting investors or securing access to credit at the early stage of a business is a major challenge. An explanation for this finding is that emerging bio-based companies are less attractive for traditional investors [22]. Previous studies show that bio-based businesses require greater investments in the short-term, whereas their results tend to materialize in the long term [72]. Our findings are in line with previous research which stated that due to the innovative nature of these businesses, public and private investors are not always familiar with the products and services

provided by these companies [4]. Thereby resulting in difficulties to assess the opportunities and risks associated with investments in the bio-based sector.

Recent research on bioeconomy businesses demonstrated that interactions with various stakeholders such as research institutes and universities may enable emerging enterprises to create a consortium that makes it easier to apply for funding but also to understand the regulations for application and the obligations following the approval of financial resources [22]. To bring grass-based products to the market, emerging businesses require aligned funding mechanisms that incorporate and promote the specific benefits generated by grass-producing and grass-processing companies. The need to ensure a high level of funding readiness as an early prerequisite for innovation progress may also be a reason for the emergence of new forms of financing such as crowdfunding, prosumer models, Science-to-Business (S2B) and Business-to-Business (B2B) models [18,22].

#### 4.4. Team

Entrepreneurs and entrepreneurial behaviors play an important role in the development of new business models [21,73]. However, individual entrepreneurial activity is not sufficient for a bioeconomy transformation [74]. Thus, securing the right skills and competencies and having a well-structured team emerges as a top priority for emerging grass-based businesses. As opportunities for new business fields emerge, the needed knowledge may exceed the competencies of traditional business models. New processes and technologies often require special skills and training. This triggers several challenges related to the development of the Bioeconomy and knowledge generation in converging industry fields [71].

New forms of cooperation both up-stream and downstream in the supply chain are of paramount importance to develop new bio-based value chains [75]. In line with previous research, we highlight the importance of investing in local relationships and networks [76,77]. Networks and collaborative structures may contribute to connecting and engaging farmers unto new practices required for the harvesting and collection of grass biomass. Furthermore, the involvement of stakeholders with multi-disciplinary skills, knowledge and expertise throughout the development of grass-based businesses might also support the identification and timely resolution of complex situations [74]. Identifying stakeholders to engage in the innovation process is important to collect diverse insights from stakeholders, to foster inclusion and diversity of perspectives, and even to shape collective expectations [78,79]. Finally, because the Bioeconomy is, by definition, a knowledge-based economy, academic research is particularly important for the groundwork of entrepreneurial activity and can facilitate knowledge transfer [80]. There is an urgent need for capacity development to develop a grass-based economy.

#### 4.5. Manufacturing

The bio-based economy relies on sustainably produced biomass as raw materials for the production of various products [81]. The availability and quality of grass are the foundation of grass-based businesses. In order to achieve full-scale operations, businesses require sufficient biomass feedstocks with the right quality. Our results indicate that securing biological resources and critical infrastructure for production, have a large effect size for upscaling grass-based businesses. We found that single product approaches often struggle to create sufficient revenues to cover subsequent processing costs. As such, the viability of grass-based businesses depends on the range of suitable applications identified for the separate fractions. It has been demonstrated that a multiple-product approach, or cascading use of biomass can facilitate the efficient utilization of the whole plant and any process residues [82].

Grass as a raw material is a seasonally accruing material [83]. Hence, to ensure a predictable quality and a constant year-round supply of feedstock to a biorefinery facility, grass usually needs to be harvested and stored as silage [11]. The chemical composition of grass presented to the biorefinery determines the potential range of products that can

be produced [10–12]. This means that grass must be harvested, preserved, pre-treated and stored in relation to certain parameters such as lignification level, moisture content and content of special ingredients such as fibers, proteins, polyphenols, ecdysone or other high-value components [84,85]. Specific management factors such as harvest date and nutrient management also have a significant impact on the yield and chemical composition of the feedstock [11]. The optimal stage for harvesting is determined by the particular grassland biomass use. For example, grass harvested at earlier growth stages may be more suitable for biogas production through anaerobic digestion [81], while grass harvested at later growth stages may be more suitable for technical fiber or combustion [83]. Hence, a key challenge for grassland farming is to develop management strategies in which the multiple ecosystem services of grasslands are sufficiently provided.

Recent research also shows that difficulties in mobilizing biomass is one of the main barriers that hamper the development of bio-based supply chains [15]. Therefore, logistics play an important role in the economic utilization of grass. An optimal design and operation of biomass supply chains are of critical importance for upscaling [86]. We found that emerging grass-based businesses seek to cultivate buyer-supplier relations and to secure a steady supply by experimenting with alternative sources of grass, including grass from roadsides, farmlands, nature conservation areas and municipal sources.

#### 4.6. Business

In line with previous research, we found that the practical implementation of the bio-based businesses in general, and grass-based businesses in particular, is still lagging, and companies are struggling to develop effective business models in which revenue streams and economic feasibilities are clear [87]. A potential reason is that most grass-based products are targeted at very early-stage markets (e.g., grass biochar) or markets where the grass-based products compete with well-known alternative solutions (animal bedding, soybean protein or wood fibers). We found that innovative ideas based on grass biomass were fostered from observations of market inefficiencies and for valorizing underutilized biomass unto new products or services solutions. Starting a new industry, even in small scale, requires significant investments, reliable supply chains and time for new markets to form. Therefore, framework conditions are fundamental for the readiness of these businesses and affect each of the focus areas under study. Previous research has shown that the success or failure of organizations is not determined by the business model elements themselves, but rather through their complementarity, interrelations and alignment with the business environment [22,88]. Our findings highlight that national regulations, strategies and policies can stimulate demand in certain sectors (e.g., organic fertilizers), establish relevant infrastructure (e.g., biogas plants), and underpin investments that enable certain mechanisms to function unto the development of new value chains and markets. Finally, optimizing operations and reducing the risks of the business model, requires alignment with local conditions in which local needs are fulfilled.

#### 4.7. IPR

We found that IPR has the least effect for upscaling innovative grass-based businesses. It seems logical that IPR might have a lower effect in comparison to the other conditions as not all businesses are interested in protecting intellectual property. Several stakeholders argued that IPR should not be considered in our innovation readiness framework as protecting IP might obstruct the efficient upscaling and replication of sustainable businesses in Europe. Yet, whether an organization has intellectual property rights (IPR) to protect or not, developing a strategy for assessing and developing IP protection might enhance the competitive advantage of the business and protect the benefits of investments. IPR might come in the form of patents for new inventions, trademarks for distinctive identification of products and services, registered designs for external appearance or trade secrets for valuable information not known to the public. Conducting a Freedom to

Operate (FTO) analysis might be useful to have an overview of potential IPR in relation to the new products, services and business activities.

## 5. Conclusions

In competitive global environments, innovation is fundamental for ensuring that societies are able to produce more with fewer inputs, while simultaneously striving to ensure production is as sustainable as possible [89]. However, innovation is a broad concept covering innovation processes, structures, outcomes, antecedents, and behaviors at the organizational level in the private and public sectors as well as at the individual, national, and professional levels [19]. Therefore, it is becoming more evident that innovation can only be understood when viewed from various perspectives [90].

### 5.1. Theoretical Implication

We developed a framework to assess processes of innovation readiness and tested the operation in measure of seven focus areas: Technology, Manufacturing, Business, Customer, IPR, Team and Funding. With this, we contribute to a better understanding of the multidisciplinary nature of innovation processes and advance our understanding of the factors that limit complex innovations in grassland systems.

### 5.2. Practical Implication

One of the fundamental aims of the GOGRASS project, which served as a research platform for the current study, is to support the transition from demonstration cases financed by the EU, to self-sustaining businesses that can be replicated in Europe and beyond. In this study, our chosen sample ranges from demonstration to established grass-based businesses, with different levels of innovation readiness and different levels in the independent variables. Our aim was to identify which necessary conditions are critical at different stages of the upscaling process and to identify bottlenecks in emerging grass-based businesses. The results presented in this paper aim to foster real-world actions that increase sustainability and to provide further scientific knowledge on business research and innovation management.

### 5.3. Limits and Future Research Topics

The main challenge of multiple case study research involves issues of generalizability [39]. Our data were drawn from a small set of grass-based business models in Europe and the findings may or may not extend to other sectors and locations. At the same time, the surveyed enterprises function in various business environments and operate in various socio-economic conditions. Due to the complexity of socio-ecological systems and the interdisciplinary nature of sustainability sciences, no silver bullet exists that balances the benefits of situated knowledge with those of strong generalization [91,92]. Therefore, subsequent studies should focus on achieving a more holistic understanding of grassland systems and business conditions at the local level to help minimize trade-offs and maximize synergies between business and environmental wellbeing and lead to the attainment of Sustainable Development Goals (SDGs) [93].

We have presented NCA as an emerging approach capable of testing necessity. Yet, because NCA operates on a “necessary but not sufficient logic”, it can only be used to identify determinants whose absence would prevent an outcome from being achieved, but not determinants that will produce an outcome [94]. Accordingly, NCA represents a complement for, not a replacement of current analytical approaches such as, for example, OLS regression [52].

On the other hand, the constructs used in this study are derived from the literature and proven to be main focus areas in the innovation process. Yet, this is a simplification which does not consider the full complexity of highly interconnected and interdependent innovation processes and their networks of action situations [95,96]. In addition, the study

focuses on the “internal” or “endogenous” processes of the cases and does not discuss fully their business environment [22], socio-ecological [97] nor spatio-temporal [98] specificities. While the use of “innovation” related indicators as the output of the innovation process provides a useful indicator on the success of innovation-related activities, it does not tell us how such output influences firm’s overall performance such as revenue growth and sustainability. For this literature to move forward, more comparative analysis of larger number of cases over a longer period of time as well as looking at the developments contributing to higher readiness levels are required.

As research on grass-based businesses and industries in sustainability transitions is quite recent [24], there is significant potential to intensify research at the intersection of business model innovations and Bioeconomy transitions [29]. Empirical analyses are indispensable for the advisory process in Bioeconomy transitions [99]. Future research could replicate the approach presented here and study necessary conditions in other regions, emerging industries or bio-based businesses. New readiness levels could also be incorporated in the analysis and suited to the specific research. Future research could use the NCA view of necessity thinking, for example, to understand what conditions are critical for agricultural producers to engage in new business activities related to the Bioeconomy. In tandem, contemplating the role of consumers seems to be especially promising to better understand entrepreneurial value creation and business models [4].

Finally, the value of the different ecosystem services needs to be taken into account for an appropriate use of grasslands as these are often in a trade-off relationship with each other [100,101]. We see a need for monitoring the effect of innovations and new business models which may compromise some ecosystem services provided by grasslands. In addition, we recommend that the socio-economic and institutional readiness of business environments be included in the assessment to ensure the promotion of rural communities, communication with relevant stakeholders and sustainable development [7]. In doing so, sustainability research must address the specifics of each case to avoid continuing the path of blueprint solutions [102]. We believe it is essential to address the multidisciplinary nature of innovation processes through collaborations with industry, governments and the public, as a basis for helping to build a comprehensive circular bio-based economy and for transforming the socioeconomic structure of contemporary society into a sustainable one.

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### Appendix A: Template of Innovation Radar Questionnaire

General Information		
Organization name		
Location		
Goal(s) in GO-GRASS		
Innovation Description		
Innovation name		
Innovation type (hardware, product, software, service, etc.)		
Short innovation description		
Innovation characterization		
Current TRL (1–9)	Choose from the list	
Level of innovation	Choose from the list	
Market Description (if relevant)		
Market size	Choose from the list	Market trends
Targeted geography (country, region, etc.)		
Targeted customer segments		
Market maturity	Choose from the list	
Unique selling points (USPs), compared to existing solutions. (in short bullets)		
Supply Chain/value chain (if relevant)		
Grass (Input): Have you identified how you will get enough raw materials for your production?	Yes <input type="checkbox"/> No <input type="checkbox"/>	If yes, please elaborate
Grass (Input): Do have indication of the price of the raw materials?	Yes <input type="checkbox"/> No <input type="checkbox"/>	If yes, please elaborate
Product (Output): Have you identified and/or been in contact with potential customers?	Yes <input type="checkbox"/> No <input type="checkbox"/>	If yes, please elaborate
Product (Output): (If yes above) are the customers willing to pay a premium for the new product (if needed)?	Yes <input type="checkbox"/> No <input type="checkbox"/> N/A <input type="checkbox"/>	If yes, please elaborate
Waste stream (Output): Do you know what to do with the waste grass after production?	Yes <input type="checkbox"/> No <input type="checkbox"/>	If yes, please elaborate
Financial Information (if relevant)		
Additional funding needed to bring innovation to market.	Choose from the list	Founding sources (choose as many as relevant)
Expected revenue from innovation at end of project	Choose from the list	Expected revenue from innovation 5 years after end of project
Expected employment growth from innovation at end of project (FTE±: full-time equivalent)	Choose from the list	Expected employment growth from innovation, 5 years after end of project
IPR (Intellectual Property Rights) & Standards (if relevant)		

Status of IPR: Background (type and partner owner)		
Status of IPR: Results/Foreground (type and partner owner)		
Are there any IPR/Patents issues to be resolved with the consortium?	Yes <input type="checkbox"/> No <input type="checkbox"/>	If yes, please elaborate
Do you expect to be able to apply for patents during/after the project?	Yes <input type="checkbox"/> No <input type="checkbox"/>	If yes, please elaborate
Do you expect to be able to apply for trademarks or other IPR during/after the project?	Yes <input type="checkbox"/> No <input type="checkbox"/>	If yes, please elaborate
Standardization:		
Describe whether there are any legal, normative or ethical requirements connected to the development of your product/Early requirements?	Yes <input type="checkbox"/> No <input type="checkbox"/>	If yes, please elaborate

## Appendix B: Definitions of Conditions and Outcome

**Table A1.** Definition of Outcome- Innovation Readiness Level (<https://www.esabic.no/wp-content/uploads/2018/12/a.-Innovation-Readiness-Level.pdf>).

Innovation Readiness Level-IRL		Definition
1	Inventor or team with a dream	Lowest level of readiness where the intention surfaces to translate an idea, of a space system application or a space technology transfer, into a business venture.
2	Paper studies produced	Once the basic ideas have been formulated, they are put down on paper in studies and analyses on the business opportunity.
3	Experimental evidence of business opportunity	Active research and development is initiated, including analytical/laboratory studies to validate predictions regarding the market, the competition and the technology.
4	Capability to work limited-scope programs with project teams	Basic technological and business components are developed to establish that they will work together; an initial business plan is available.
5	Capability to support project engineering development and design (no product, no revenues)	The basic technological and business components are integrated with reasonably realistic supporting elements. The business plan is credible, but still needs to be validated against the final product characteristics.
6	Capability to support development and design with a market-driven business team (product, no revenues)	A representative prototype system is tested in a relevant environment. The business team is still incomplete and the venture not yet ready for commercialization. A full business plan including market, operational, technological and financial aspects is available
7	Capability to support limited production; full business team in place (product and limited revenues)	The business can run on a limited scale. The full team is in place.
8	Capability to transition to full production and distribution (product and revenues)	The technology has been proven to work and the venture structure has proven to be able to support growing market shares.
9	Fully articulated business with appropriate infrastructure and staffing (growing market share)	The offering incorporating the new technology has been used in operational conditions and the business is running with a growing market share.

**Table A2.** Definition of seven necessary conditions (<https://kthinnovationreadinesslevel.com/>).

Level	Technology Readiness	Manufacturing Readiness	Business Readiness	Customer Readiness	IPR Readiness	Team Readiness	Investment Readiness
1	Basic principles observed	Concept proposed with scientific validation	Hypothesizing on possible business concept (limited knowledge or insight into market and competition)	Hypothesizing on possible needs in market	Hypothesizing on possible IPR you might have (such as patents, software, copyright, design, trade secrets et al.)	Little insights on the needs for a team (typically an individual). Lack of necessary competencies/resources.	Initial business idea with vague description. No clear view on funding needs and funding options.
2	Technology concept and/or application formulated	Application and validity of concept validated or demonstrated	First possible business concept described. Identified overall market and some competitors/alternatives	Identified specific needs in market	Identified different forms of possible key IPR that you have. Ownership is clarified and you clearly own/control IPR.	Insight and first idea on necessary competencies or external resources (e.g. partners)	Description of business concept (e.g., for NABC). Defined funding needs and funding options for initial milestones.
3	Analytical and experimental proof of concept of critical function and/or characteristics	Experimental proof of concept completed	Draft business model in canvas excluding revenues/costs. Described market potential and complete competitive overview	First market feedback established	Detailed description of possible key IPR (e.g., invention or code). Initial search of technical field and existing IPR.	A few necessary competencies/resources are present. Defined needed competencies/resources (and plans for finding).	Well described business concept and initial verification plan. First small soft funding secured.
4	Technology validation in laboratory	Production validated in lab environment	First version of full business model in canvas (including revenues/costs). First projections to show economic viability and market potential	Confirmed problem/needs from several customers or users	Confirmed if protection is possible and for what (e.g., patentability). Decided why to protect certain IPR (business relevance)	A champion is present. Several needed competencies in place. Initial plan for recruiting or securing additional key resources.	Good pitch and short presentation of the business in place. Plan in place with different funding options over time.
5	Technology validation in relevant environment	Basic capability demonstrated	Parts of business model tested on market and canvas updated. First version of revenue model	Established interest for product and relations with target customers	Draft of IPR/patent strategy implemented and supporting business. Filed first complete patent	Initial founding team with main needed competencies. Team agrees on ownership	Investor oriented presentation and supporting material

			including pricing hypothesis. Verified competitive position/uniqueness through market feedback.		application (or other IP registrations)	and roles and has aligned goals.	tested. Applied for and secured additional larger funding (soft or other)
6	Technology demonstration in a relevant environment	Process optimized for production rate on production equipment	Full business model including pricing verified on customers (by test sales)	Benefits of the product confirmed through partnerships or first customer testing	IPR/patent strategy implemented and supporting business. Positive response on filed applications. Initial assessment of freedom-to-operate (or landscape)	Complementary, diverse and committed team with all necessary competencies/resources including both business and technology.	Improved investor presentation in place including business(financials). Decided on seeking private investors and initial contacts taken.
7	Technology prototype demonstration in an operational environment	Capability and rate confirmed	Product/market fit and customers payment willingness demonstrated. Attractive revenue v. cost projections (Validated by data and sales)	Customers in extended product testing or first test sales	All relevant IPR filled (e.g., additional patents). Patent entry into national/regional phase.	Team and culture is fully in place and proactively developed. Updated plan for building necessary team on longer term.	Team presents a solid investment case including business/financials. Decided on seeking private investors and initial contacts taken.
8	Actual technology system completed and qualified through test and demonstration	Full production process qualified for full range of parts	Sales and metrics show business model holds and can scale. Business model is fine-tuned to explore more revenue options	First products sold and increased structured sales efforts	IPR management and IP management fully implemented. More complete assessment of freedom-to-operate.	Management and CEO in place. Professional use of boards/advisors. Activated plan and recruitment for building long term team.	There is corporate order and structure enabling investment. Team sheet discussions with interested investor(s).
9	Actual technology system proven in operational environment	Full production process qualified for full range of parts and full range of metrics achieved	Business model is final and is scaling with growing recurring revenues that result in a	Widespread products sales that scale	Strong IPR support and protection for business. Patent granted in relevant countries and maintained force.	High performing, well-structured team and organization that is maintained and	Investment obtained. Additional investment needs and options continuously considered.

	profitable sus- tainable busi- ness	performs over time.
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