D2.3. Developing lignocellulosic feedstock supply chains for the production of advanced liquid bio-fuels

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ADVANCEFUEL at a glance

ADVANCEFUEL (www.ADVANCEFUEL.eu) aims to facilitate the commercialisation of renewable transport fuels by providing market stakeholders with new knowledge, tools, standards and recommendations to help remove barriers to their uptake. The project will look into liquid advanced biofuels – defined as liquid fuels produced from lignocellulosic feedstocks from agriculture, forestry and waste – and liquid renewable alternative fuels produced from renewable hydrogen and CO2 streams.

In order to support commercial development of these fuels, the project will firstly develop a framework to monitor the current status, and future perspectives, of renewable fuels in Europe in order to better understand how to overcome barriers to their market roll-out. Following this, it will investigate individual barriers and advance new solutions for overcoming them.

The project will examine the challenges of biomass availability for second-generation biofuels, looking at non-food crops and residues, and how to improve supply chains from providers to converters. New and innovative conversion technologies will also be explored in order to see how they can be integrated into energy infrastructure.

Sustainability is a major concern for renewable fuels and ADVANCEFUEL will look at socio-economic and environmental sustainability across the entire value chain, providing sustainability criteria and policy-recommendations for ensuring that renewable fuels are truly sustainable fuels. A decision support tools will be created for policy-makers to enable a full value chain assessment of renewable fuels, as well as useful scenarios and sensitivity analysis on the future of these fuels.

Stakeholders will be addressed throughout the project to involve them in a dialogue on the future of renewable fuels and receive feedback on ADVANCEFUEL developments to ensure applicability to the end audience, validate results and ensure successful transfer and uptake of the project results. In this way, ADVANCEFUEL will contribute to the development of new transport fuel value chains that can contribute to the achievement of the EU's renewable energy targets, and reduce carbon emissions in the transport sector to 2030 and beyond.

To stay up to date with ADVANCEFUEL's stakeholder activities, sign up at:
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Abbreviations

BMC	Business Model Canvas
CERTH	Centre for Research and Technology Hellas
PPP	Public-Private-Partnership
R&D	Research and Development
SRC	Short rotation coppice
SWOT	Strengths-Weaknesses-Opportunities-Threats
TOWS	Threats-Opportunities-Weaknesses-Strengths (inverted SWOT-Matrix)
TRM	Technology Roadmap

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Executive Summary

The aim of the EU ADVANCEFUEL project is to facilitate the market-roll out of second generation biofuels. In the deliverable report D2.2 we identified several cropping schemes innovations and assessed them in regard to their cost reduction potential, environmental, and social performance (Germer et al., 2019). The present deliverable builds upon these findings and aims to identify milestones and strategies conducive for the integration of such innovations into business models for feedstock production for advanced fuels. The results contain: 1) a *Technology Roadmap (TRM)* on the market extension of an exemplary lignocellulosic feedstock (i.e. poplar wood chips), which presents milestones that need to be undertaken in politics, society, economy and businesses, knowledge and technology, training and education, and research and development (R&D), and 2) *Business Model Upgrading Strategies*. The latter objective is based on four case studies: 1) a Public Private Partnership (PPP) to foster miscanthus cultivation in Belgium, 2) a flexible logistic chain for olive pruning collection efforts in Italy, 3) miscanthus cultivation on large-scale in Europe, and 4) increased mid-term and final harvest frequency of agroforestry wood in Greece. We assessed these innovative cases using the Strengths-Weaknesses-Opportunities-Threats (SWOT) analysis method (Chapter 3.2.2) and derived upgrading strategies from applying the Opportunities-Threats-Weaknesses-Strengths (TOWS) analysis method (Chapter 3.2.3.).

Our investigation resulted in the following recommendations for lignocellulosic business model upgrading:

- *Make lignocellulosic supply chains a co-business* to supplement current agricultural business models. Existing elements, such as land, machinery, workforce and existing technical skills can be used to generate added value (FORBIO, 2018).
- *Diversify the agricultural supply portfolio*. A lignocellulosic co-business enables the farmer to increase and diversify income streams.
- *Establish long-term collaboration agreements* for biomass feedstock supply with a biomass/ biogas/ bioethanol plant (FORBIO, 2018).
- *Enhance information sharing*. This will unleash the potential of rural lignocellulosic business models.
- *Construct and enhance sustainable partnerships* by negotiating different interests and ensuring a win-win situation among all actors.

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- *Close nutrients cycles in returning unused nutrients to the field.* For instance, thermo-chemical processes produce ash as a by-product which can be returned to the field in order to maintain soil quality and save production inputs.
- *Minimize storage losses*. Storage losses are among others influenced by the material type which is stored (e.g. wood chips, pellets, bales etc.) and its size. Medium sized wood chips (P45) showed the best results after storing them for seven months in terms of moisture content (26%), dry matter loss (17%), and fines fraction (< 5w-%) (Pecenka et al., 2018).
- *Design flexible logistic chains irrespective of farm size*. This can facilitate the social inclusion of small-scale farmers.
- The processing unit should be within *a radius of 50km from the source of lignocellulosic biomass supply* (FORBIO, 2018).
- *Establish a strong network of best practice business cases*.
- *Implement a capacity building programme*. For example, through establishing a competence centre for dedicated energy crops and including the management of dedicated energy crops as an integral part of vocational and university education.
- *Take unexpected issues into account*. For instance, extreme weather conditions (SEEMLA- Greece, 2018)
- *Do not expect fast results* (SEEMLA- Ukraine, 2018).

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1. Introduction

The aim of ADVANCEFUEL is to facilitate the market roll-out of RESfuels. To achieve this objective, a fundamental limitation must first be addressed. Production volumes of biomass are limited and far from meeting current and future (towards 2050) bioenergy demands (Zappa et al. 2019). For this reason, sound and viable business models for lignocellulosic feedstock provisioning are needed in order to secure a stable supply of lignocellulosic biomass for the production of RESfuels (Uslu et al., 2018). Studies have shown that Europe has in fact significant biomass potential, though much of this remains untapped (Germer, 2019). According to the spatial model described in D4.3, 13,828,000 km^2 (mainly scrubland), may be available for energy crop production in 2050 in Europe (Vera et al., 2019).

Against this background, the present report addresses the following question:

- What upgrading strategies for the supply of lignocellulosic biomass can take advantage of the available land potential for energy crops?

This report takes the identified "Barriers related to feedstock supply" (Table 5) in D1.1 as the starting point for the investigation (Uslu et al., 2018). Furthermore, D2.2 has investigated upon various cropping innovations and assessed them in regard to their economic, environmental, and social performance (Germer et al., 2019). The scientific purpose of this work is (1) to investigate the implementation process of the innovations identified in D2.2 in a supply chain and (2) to propose strategies on how this process can be improved.

Accordingly, the methodology, results and discussions of this report are presented in two stages:

(1) Development of a Technology Roadmap (TRM) for RESfuel feedstock which defines the future vision for 2040 and visualises strategical milestones how to get there.
(2) Identifying upgrading strategies for lignocellulosic feedstock supply chains to facilitate the market roll-out of RESfuels.

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2. Methodology

2.1. Technology Roadmap Analysis (TRM)

A TRM is a graphic representation of innovations and their links over time (Fig. 1) (Möhrle and Isenmann, 2017). It is an instrument which enables us to assess the status quo and identify the bottlenecks of a defined research objective. Key objectives of this method are (1) to develop a vision until 2040 and beyond in regard to feedstock quality, economic, ecologic, and social impacts, and (2) to identify milestones which need to be accomplished until 2040. The presented TRM focuses on the end-product *poplar wood chips*. This choice has been based on the ADVANCEFUEL deliverable 3.5, which focuses on the supply of poplar wood-chips for the production of methanol and dimethyl-ether (DME) (Karka, 2019). In D1.1, Uslu et al. (2018) compiled key barriers for RESfuels based on recent literature. The present report builds upon the identified barriers to develop a TRM for lignocellulosic feedstock supply.

First, a thorough literature review was carried out to collect information on how to overcome the barriers previously identified (S2Biom D4.5., ENPLUS, certification ForBio D4.3., AUFWERTEN project, etc.). This was followed by four semi-structured expert interviews (see Annex – Questionnaire 1). The interviewees are representatives from the German Biofuels Industry Association (VDB), the German pellet institute GmbH (DEPI), the Federal Environment Agency, and the Leibniz Institute of Agricultural Engineering and Bioeconomy. Lastly, the TRM was presented at the 4th ADVANCEFUEL Workshop in Brussels in November 2019 in order to validate and complement the preliminary TRM. Detailed information of this workshop can be found in ADVANCEFUEL Deliverable 7.4 (Gonzalez, 2020).

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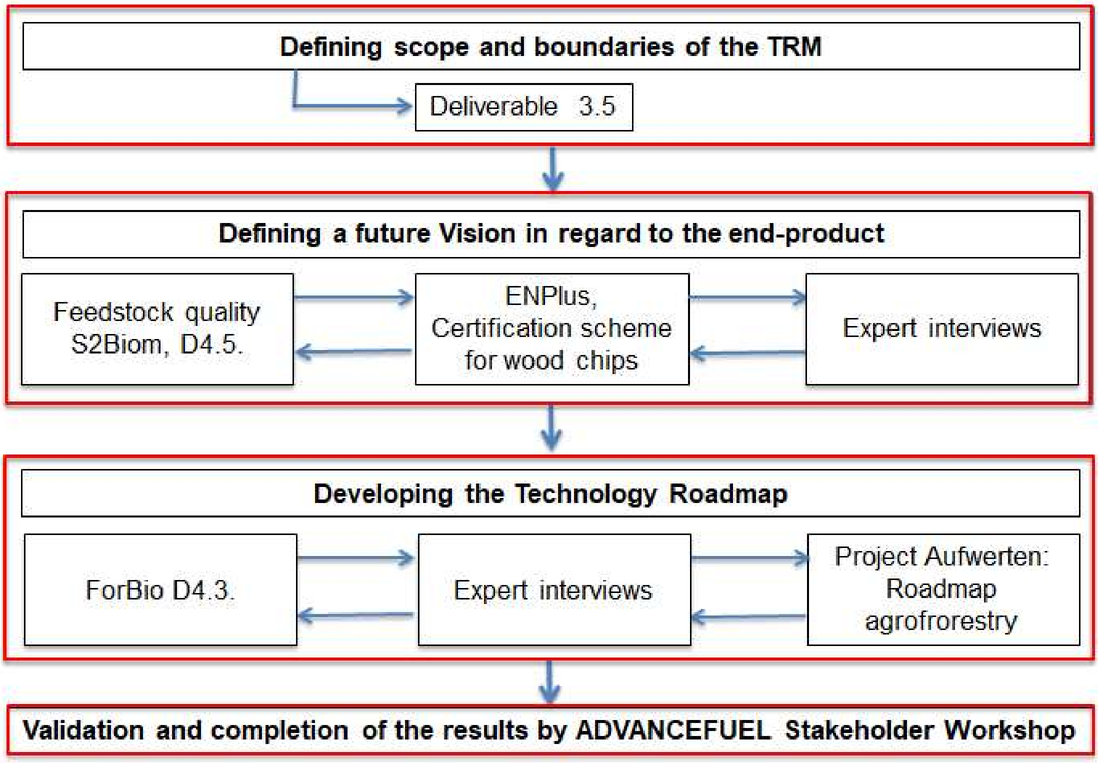

Figure 1: Graphical representation of the TRM method

Using a *Live polling* tool we discussed the following questions with the audience during the 4th ADVANCEFUEL stakeholder workshop:

1. Which element is most important when it comes to developing a vision for 2040: feed-stock costs, feedstock quality, environmental impact or social impact?
2. Is it even possible to agree upon one vision for RESfuel feedstock? What are the hurdles (for example public acceptance etc.)?
3. If there is an agreement, what actions need to be taken, in order to reach the agreed vision?
4. What are the most critical milestones?
5. Do the responsible actors have the necessary resources in place to achieve these mile-stones?

2.2. Upgrading Strategy Analysis

Our second objective was to identify upgrading strategies for lignocellulosic feedstock supply chains. To this end, we began with a case study screening using as sources grey and academic literature, project websites in the internet, and experts. Case studies were selected according to

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the following criteria: (1) agricultural business models which value proposition is based on lignocellulosic biomass, (2) past integration of an innovation aiming for business model upgrading, and (3) location in an EU member state. Second, we conducted a one day stakeholder workshop on the 21st November 2018 in the Square Conference Centre of Brussels. Details on the workshop organisation and other sessions can be found in the ADVANCEFUEL deliverable 7.2 (Sternberg et al., 2019). We invited various experts from different EU projects (e.g. Grace, uP_running, Seemla, Gembloux Project) and other professionals. Before the workshop took place, we developed a questionnaire in order to identify and describe the innovations being implemented in the respective EU projects for supply chain upgrading (see Annex – Questionnaire 2).

Next, based on the analytical questions stated in the *Manual for Analysing Technical Innovation Systems,* the development phase for the respective innovations were determined. This is useful for tracking the success of an innovation (Hekkert et al., 2011). The development phases are: Pre-development, development, take-off and acceleration phase (Fig. 2). The aim of the workshop was to assess the implementation process of innovations into the respective business model as well as finding strategies to improve these processes.

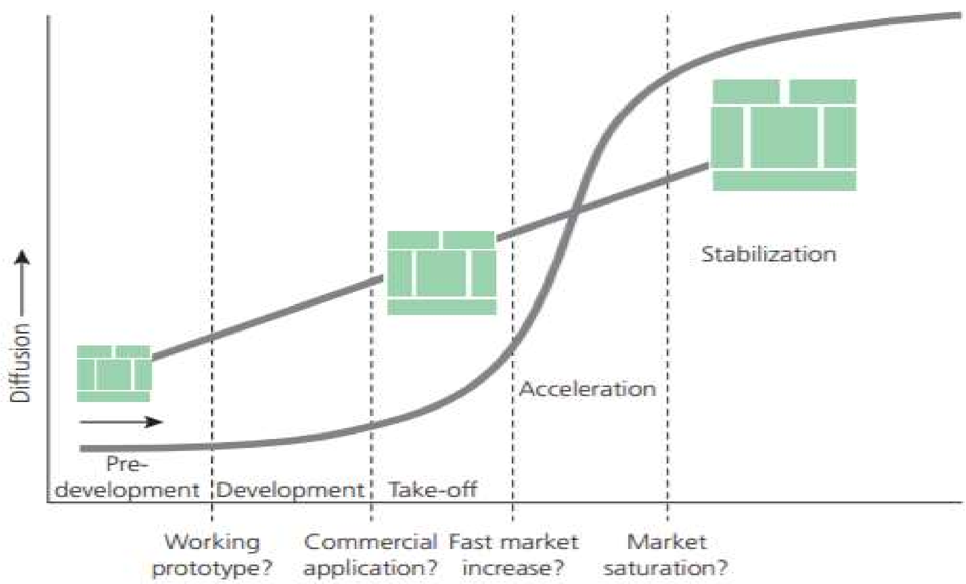

Figure 2: Innovation development phases (Hekkert et al., 2011).

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Internal Factors / External Factors	**Strengths (S)**	**Weaknesses (W)**
Opportunities (O)	SO Strategies Short-term	WO Strategies Medium-term
Threats (T)	ST Strategies Medium-term	WT Strategies Long-term

Figure 3: Poster used during the workshop for conducting the SWOT and TOWS analysis of the case studies

Lastly, to identify upgrading strategies for the respective business models, we conducted a Strength-Weaknesses-Opportunities-Threats (SWOT) analysis (Fig. 3). This was followed by a Opportunities-Threats-Weaknesses-Strengths (TOWS)-Matrix, which systematically matches the SWOT components, e.g. how strengths can be used in order to overcome threats. Consequently, the TOWS results correspond to the upgrading strategies. The information was documented via protocols.

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3. Results

3.1. Technology Roadmap (TRM)

3.1.1. Description of the Vision

For an expedient roll-out of lignocellulosic feedstock supply chains, first, the future feedstock product and process requirements of biofuels industries and other stakeholders need to be defined. These, in terms of the quantities of feedstock, the time and place, the specific qualities as well as the intended ecological, social and economic impacts. At the 4th ADVANCEFUEL stakeholder workshop, we asked the audience which elements are most important to consider when it comes to developing a vision for lignocellulosic biomass until 2040 and beyond. As illustrated in the figure below (Fig. 4), 51% of the workshop participants found the feedstock price to be the most critical element when agreeing on a shared vision for lignocellulosic feedstock.

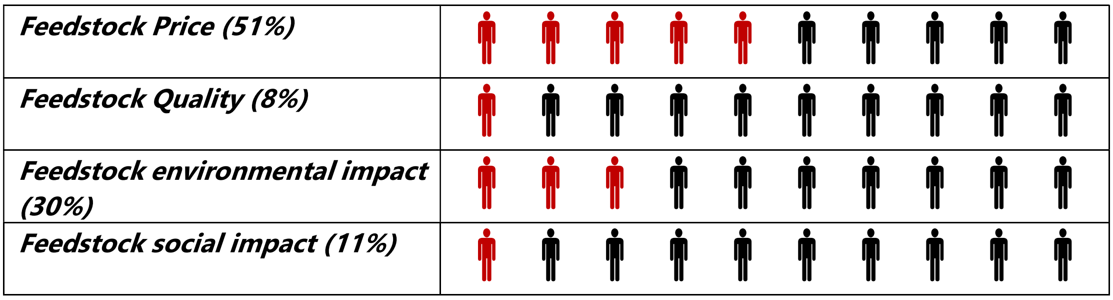

Figure 4: Live polling tool result of the 4th ADVANCEFUEL stakeholder workshop. The participants were asked to answer the question: "Which element is most important when it comes to developing a vision for lignocellulosic feedstock until 2040 and beyond?" The total number of respondents was 37.

Table 1 illustrates the set vision until 2040 and beyond which we identified based on expert interviews, the feedstock quality criteria set by the EU project S2Biom (Lammens et al., 2016), and the ENplus certification scheme. The vision is developed for lignocellulosic feedstock technology supply chains from cradle to gate in Europe until 2040 and beyond. The underlying processes result in methanol and dimethyl-ether (DME) production from syngas, as stated in D3.5 (Karka, 2019). These are already commercially produced fuels from fossil resources. Additionally, they can also be generated from renewable pathways from syngas as an intermediate. Both products are produced from hybrid poplar wood chips (Karka, 2019).

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The current price for poplar accounts is 45-100 €/tDM, depending on whether it is local or imported, with an average yield of 10 tDM/ha and a moisture content of 30 – 40% (Pecenka, personal communication, 2019). Our vision until 2040 and beyond is to reach an average yield of 15 tDM/ha. In the column "2040 and beyond" we compiled numbers from the ENplus certification group A1, which is the highest ENplus standard, and the Bio2Match Tool which presents the quality requirements of feedstock biomass needed for the respective conversion pathways. However, in the ENplus certification standard the A1 quality criteria for the Ash content accounts for <1%. The ash content is mainly determined by bark and branch content of the burned material. An ash content of >1% would mean that the tree has almost no bark. Thus, we set the future vision for ash content at 1.5% (Pecenka, 2019, personal communication). For the ecological and socioeconomic impacts we set qualitative criteria.

Table 1: Vision for SRC poplar wood chips until 2040 and beyond

	Unit	Today	2040 and beyond
Economic impact			
Biomass price	€/tDM	70[1]	
Biomass yield	tDM/ha	10[4]	15[4]
Feedstock quality			
Moisture	w-% dry	30-40 [(4)]	≥ 8 until ≤ 25[2]
Lignin	w-% dry	22.9[(3)]	<10[3]
Carbohydrates (cellulose + hemicellulose)	w-% dry	69.7[(3)]	>65[3]
Chlorine content	w-% dry		<0.02[3]
Ash deformation temperature	(DT) °C	1320[(3)]	>1200[3]
Ash content	w-% dry	2[(4)]	≤ 1.5[4]
Nitrogen content	w-% dry	0.4[(3)]	<0.3[3]
Feed size	mm		120[2]
Coarse Fraction	%		≤ 6 % in P31S (>45mm)[2]
Fine particles	%		≤ 5 % in P31S (<3.15mm)[2]
Bulk density	kg/m^3	150[(4)]	≥ 150[3]
Ecological impact			
Carbon monoxide	mg/m^3	400	Zero- emissions
Nitrogen leakage			Zero nitrogen leakage
Water Quality			Neutral/positive effect on water quality
Biodiversity			Neutral/positive effect on biodiversity
Soil organic carbon			Neutral/ positive effect SOC content
Socioeconomic Impact			
Job creation			Neutral/positive effect on job creation
Consumer price			Neutral/positive effect on consumer prices

[1] Vöcking, 2019, personal communication.
[2] Enplus A1 certification standard for wood chips (Deutsches Pelletinstitut, 2016).
[3] Bio2Match Tool (Lammens et al., 2016).
[4] Pecenka, 2019, personal communication.

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If it is ever possible to agree upon one vision for RESfuel feedstocks depends on:

- A formulated future vision which is flexible for different conversion requirements, social and environmental regions as well as the regions' size.
- Technical uniformity to convert biomass feedstock.
- The level of sector coupling
- Social acceptance and awareness among the general public
- Strong and clear policies which reject fossil fuels as dominant contributor to our society

3.1.2. Characterization of the Technology Roadmap (TRM)

Various options for action and possible implications were identified to reach the set vision. The analysis was conducted in the context of the five framework-forming dimensions of politics, society, economy & business model level, technology, and R&D. Finally, the specific presentation of concrete options for action in the form of dimension-related milestones was achieved by the conception of a TRM (Fig 5). The TRM graphically represents the dimension-related milestones over time. Intra-dimensional sequences result from the order of the milestones over time; interdimensional interdependencies are modeled with the help of arrows. The important milestones of the individual dimensions are presented concisely in Figure 5 This is followed by a more detailed description of the interdependencies between the dimensions (1) political, (2) social, (3) economy and business models, (4) technology, and (5) R&D.

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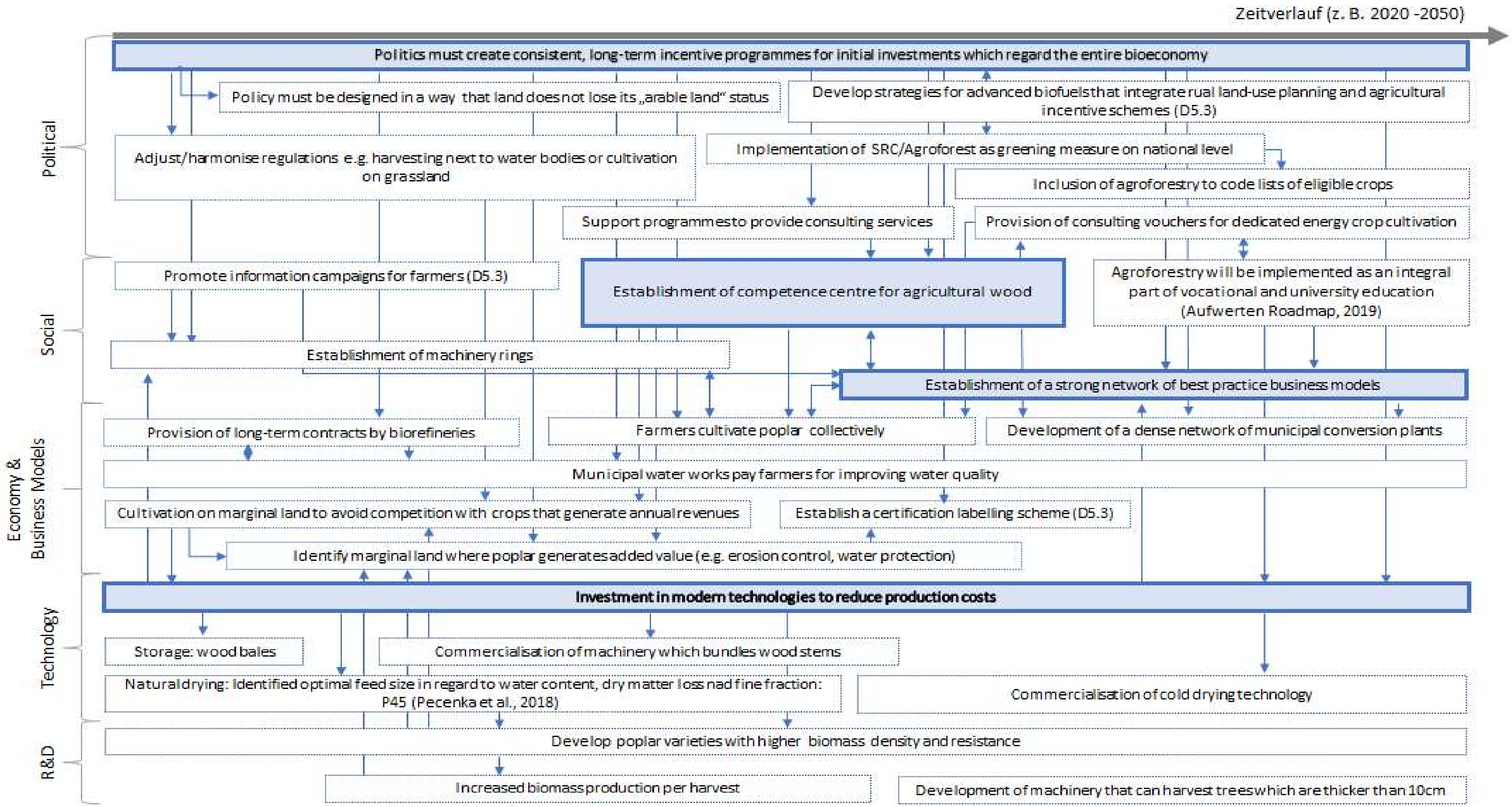

Figure 5: TRM to facilitate the market roll-out of poplar wood chips

3.1.3. Political Dimension

In order to make wood chip production from hybrid poplar attractive, politics must create consistent, long-term incentive programmes for initial investments which regard the entire Bioeconomy (Areekul and Panoutsou, 2019). When looking into policy frameworks, it is also important to be aware of regulatory bottlenecks. For instance, combining water purification and the production of dedicated energy crops faces the hurdle that trees planted next to water bodies cannot be harvested according to the EU Water Framework Directive (2000/60/EC) (Germer et al, 2019). In the German federal state Brandenburg, there is an agroforestry pilot project which is allowed to harvest the trees after sufficient lobby work (Pecenka, personal communication, 2019). Such examples lead us to the proposal of designing policies in a way that land does not lose its "arable land" status. We also suggest further adjustment and harmonization of the current regulations. The provision of water purification and other provided ecosystem services should be integrated in agricultural incentive schemes in combination with rural land-use planning. In Germany, short rotation coppices (SRC) are eligible as ecological compensation conservation areas, but only by a factor of 0.5. "Lack of knowledge among farmers" is another barrier related to feedstock supply (Uslu et al., 2018). This can be overcome by support programmes that provide consulting services similar to organic advisory services, which were implemented to facilitate the transition of a farm from conventional to organic. One concrete example is the provision of consulting vouchers for dedicated energy crop cultivation by the respective government.

3.1.4. Social Dimension

As a short-term and most cost-efficient strategy, information campaigns for farmers should be promoted (Areekul and Panoutsou, 2019). A long-term strategy to enhance knowledge sharing is to establish a strong network of best practice business models. Best practice cases serve as flagship cases which increases awareness of innovative business lines, enable actors to share lessons learned and estimate potential risks. The next logical step would be to establish a competence center focused on agricultural wood. Such a competence center, would serve as a backbone for the provision of consulting vouchers as mentioned in the political dimension. With increasing demand for advisory services, it is pivotal to have experienced personnel in place. Thus, agroforestry should be implemented as an integral part of vocational and university education (Nawroth et al., 2019). Another action that can increase the market roll-out of second generation biofuels based on poplar wood-chip inputs is the establishment of machinery rings among farmers. The collective purchase and sharing of machineries could increase the willingness of small to medium- scale farmers to enter new markets due to reduced production costs

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and utilisation of full machinery capacity (Uslu et al., 2018). These machinery rings could be promoted through information campaigns and policy incentives.

3.1.5. Economy & Business Models Dimension

The next step after implementing machinery rings among farmers would be to grow poplar collectively. This would mitigate the exclusion of small-scale farmers from establishing innovative business models (Uslu et al., 2018). Up to now, there are only a few contractors on the market which have SRC machineries within their portfolio. Due to such oligopolies, the service costs are relatively high. Collaborative poplar cultivation in the same region has the potential to diffuse such costs among partners and decrease travel costs of contractors per hectare (Vöcking, personal communication, 2019). Such collaborations can be promoted by long-term contracts with RESfuel biorefineries to secure long-term demand. One example for the provision of long-term contracts is the subsidiary of one of the largest heat and electricity suppliers in Europe, which provides 15-20 years contracts to farmers for implementing poplar on their fields (Keutmann et al., 2016a). The contract provider manages the entire crop cycle from establishment to harvest. One lesson learned from this contract farming example is that decentralised municipal conversion plants could have a better influence on the supply chain's economic and environmental performance. However, the business model follows a centralised approach, since the wood chips are transported within a ~100 km radius to a heating power station in Berlin. There is sufficient demand for various wood-based end-products regionally (Pecenka, persona communication, 2019). One promising approach to increase profitability is to utilise multi-purpose crops (Germer et al., 2019). Flagship cases already exist in which water works pay farmers to grow woody biomass for water purification services. There was also one study case in which the municipal water works supported local farmers to cultivate SRC because it led to higher water quality. They were facing high sediment and nitrate discharges in their water bodies (Pecenka, personal communication, 2019). Other applications for multi-purpose crops could be the long-term remediation of contaminated, marginal lands, for instance.

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Excursus: Cultivation on marginal land

As illustrated in the TRM (Fig. 5), within the economic and business model segment, the experts involved in the TRM development agree that the use of marginal lands offers great potential for the supply of lignocellulosic biomass. *Cultivation on marginal land to avoid competition with crops that generate annual revenues* is a strategy which is investigated upon in various projects (e.g. Magic, Grace, ForBio etc.). Within the ADVANCEFUEL project, we investigated the case of the Lower Oder Valley National Park in the federal state of Brandenburg, Germany, the perceptions and expectations of stakeholders and other actors using or being affected by the use of marginal lands for biomass production prior to its implementation (Orozco, 2019). The study addressed the question: What are the perceived expectations of the use of marginal lands for the supply of lignocellulosic biomass in terms of socio-economic, environmental and other effects? Table 7 summarizes the findings from 9 semi structured interviews conducted in the time period between July and November 2019 with actors from different groups including agricultural producers, national park administration, state representatives and industry using a semi-structure interview guideline (Annex 3). The findings provide further evidence that the use of lignocellulosic biomass from marginal lands for business activities related to the bioeconomy can, from the stakeholder's perspective, provide socio-economic as well as environmental benefits.

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Table 2: SWOT analysis for biomass production on marginal lands – the case of the Lower Oder Valley National Park

STRENGHTS	WEAKNESSES
1: Availability of land (672 ha) 2: Available human resources 3: Existing collaborations 4: Common goals	1: High coordination needed to fulfill environmental commitments 2: Lack of trust with industry partners due to previous unfulfilled expectations 3: More experience and skills needed for specialized processes 4:Low yield and income expectations
OPPORTUNITIES	**THREATS**
1: Renaturation of fallow grasslands 2: Biodiversity and ecosystem conservation 3: Capacity development 4: Emerging conversion technologies 5: Increasing biomass supply	1: Negative perception of tourists concerning agricultural practices in the national park 2: Increased noise due to biomass transport 3: Unstable bird migration patterns 4: Unstable policies and short term perspectives 5: Financial risks

It is important to note that in this case, the marginal areas may be used for harvesting biomass from fallow grass- and shrubland under certain conditions, although these areas are part of a national park. This exception was made to preserve the cultural landscape of the national park. In the course of historical farm-based land use, these continental dry grasslands have been shaped by sheep, goat, and even horse grazing. Currently, the national park administration among other actors perceive these lands as being underutilized, generating costs and lost benefits for individual actors (e.g. farmers) as well as society. For this reason, cultivation on these marginal lands is currently being deliberated upon.

Overall, the future market roll out of RESfuels depends very much on the amount of biomass that can be supplied in a sustainable way. The use of marginal lands appears to be a viable option to secure a stable supply of lignocellulosic biomass for the production of RESfuels. Nevertheless, further site-specific research is needed to avoid the risk of generalizing marginal lands across Europe and overestimating the potential of biomass that can be produced. On the other hand, it is necessary to identify marginal lands where feedstock production can

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generate added value by providing environmental benefits such as additional erosion control and/or water protection (Pecenka, personal communication, 2019).

3.1.6. Technology Dimension

Investment in modern technologies to reduce production costs is fundamental in bringing SRC poplar production forward. As long as the market is small, it is not feasible for machine manufacturers to develop modern technologies for the agroforest sector (Vöcking, personal communication, 2019). This results in high machinery costs. Machines are used for harvesting, storage and drying. Regarding the harvest of SRC, there are many different practices, techniques and equipment available. Their use depends on the following factors: Crop species and variety, desired end product, quality of the end product, availability of machines, cultivation shape, size and shape of the field, amount of harvested wood, and soil moisture (Dimitriou and Rutz, 2015). Different storage options have also been researched. These include storing in piles, bales, bundles, among others. Bales were found to decrease the biomass quality. Wood dries faster in bundles. However, the machinery to bundle wood stems is not yet available on the market. Under optimal external biophysical conditions, natural drying in piles is the most cost efficient option. According to (Pecenka et al., 2018), medium sized wood chips (P45) showed the best results after storing them for seven months in terms of moisture content (26%), dry matter loss (17%), and fines fraction (< 5w-%). Other currently researched drying methods are cold drying. The outside air is sucked in and used for drying. The performance of this method depends on the respective weather conditions. But it is a more energy efficient method compared to heat drying and faster compared to natural drying (Pecenka, personal communication, 2019).

3.1.7. Research & Development (R&D) Dimension

In order to improve supply chain logistics and achieve high profit margins on lignocellulosic crops such as poplar cropped on marginal land, it is essential to continue investing in R&D. Efforts should also target increased biomass production per harvest. The development of machinery that can harvest trees which are thicker than 10 cm can e.g. increase the rotation period from 3 to 5/6 years. Thicker trees have fewer branches and less bark per harvested unit (Pecenka, personal communication, 2019). Breeding efforts can further contribute significantly to increased biomass production per harvest.

3.1.8. Critical Milestones in the TRM

The critical milestones are highlighted in blue in the TRM (Fig. 6). These are considered particularly essential by the experts for the successful market extension in this case of poplar wood

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chips as an example for a lignocellulosic feedstock. Further critical milestones were identified in the 4th ADVANCEFUEL stakeholder workshop, including:

- Specific funding opportunities
- Stable political framework
- Lack of investment into modern technology
- Visibility of good practice cases
- Social acceptance
- Awareness of policy-makers
- Attract costumers

When asked if the responsible actors in the sector have the necessary resources in place in order to achieve the identified milestones, 48% of the participants of the 4th ADVANCEFUEL stakeholder workshop were confident that the required resources are already in place (Fig. 6). The fact that 52% of the experts in the workshop consider the conditions regarding the availability and/or accessibility of resources to be insufficient indicates that much remains to be done to ensure the overall results of the TRM.

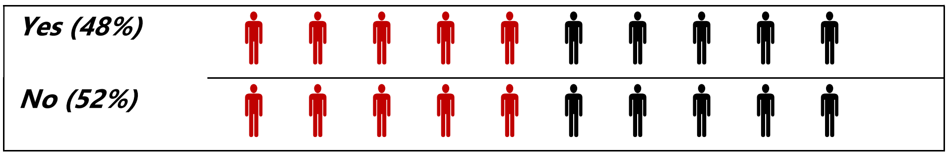

Figure 6: Live polling tool result of the 4th ADVANCEFUEL stakeholder workshop. The participants were asked to answer the question: "Do the responsible actors have the necessary resources in place to achieve the presented milestones?" The total number of respondents was 21.

3.2. Upgrading Strategies

The underlying aim of this chapter is to identify and derive upgrading strategies based on the particular innovations proposed in each studied case. This will be achieved by describing the cases (Chapter 3.2.1.), assessing the innovation's performance (Chapter 3.2.2), and deriving upgrading strategies based on the performance assessment (Chapter 3.2.3.). The four investigated case studies are listed in table 3. The first two study cases on the implementation of a public private partnership (PPP) and a so called Flexi-Chain are actual business models. The cultivation of miscanthus on large-scale, and increasing harvest frequency in agroforestry are cases based on field trials.

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Table 3: Four cases of lignocellulosic feedstock production including the innovation and project location.

No.	Case study name	Description of the Innovation	Project
1	**Public Private Partnership (PPP)**	A Public Private Partnership (PPP) fostering miscanthus cultivation	Gembloux, Belgium
2	**Flexi-Chain**	A flexible logistic chain for olive pruning collection and transportation	uP_running, Italy
3	**Large scale miscanthus cultivation**	Miscanthus cultivation on large-scale	Grace, EU
4	**Higher harvest frequency**	Increased mid-term and final harvest frequency of agroforestry wood	Seemla, EU

Following the diagnostic questions proposed by Hekkert et al. (2011) to identify the development phase of innovations, the three cases of the PPP, the Flexi-chain, and the SEEMLA project are considered to be in the take-off phase, since there is a commercial application but not a fast market growth yet. The case of the GRACE project for miscanthus cultivation on large-scale is considered to be in the development phase, since there is a working prototype, but no commercial application yet.

3.2.1. Description of the Innovative Business Models Case Studies

Public Private Partnership (PPP)

The Belgium city Gembloux was facing mud-slides resulting in high road cleaning cost. One measure which has been implemented to prevent further mud-slides was the installation of fascine, i.e. rough bundles of brushwood and other material using subsidies from the local government. However, farmers did not feel responsible for the maintenance of the fascine installations, which is why the fascines degraded and lost their function after some time. The city came across a similar case in France where farmers started cultivating miscanthus to mitigate erosion risks, and the city government in Gembloux decided to start up a PPP in order to foster miscanthus cultivation among the farmer. This business case described in figure 8 shows how the implementation of an organisational innovation – a PPP – by the city government enabled the cultivation of 6 ha miscanthus as lignocellulosic feedstock for a heating plant as well as the mitigation of erosion (VALBIOM, 2018). More than 150 actors are involved in the studied PPP case, among those are farmers, foresters, landowners, companies, industries, federations, universities, public administrations, and policy makers (VALBIOM, 2018). Key actors include the farmer who operates as the main biomass collection and storage point, the city government, a non-governmental organisation (NGO), an agricultural technical centre, and a local end-user. In order to keep transaction costs for the residents as low as possible, one farmer holds a 15-years contract with the end-user, while he also holds contracts to the other farmers who are involved in the project. Thus, he serves as collection point for the crushed material and provides storage space from where the biomass is transported the biomass to the end-user, i.e. heating plan (Fig. 7).

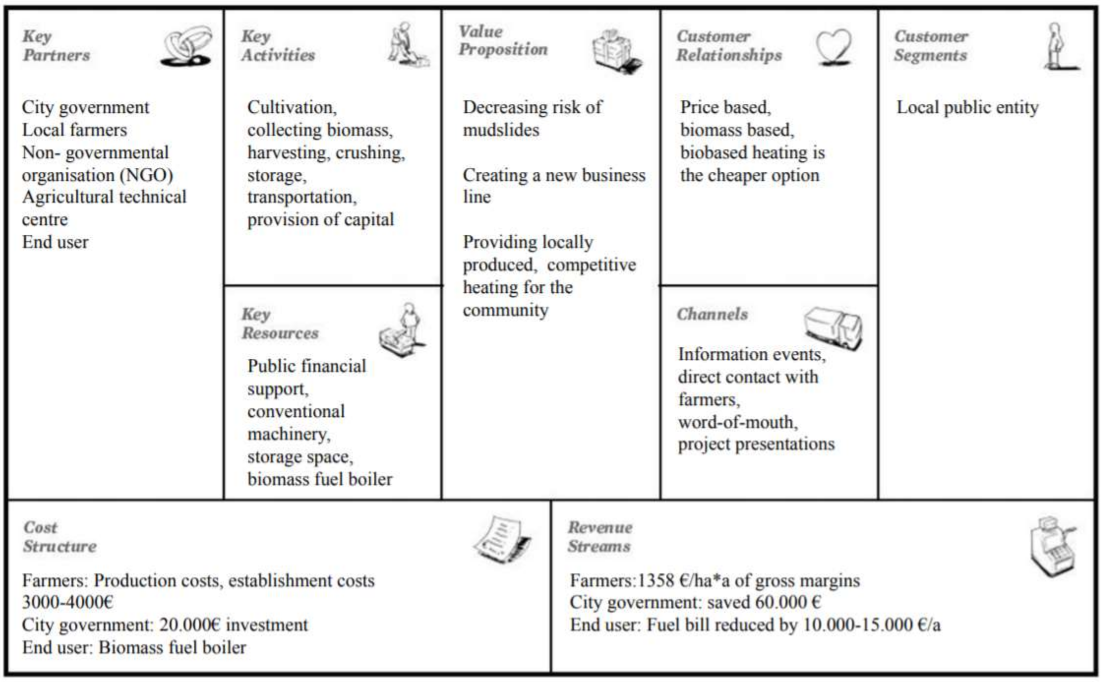

Figure 7: PPP Business Model using Business Model Canvas (BMC) (adopted from Osterwalder Pigneur & Smith (2010), www.strategyzer.com)

Miscanthus has a life span of >20 years and gets annually harvested from the 2nd/3rd year. The Belgian farmers operate with conventional machinery, which does not require any additional investments. Fertilizer is not applied on the fields, and pesticides are only applied in the first and second year. The crop residues staying on the ground have an anti-erosive effect. Additionally, miscanthus prevents nutrient losses into water bodies and increases soil carbon contents. The crushed material has a good calorific value and can serve for multiple applications such as substrate material for horticulture and livestock farming or as a raw material for the building sector. The low density of 130 kg/m^3 makes it only suitable for local supply chains (ValBiom, 2018). The high costs of the rhizome-based establishment which account for 3000-4000 €/ha represent relatively high entry costs (Hastings et al., 2017). These costs are shared in

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the case under consideration by the PPP. The city saves 60,000 € of costs for cleaning operations, the residents save 10,000- 15,000 €/a costs for heating and the farmers gain an additional profit of 1358 €/ha*a from the production and supply of miscanthus feedstock (ValBiom, 2018).

Flexi-Chain

This case study was selected as a flagship case in the uP_running project (https://www.up-running.eu/), because it is an example of a biomass-to-power business model, and the first known case of power production using exclusively olive tree prunings (Fig. 8). The current innovative technologies for pruning harvest reported in the literature include: 1) non-stop balers which decrease the time to unload the bales in the field, 2) modular machines which main features are adjustable to pruning characteristics, and 3) combining the harvester with the pelletizer for increased energy content per transported volume (Pari et al., 2017). Harvest is an important leverage point when it comes to SRC since it accounts for 50-80% of the biomass production costs (Dimitriou and Rutz, 2015). In the studied case, 1,200 farmers (60% of the local farmers) within a 10 km radius, supply their olive tree prunings for free to the power plant operated by the company Fiusis. The area has an olive pruning potential of 25-26,000 t from which 8,000 t are currently utilised by Fiusis. Farmers pile the material on the field side until it gets collected. The farmers benefit from not having to burn any longer the lignocellulosic material, which is costly and harmful for the environment. The company Fiusis founded the subsidiary Ligna which chips, collects and transports the material, after this solution turned-out to be more cost-efficient than the employment of an intermediary company for collecting and transporting the lignocellulosic material. We named this case study "Flexi-Chain", since it includes the following two different transportation chains in place depending on the field size:

- Logistic chain type 1: This logistic chain was established for smaller fields (≤ 400 trees). The farmers collect the branches and align them in rows, while Ligna's responsibility is to harvest and chip the biomass material. The utilised machines have a processing capacity of 20 – 25 tons of pruning per working day.
- Logistic chain type 2: The second logistic chain is applied on larger fields (>400 trees). In this supply chain, Fiusis undertakes all the operations. The company collects the prunings and piles them at the field side. Next, a spider grabber is used to bring the material at the field side to a static chipper operating. The utilised machine has a processing capacity of 10 tons of pruning per hour (CERTH, 2017).

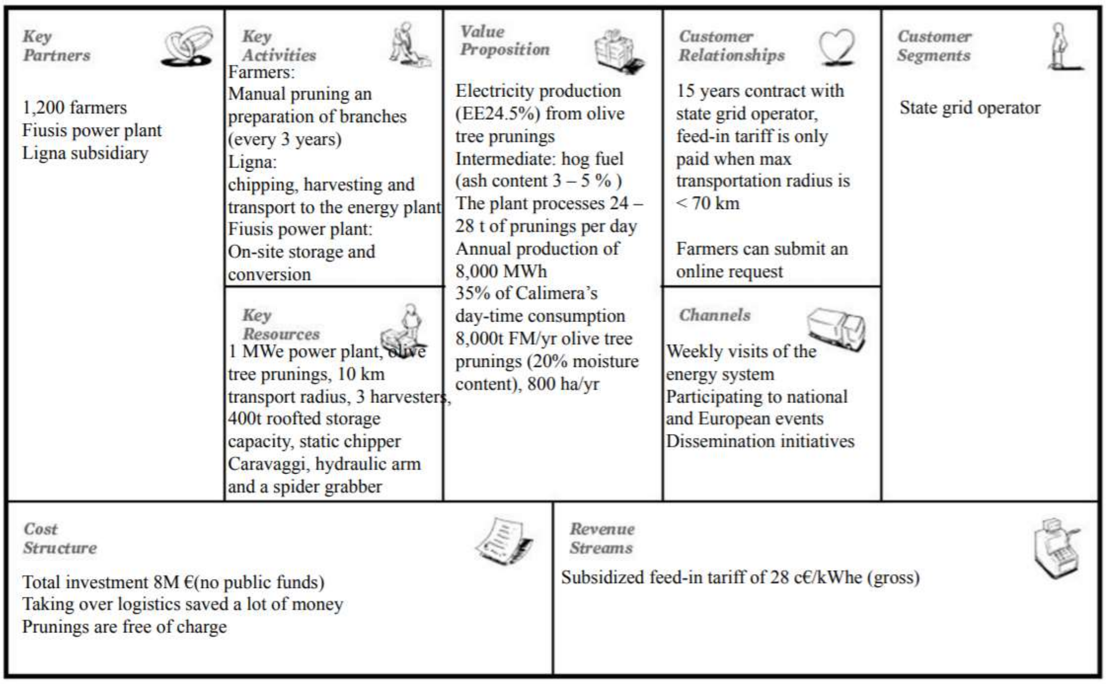

Figure 8: Flexi-Chain Business Models using Business Model Canvas (BMC) (adopted from OSTERWALDER, PIGNEUR, & SMITH (2010), www.strategyzer.com)

The olive trees get cut every 3 years during winter/spring and autumn months from January to June or September to December, and the biomass productivity accounts for 10 t/ha. The biomass gets collected 25-30 days after the harvest. The harvest between winter and spring generates a total biomass of 110 t per day with a moisture content of 37-38 %, while the autumn harvest generates 35-40 t per day with a moisture content of 15-16 %. The small scale power plant (1MW) requires an input of 24/28 t of prunings/day. The plant has a sheltered storage space of 400 t. The shredded material is very homogenous. Thus, it is called hog fuel instead of wood chips. As a pre-treatment step, the already shredded material gets shredded a second time and chipped until the particle size suits the requirements of the boiler (CERTH, 2017).

Large-scale miscanthus cultivation

The aim of the Grace project is to utilise abandoned, contaminated or land of low productivity for hemp or miscanthus cultivation. The project addresses the dilemma that farmers will not start growing lignocellulosic biomass unless there is an industry receiving their product, and vice versa, i.e. the enterprises using the biomass will not start operating without a security of supply of feedstock for the plant. Among others, the GRACE project focuses on the potential impacts of miscanthus when cultivated on a large-scale. Since we could not observe an established business case which could serve as a reference for a large-scale miscanthus cultivation, therefore we analysed this innovation on a conceptual level using also general information on miscanthus cultivation already described previously for the PPP business case.

High harvest frequency of lignocellulosic biomass

The case of a high harvest frequency of lignocellulosic biomass was investigated on the basis of the Seemla project. The case aims to produce wood from black pine, black locust, and willow on marginal land in Greece (25,58375N, 41,232297E). The technical innovation implemented in this case consists of a higher mid-term and final harvest frequency of the biomass. Midterm cuttings are taking place every 3 years instead of 10 years, and final harvest every 21 years instead of 50 years. This procedure is expected to potentially reduce wood production costs up to 3-5 %, which is being demonstrated in a field trial (Kiourtsis et al., 2018). The harvested biomass is temporarily stored on the field for 1-2 weeks. The transport distance to the point of use at the ALFA Wood processing company is 75 to 150 km depending on the location of the fields. With a production capacity of 60,000 t per year and 40 employees, ALFA Wood is the largest producer of wood pellets and briquettes in Greece. The pellets of ALFA Wood are certified by the certification scheme ENplus.

3.2.2. Performance assessment of case studies (SWOT Results)

This chapter assesses the current performance of the innovative lignocellulosic business model/ case study in regard to its Strengths, Weaknesses, Opportunities, and Threats.

Public Private Partnership (PPP)

A PPP is an organisational innovation which frees the farmer from possible risks in regard to the high upfront costs of miscanthus establishment. Shared risks, increased incomes, partnership, knowledge exchange, and a positive environmental performance facilitate the adaptation process of the PPP, while potential low social acceptance, yield uncertainties, and lack of know-how

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and information are the perceived hurdles when implementing the according innovation to the respective business model. In order for this innovation to reach the next development phase (Acceleration Phase) (Hekkert et al., 2011), short, middle, and long-term upgrading strategies have been defined. The case has shown that based on the PPP, the value proposition for the farmers is manifold, since they do not only cultivate miscanthus to be used as a cheaper fuel for a public entity, but also to reduce erosion risks which caused high investments for road clearance (Table 4).

Table 4: SWOT analysis of the innovation implementation process in the PPP case study from the perspective of the workshop participants.

STRENGTHS	**WEAKNESSES**
1: Shared risks between land owner, municipality, and end user; increasing energy security 2: Mixed species (miscanthus + willow) + mixed feedstock boiler 3: Supplier certainty (for end user) 4: Proximity, marginal land being used is close to end-user	1: Lack of long-term management and crop production know-how from involvement of contractors/ land leasing 2: Knowledge is in contractors, not partnership itself 3: Lack of information
OPPORTUNITIES	**THREATS**
1: Income generation potential 2: Soil remediation & increased productivity of land 3: Establishment of farming cooperatives 4. Strengthening partnership & knowledge sharing 5.Enhancment of generating and sharing knowledge	1: Competing land use 2: Potentially low yields due to unfavorable climate conditions 3: Green groups concerned about biodiversity 4: Social acceptance: Some people prefer to leave marginal land as it is 5: Semi-urban environment needs further development

Flexi Chain

A flexible logistic chain enables a more efficient use of resources depending on the size and type of the farm, from which the biorefinery (Fiusis) wants to collect biomass from. The strengths of the Flexi-Chain case study are that the high flexibility firstly, allows a wider portfolio of producers- not only large ones. Secondly, if only a small amount of biomass material is available and sufficient man power is present, the material can be transported to the conversion plant by the farmer himself. A Flexi-Chain requires lose agreements which react flexible to changing circumstances, rather than rigid long-term contracts. Another benefit of a lose agreement rather than rigid contracts is supplier flexibility. In one year, farmer A might have a lot of biomass available, while in the other year farmer B has a lot of biomass and farmer A is lacking available

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biomass. For end-user it does not play a role where the material is coming from farmer A or B, but that the biomass demand is met. Other strengths are increased job creation within the respective region. Drawbacks are that a flexible supply chain requires a high level of coordination efforts to align different responsibilities across actor groups. Capacities are not fully used, and the flexibility of the supply chain, does not allow for stable long-term partnerships (Table 5).

Table 5: SWOT analysis of the innovation implementation process in the Flexi-Chain case study from the perspective of the workshop participants.

STRENGTHS	**WEAKNESSES**
1: High Flexibility in various ways: allows wider portfolio of producers (not only large ones) 2: Job creation through increased participation 3: Wide range of biomass types	A: Coordination of players in cooperative supply chain B: Capacities are not always fully used e.g. machines are not operating all the time C: flexibility does not allow continuity in business relationships D: Ash content only partial use of ashes (circularity) E: Flexibility does not allow long-term contracts
OPPORTUNITIES	**THREATS**
1: Enforcement of regulations to prohibit burning prunings on field 2: Skilled labor force available 3: Development of information systems 4: Replication interest from other regions 5: Long-term support by the municipality due to the provision of district heating	1: Low information 2: Changing regulation regarding pruning collection/ Establishment of constraints to collect prunings from the field 3: Public opinion

Large-scale miscanthus cultivation

The innovation of implementing miscanthus on a large-scale has the benefit to cut costs due to scaling effects (Germer et al., 2019). Furthermore, due to a range of established field trials, this hypothetical business model can be built upon existing knowledge and expertise generated in research. Furthermore, the Grace project investigates a wide range of sustainable end-products which could be produced from miscanthus such as building material, fertilizer, animal bedding etc. The weakness of cultivating miscanthus on a large-scale is that rhizome-based establishment costs are very high, and seeds for a more cost-efficient establishment are still not available on the market (Hastings et al., 2017). These high establishment costs, lead to generally high upfront costs, which makes the farmer hesitant to start implementing miscanthus on their field (Table 6).

Table 6: SWOT analysis of the innovation implementation process in the miscanthus on a large-scale case study from the perspective of the workshop participants.

STRENGTHS	**WEAKNESSES**
1: Cost reduction due to economy of scale 2: Experience on marginal land, Established field trials 3: New sustainable products 4 Maize is more vulnerable to weather extremes than miscanthus	1: Upscaling of seed quantity and quality, what we currently do not have 2: High upfront costs, slow ROI 3: Farmer's acceptance (farmer has an issue to dedicate land for 20 years to one crop
OPPORTUNITIES	**THREATS**
1: Penetrating new markets 2: New crop for marginal land 3. Diversification of products we can sell 4. Bio-refinery on-farm, farmers want higher share of revenues 5. Intercropping maize and miscanthus	1: There is not genotype on the market 2: Lower yields on marginal land which leads to lower revenue 3: Knowledge gap 4: Low social acceptance when we introduce a new crop: Miscanthus on a large scale looks like a wall (comparable with maize which is publically also not accepted on a large scale)

Higher harvest frequency of lignocellulosic biomass

The innovation to increase mid- and final harvests has the potential to increase the biomass productivity. Furthermore, it has the benefit to generate an additional income, and make use of an already existing infrastructure and knowledge. The weakness is that there are yet no supply chains in place which generate an income from the produced biomass. Furthermore in Greece, there are constraining regulations in place that prevent the utilisation of agroforestry biomass, while the use of forestry biomass is allowed. This can lead to serious consequences regarding deforestation. The opportunities of this innovation are to establish local supply chains, strengthen local cooperatives, and extend bio-based energy markets. Potential threats are high resource costs and unfavourable biophysical conditions in combination with cropping on marginal lands. Furthermore, the mountainous topography in Greece makes biomass more difficult to access and increases transportation costs (Table 7).

Table 7: SWOT analysis of the innovation implementation process in the wood case study with increased mid-term and final harvest frequency from the perspective of the workshop participants.

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STRENGTHS	WEAKNESSES
1: Additional income 2: Existing infrastructure 3. Knowledge exists	1: Absence of supply chains (on regional and national level 2: We have constraining regulations, regulations wants us to use wood-cutting (we change land from forest to non-forest), Farmers can use regulations to do logging 3: Change of land use
OPPORTUNITIES	**THREATS**
1: Create small local supply chains 2: Strengthen local cooperatives 3: Expansion of energy market (heating/ electricity)	1: High cost of resources and logistics 2: Adverse climate conditions in relation to marginal lands 3: Long transportation distances from field to conversion plant 4: Mountainous topography

3.2.3. Upgrading Strategy Results

This section presents for each of the four studied cases strategies for moving to the next technology readiness level (TRL) determined in section 3.2.1. The proposed upgrading strategies are expected to support the cases Public Private Partnership (PPP), up Running´s Flexi-Chain and Higher harvest frequency to move from the take-off phase to the acceleration phase, characterized by a fast market growth. And the case of large scale miscanthus cultivation is intended to transit from the development phase to the take-off phase (Hekkert et al., 2011).

Upgrading strategies take place on various levels. Well-known upgrading strategies for supply chains include, among others, horizontal and vertical coordination, functional upgrading, process upgrading, product upgrading, inter-chain upgrading, or enabling environment. The upgrading strategies are identified by applying the TOWS analysis results. The presented results of this chapter are based on the previous performance evaluation and are thus tailor-made.

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Public Private Partnership (PPP)

The first action taken by the city to prevent mudslides was not successful, since it did not offer any business opportunities to the farmers and the rural community. Leveraging partnerships from all sections of the supply chain and including all actors of the value chain in the decision-making process increased the social acceptance. Furthermore in the past, the local community and the farmers had been in conflict, since the street pollution interfered with the livelihood of the population in the region. Accordingly, various upgrading strategies were proposed to increase social acceptance and consequently create legitimacy and avoid the repetition of mistakes from the past. The transaction costs occurring during the transition towards the implementation of a PPP were mainly hold by the city government, which has significantly facilitated the establishment of the project.

The first upgrading strategy identified, is to leverage partnerships by bringing key actors together. Increased cooperation among local actors can enable key actors to learn from entrepreneurial "front-runners" that already cultivate miscanthus. The knowledge and experience gained through early adopters can support local entrepreneurs to make an informed decision on the type of land and species coinciding with biodiversity targets. Furthermore, this knowledge can be made available to other local entrepreneurs. Partnerships can also help actors to have a stronger voice in regard to policy development, interest articulation, and to engage in the public debate. Partnerships can collectively demand capacity development programmes for farmers as a measure for sustainable rural development. These programmes could also train farmers on Good Agricultural Practices in regard to miscanthus cultivation. Such programmes can also help create social acceptance to successfully extent the business ideas to other marginal lands available in the immediate surrounding.

A future mid-term strategy would be to diversify the supply of dedicated energy crops with alternatives other than miscanthus. According to one workshop participant, on a large scale, miscanthus appears as a huge wall which has the potential to destroy the regional landscape, since it grows relatively high. Hence, diversification could result in higher social acceptance.

In a long-term perspective, the visions and expectations of "green actor groups" can be integrated in the discussion, also voting schemes in partnerships can be utilised in order to decide upon changes in regard to local and entrepreneurial activities. This can ensure higher social acceptance. Through the empowerment measure for farmers of implementing a capacity building programme, they will hold a more active part in the PPP. Publicly available information, decreases required efforts of the local government and the consultancy regarding knowledge exchange and development. On the other hand, bringing the expectation of all partners together, increased partnership communication, and implementing voting opportunities for change will result in a higher engagement of all key partners. This may translate into higher

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transaction costs. However, transaction costs for the end-user are expected to remain the same, since the expectation of the end-user is already fulfilled in providing the fuel and further engagement in the partnership is unlikely to guarantee additional benefits. These upgrading strategies, can lead to a clear shift from high transaction costs on the side of the external key partners, and low transaction costs of the farmers' side, to a more balanced distribution of the transaction costs. Nevertheless, an overall reduction of transaction costs is not very likely.
In the following, the strategies are listed again in brief:

- Short-term strategies
    - Leverage partnership voices from all parts of the supply chain
- Medium-term strategies
    - Management of the land by surrounding farmers to spread knowledge into farmers' community
    - Implement capacity building/training programmes to enhance capabilities of farmers and foster long-term income
    - Choice of land and species coinciding with biodiversity targets. Miscanthus cultivation should co-exist with high value habitat (noise pollution, type/ native status, phenology)
    - Diversifying agricultural supply (not only miscanthus cultivation) in order to mitigate risks
    - Communication and partnership involvement/leverage in public debate/ image
- Long-term strategies
    - Partnership for voting processes for change
    - Foster knowledge exchange and provide information
    - Alternative marginal lands in vicinity
    - Leveraging partnership aspect by including "green groups" in discussion.
    - Creating legitimacy

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Flexi-Chain

The Flexi-Chain case is the first of its kind in Europe which solely uses olive tree pruning for power generation. Therefore, a first pivotal upgrading strategy is to implement information systems in order to collect and share lessons learned by market actors. Another strategy to make risks and opportunities more tangible is to develop a showcase from which actors can learn. For risk management purposes of the farmers, it is also recommended to diversify the end-use of the farmer in serving a broad range of customers or market segments, e.g. through exploring the market for potential material usage.

Medium-term upgrading strategies are the development of communication strategies that enables other farmers to participate in the business model as well. Clear communication would also prevent redundant work and overlap of internal processes. Power generation produces ash as a by-product. This ash is currently not returned to the field in order to feed the lost nutrients back to the soil. Returning the ash back to the soil should contribute to better soil quality and increase the circularity of the business model. One weakness revealed from the SWOT analysis was that machinery capacities are not fully utilised. This can be avoided by establishing machinery rings. An additional benefit of this strategy is, to keep CAPEX costs low. In order to make full use of the flexibility of this business model and react to changes in supply streams and market structures, it is important to have agreements for cooperation in place, rather than rigid contracts. Communicating business activities to policy-makers is important in order to raise awareness of the need in regard to a favourable business environment (Martinidis et al., 2019). This could lead to a stable regulatory framework in the long-term run.

In the following, the strategies are listed again in brief:

- Short-term strategies
  - Implementing an information system, gather and share information from all actors
  - Develop a show case
  - Diversify supply via wide range of products
  - Diversify demand
- Medium-term strategies
  - Develop communication strategies and opportunities for participation
  - Disseminate knowledge to policy makers
  - Bring ash back to the field to ensure circularity
  - Machinery sharing
  - Agreement for cooperation, since contracts are too restricting

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- Long-term strategies
    - Create stable regulatory framework
    - Lobbying activities in order to raise awareness for olive pruning utilisation and its further needs for policies

Large scale miscanthus cultivation

In the PPP case study we have already seen how important the influence of the French miscanthus case study was to kick-start the PPP case in Belgium. Therefore, the proposed short-term strategy to cultivate miscanthus on a large-scale is to invest efforts into dissemination activities and development of a show case. The high upfront costs of miscanthus also make long-term contract attractive for the farmer in order to guarantee the return on investment. As, demonstrated by the EU GRACE project, miscanthus has a wide spectrum of potential applications. These markets could be further developed.

A medium-term strategy is to provide good practice guidelines and organise field demo days for farmers to account for risks and potentials. Furthermore, the implementation of innovative cropping schemes can enable the farmers to significantly reduce production costs. The innovation with the biggest cost reduction potential regarding miscanthus is to provide seed-based establishment options on the market. Further, innovative cropping schemes and their cost reduction potential are described in ADVANCEFUEL deliverable 2.2 (Germer et al., 2019).

On a long term run new varieties are expected to be registered and research on further breeding and propagation efforts could further contribute to the upgrading.

In the following, the strategies are listed again in brief:

- Short-term strategies
    - Dissemination of knowledge (Farmer-science-industry-public)
    - Development of show cases
    - Cooperation (long-term contracts) between farmers and corporates in order to share costs and guarantee long-term demand/supply
- Medium-term strategies
    - Development of new markets
    - Share good practice guidelines
    - Organise field demo days for farmers
    - Decrease production costs to compensate for reduced yields e.g. through seed-based establishment (50% cost reduction potential of establishment costs)

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- Long-term strategies
    - Registration of new varieties
    - Increased breeding area and propagation

High harvest frequency of lignocellulosic biomass

Growing woody biomass on agricultural land and increasing the harvest frequency of lignocellulosic biomass for a more lucrative cultivation can be supported through knowledge transfer from forestry to agroforestry, as well as training for the respective businesses. Since, the establishment of trees generates a number of ecosystem services; one upgrading strategy proposed is to establish a credit policy for farmers, factories and, end-users to facilitate the transition towards agroforestry. This transition would first of all require green energy targets. Once those targets are in place, it is easier to demand for local funds or green certificates.

In a long-term run, local supply chains need to be established. One weakness revealed in the SWOT analysis concerns the legislation which enables actors to utilise forest biomass. Logging could be prevented and agroforestry enhanced by changing the legislations which de facto constrain forest biomass usage.

Another constraining factor is long transportation distances. This barrier could be overcome by establishing a dense network of agroforestry suppliers. The ADVANCEFUEL deliverable 1.1 points at the lack of a well-established infrastructure (Uslu et al., 2018). This could be supported by the creation of national grants. Agroforestry accounts for much longer life spans than cultivation annual crops. The adaptation of land rental contracts is expected to further facilitate the adoption of agroforestry systems.
In the following, the strategies are listed again in brief:

- Short-term strategies
    - Knowledge transfer from forestry to agroforestry
    - Training/consulting for bio-businesses
- Medium-term strategies
    - Local green energy targets
    - Establishment of financial measures for farmers, factories, end-users, investors etc./ green certificates/ local funds
- Long-term strategies
    - Development of local supply chains
    - Changing legislations in regard of the utilization of agroforestry biomass
    - Legislation determines species, planting density, way of logging

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- Changing legislation of forest property rights e.g. allowing farmers to rent public land for 50-100 years
- A dense network of agroforestry suppliers decreases transportation distances
- Improvement of infrastructure e.g. through national grants

4. Discussion

The first objective of this report was to develop a *Technology Roadmap (TRM)* for RESfuel feedstock, defining the future vision for 2040 and strategical milestones how to get there. The present report provides further evidence of the usefulness of the TRM as an instrument to assess the status quo and identify the bottlenecks of a defined research objective. Developing a TRM and identifying business upgrading strategies, provides insights into the lignocellulosic biomass sector at two levels. First, the TRM gives us an overview of milestones which need to be reached on the sectoral level. Second, the upgrading strategies zoom onto a micro-level, in this case the level of the businesses and value chains.

The TRM on poplar wood chips production which was analysed in this study, defines milestones to be reached for a sustained development in the dimensions of politics, society, economy & business models, technology, and R&D. Relevant insights for practice, research and policy were derived for each of the dimensions. Other projects focusing on lignocellulosic supply chain and business development include (1) Sucellog, which aims to trigger the creation of biomass logistic centers by the agro-industry, (2) AgroinLog, and (3) SRC+, which aims to facilitate the development of local supply chains of SRC (Dimitriou and Rutz, 2015). Such projects have also reported flagship cases in Europe. Within the ADVANCEFUEL project, a key finding of the TRM analysis is the need to establish a strong network of best practice cases. ADVANCEFUEL already kick-started this measure by publishing a report on "D5.2 - Good Practices along the RESfuels Value Chain" (Christensen et al., 2018). Other critical milestones are a stable political long-term framework and investments in modern technologies to reduce production costs.

The second objective of this report was to formulate *upgrading strategies for lignocellulosic feedstock* supply chains that facilitate the market roll-out of RESfuels. Some of the upgrading strategies investigated are case specific, while others were found relevant in various cases. As illustrated in Chapter "3.2.2. Performance assessment of case studies (SWOT Results)", all case studies share the strength "diversification of supply". Other aspects are case-specific, such as the high flexibility in the logistic chain of the uP_running project. This flexibility enables the social inclusion of small—scale farmers.

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Shared barriers among all four cases are "low social acceptance" and "lack of knowledge". Further issues are high cooperation efforts and underutilised machine capacities in the Flexi-Chain (uP_running), and no available genotype for seed-based establishment and "low yields on marginal land" in the large-scale miscanthus cultivation of the Grace project working on the upscaling of miscanthus. In the Seemla project "constraining regulations" and "long transportation distances" are the case-specific identified barriers.

Table 8 illustrates all four case studies having the upgrading strategy of "information sharing" in common. Other re-occurring strategies are "partnership enhancement", "economic diversification", and "the development of a show case/ field demo days". However, there are also very case-specific catalysts mentioned in the other cases such as the return of the ash to the field in order to close nutrient cycles (Flexi-Chain case study), and the registration of new species in order to increase biomass productivity (Large scale miscanthus cultivation case study).

Table 8: Shared patterns of upgrading strategies among the four case studies

	Case Studies			
Upgrading strategy focus	**PPP**	**Flexi-Chain**	**Large scale miscanthus cultivation**	**High harvest frequency**
Financial support				+
Changing regulations			+	+
Partnership enhancement	+	+	+	
Information sharing	+	+	+	+
Capacity building/ training	+			+
(Economic) Diversitfication	+	+	+	
Acceptance creation	+			
Show case development/ field demo days		+	+	+

Short-term strategies can be perceived as the "low hanging fruits" when it comes to upgrading. Furthermore, the identified future upgrading strategies are most likely to be put into practice if key actors perceive transaction costs as relevant costs in regard to cost-benefit efficiency (Keutmann et al., 2016b). For instance, it can be expected that in the PPP case study, the city council will enforce the majority of the identified upgrading strategies, since it would be also the biggest beneficiary in regard to transaction cost reduction. The PPP is a multi-actor case study, whereas in the Flexi-Chain example, there are only two major actors, the farmers who provide the biomass and the Fiusis plant. The Fiusis plant prefers to control the entire supply chain in order to ensure the required feedstock quality. Furthermore, by controlling the entire supply chain Fiusis saves money since no further service providers have to be paid. We therefore conclude that both cases follow a top-down approach, but the Flexi-Chain case has decided on a hierarchical governance structure from a strategic point of view. Whereas the city council of the PPP case aims for that governance structure, to lift the financial burden and potential risks off the farmers. Thus, we expect that the PPP case study will change from a hierarchical towards a collective case study in the future. One result of our TRM is that the provision of long-term contracts is conducive for the development of feedstock production businesses. However, Keutmann et al. (2016b) compare economic benefits of a contract farming example with the independent production of SR-wood production. According to their findings, it cannot be concluded that long-term contracts are always the economically beneficial option. Transaction costs are in the end the decisive factor when choosing the business model. However, collaboration agreements are necessary in order to secure demand and supply (CIRCE and CERTH, 2018). The findings of the uP_running project illustrate that one underlying success factor for all case studies, is to negotiate a win-win situation among all actors. That is also the success factor in the PPP and the Flexi-Chain case study. However, perceived shared benefits are very complex and therefore difficult to replicate (CIRCE and CERTH, 2018). Another common success factor regarding the PPP and the Flexi-Chain case is that both lignocellulosic value chains are established as a co-business to the main agricultural business of the farmers. Making lignocellulosic value chains a co-business was also a learned lesson shared by experts from the FORBIO project during the 2nd ADVANCEFUEL workshop in Brussels. Another lesson learned from literature and stakeholder engagement is that due to a low energy density of the biomass, it is more lucrative to remain within local value chains of a 50 km radius (El Kasmioui and Ceulemans, 2013; Pecenka, personal communication, 2019).

Additionally, this research provides further evidence in terms of the methods used for the analysis, that applying the TOWS matrix can create a smart feedback loop for future business model upgrading strategies by learning from past systemic weaknesses.

Based on the influence of the French flagship case in the PPP case study, it would be also valuable to further investigate upon the role of such "front-runner" cases and whether the presence of such accelerates niche innovations entering the regime. Our recommendation for further practice is to base business model upgrading activities on lessons learned from innovation implementation processes. Furthermore, strategies should be selected based on economic feasibility and low transaction costs involved. The present study offers opportunities for future research to more fully examine other variables and factors that may contribute to or influence the market roll out of RESfuels, such as formal or informal institutional arrangements in place. The present report was able to touch only upon some of these interesting topics that deserve more attention in the future.

The methodological approach for this report presented both challenges and limitations. The most salient limitation is related to the sample size. For the TRM, we were able to conduct only four interviews. While in the case of the upgrading strategies, only four cases were identified. Such a small-size sample of case studies has implications in terms of the generalization of our findings. On one hand, the focus of the TRM was on poplar wood chips; other sources such as forestry residues, waste streams or grassland biomass were not included. In the case of grassland biomass for example, there is a big potential as feedstock supply from around 28% of the EU's total surface area is covered by grassland and green shrubs (www.go-grass.eu). Finally, to validate our proposed upgrading strategies, this methodological approach needs to be a applied on further cases.

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5. Conclusion

The TRM for the market expansion of lignocellulosic feedstock presents milestones on various levels: politics, society, economy & business models, technology, and R&D. The most critical milestones which are envisioned include (1) a stable long-term policy framework which considers the entire bioeconomy, (2) the establishment of a competence center for agroforestry wood, (3) the establishment of a strong network of best practice business cases, and last but not least, (4) investments in modern technologies to reduce production costs.

The present report also derived business and value chain upgrading strategies using the TOWS method applied during the ADVANCEFUEL 2nd stakeholder workshop. The proposed method integrates past and ongoing lessons learned – which were derived from a SWOT analysis – to reach higher efficiency and lower transaction costs among actors. Among our identified upgrading strategies there is a reoccurrence of the aspects "partnership enhancement", "information sharing", "(economic) diversification", and "show case development/ field demo days".

In conclusion, there are many opportunities to secure a stable supply of lignocellulosic biomass for the production of RESfuels. To unleash such potential, a variety of site specific innovations at all levels (social, political, economy, technology, R&D) are recommended. We also recommend a management strategy built upon comprehensive planning, multi-actor engagement and a strong information (digital) environment for an integrated natural resource management.

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Annex

Questionnaire 1: Technology Roadmap for poplar woods chips (TRM)

The following questions are intended to serve as guiding questions to develop a Technology Roadmap:

- What trends do you see for poplar wood chips in the EU?
- What future market developments do you expect?
- What are the difficulties when expanding the market for poplar wood chips?
- In your opinion, what is the vision of wood chips in terms of the parameters listed below up to 2050?

Table 1: Product properties and product requirements of poplar wood chips until 2040 and beyond

Impact	Unit	Today	2040 and beyond
Economic impact			
Biomass price	€/tdm		
Biomass quantity			
Feedstock quantity			
Moisture	w-% dry		
Lignin	w-% dry		
Carbohydrates (cellulose + hemicellulose)	w-% dry		
Chlorine content	w-% dry		
Ash deformation temperature	(DT) °C		
Ash content	w-% dry		
Nitrogen content	w-% dry		
Feed size	Mm		
Coarse Fraction	%		
Fine particles	%		
Bulk density	kg/m³		
Ecological impact			
Carbon monoxide	mg/m³		
Nitrogen leakage			
Water Quality			
Biodiversity			
Soil organic carbon			
Socioeconomic Impact			
Job creation			
Consumer price			

- What policy regulations/innovations are necessary to achieve this vision?
- What are the driving forces behind these policies/innovations?

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- What is the time frame of these policies/innovations?

Technology Roadmap- Guiding questions

Supporting questions (based on the feedstock barriers identified in D1.1.)

- What solutions can be implemented by 2040 in terms of logistics infrastructure (mobilisation from remote regions)?
- What approaches are there for improving the quality, consistency and homogeneity of raw materials?
- Is there competition for the same raw material (poplar)?
- What mechanism could be implemented to avoid high processing, storage and transport costs?
- What challenges have you experienced in regard to market transparency ?
- How can high costs for determining the quality of raw materials for biofuels and the high costs for high-quality information in general be avoided?
- How could lacking investments (e.g. in harvesting machines) be realised?
- What mechanisms could overcome farmers' reluctance to grow plants that do not generate annual income?
- How could the gap between high production costs and low sales be closed?
- How could adaptation to new agricultural practices be accelerated?
- How could the knowledge gap on management practices be closed more quickly?
- How could communication between stakeholders be accelerated?
- What are the cultural barriers of introducing new crops into a mono-crop landscape? Which mechanisms help to overcome these cultural barriers?
- Are farm size and other demographic factors (ageing agricultural population) major barriers? How can the production of renewable raw materials be made attractive for small farms?
- How can the socio-economic benefits of biofuels be increased in rural areas?
- How can the clarity of land availability and environmental requirements for energy crops be improved?
- How can legislations for sustainable cultivation methods be harmonised for both residual biomass and specific energy crops?

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Questionnaire 2: Innovative Lignocellulosic Biomass Value Chains/ Business Models

1. Project name	[Please state the project name or "private" if the respective value chain/ business model is not part of a project]
2. Country	[Please state the country of the respective value chain/ business model, you were involved in]
3. Deliverable (if, applicable)	[Please state deliverables/ reports or other reading material that describe the respective value chain]

Value Chain/Business Model Description

1. Is the value chain in the respective project a real case or a hypothetical case?

    ☐ Real case

    ☐ Hypothetical case

2. Is the respective value chain located in the rural area or near to an urban area (Please state latitude and longitude)?
3. What biomass inputs are being used (biomass type, crop specie etc.)?
4. How is the respective crop being cultivated (fertilizer, phytosanitary treatment, tillage etc.)?
5. How is the feedstock crop being harvested (key activities, machinery)?
6. What are the pre-treatment processes of the respective biomass (key activities, machinery)?
7. How is the respective biomass being stored (storage type, storage space, etc.)?
8. How does the feedstock get transported from the farm to the conversion plant (mean, distance, fuel type)?
9. What will the biomass be converted to (end-product, co-product)?
10. Was the innovative value chain developed from scratch or was it an upgrading strategy of an already existing value chain (e.g. by using waste streams)?

    ☐ From scratch *(continue with question 11)*

    ☐ Upgrading of existing value chain

    If it was an upgrading strategy, please describe the difference to the initial value chain / business model?

11. Would you describe the new value chain/business model as a success?

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☐ Yes. Why? ____

☐ No. Why not? ____

Innovations as basis for upgrading value chains/business models

12. Please, describe the innovation(s) which were implemented in the respective value chain/ business model [Innovations can be referred to as technological, but also management, institutional innovations etc.]?
13. What are the key strengths/ weaknesses/ opportunities/ threats of those **innovation(s)**?

Strengths (What are success factors of the innovation(s)? Why should operators adopt this innovation(s)?):	**Weaknesses** (What are fields of improvement?):
Innovation A:Klicken Sie hier, um Text einzugeben.	Innovation A:Klicken Sie hier, um Text einzugeben.
Innovation B:Klicken Sie hier, um Text einzugeben.	Innovation B:Klicken Sie hier, um Text einzugeben.
Innovation C:Klicken Sie hier, um Text einzugeben.	Innovation C:Klicken Sie hier, um Text einzugeben.
....Klicken Sie hier, um Text einzugeben.	...Klicken Sie hier, um Text einzugeben.
Opportunities (What would be the ideal opportunities for the diffusion of those innovations?):	**Threats** (What are the barriers of adopting those innovations?)
Innovation A: Klicken Sie hier, um Text einzugeben.	Innovation A:Klicken Sie hier, um Text einzugeben.
Innovation B: Klicken Sie hier, um Text einzugeben.	Innovation B:Klicken Sie hier, um Text einzugeben.
Innovation C: Klicken Sie hier, um Text einzugeben.	Innovation C:Klicken Sie hier, um Text einzugeben.
...Klicken Sie hier, um Text einzugeben.	...Klicken Sie hier, um Text einzugeben.

14. What is the potential cost reduction contribution of the respective innovation(s)? What is the reference value?

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15. How do those innovative value chains/ business models influence socio-economic conditions (e.g. adequate remuneration, adequate working time, employment, health, safety, training, equal opportunities, and workers' council)?
16. Please state, to what extent you agree with the following statement.

strongly agree	Agree	disagree	strongly disagree
The actors of the respective value chain/ business model react flexible to changing circumstances			
☐	☐	☐	☐
The main actors are open for a variety of solutions regarding the upscaling of the respective value chain/ business model.			
☐	☐	☐	☐
The innovation(s) will reach upscaling through a stepwise learning process rather than a radical breakthrough.			
☐	☐	☐	☐
Value chain/ business model actors will rather collaborate with incumbent actors than with "outsiders".			
☐	☐	☐	☐
Innovations are nurtured in protected niches instead of exposing them to competition in an early development stage.			
☐	☐	☐	☐
Value chain/business model actors actively engage in the public debate to increase market opportunities of the respective innovation.			
☐	☐	☐	☐

17. What lessons learnt would you pass on to someone who just enters the business?

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Questionnaire 3: Biomass Production on Marginal Lands: Socio-economic Perceptions and Expectations

Introduction

We are conducting a project related to the use of marginal lands for the bioeconomy. A fundamental part of this project is to conduct interviews.

The interview aims to identify the expected socio-economic impacts of the use of marginal lands for the bioeconomy by asking for the different perceptions, interests and expectations of local actors. This perspective will allow us to identify the different interests of the actors and to discuss together the most important issues.

This interview could also be an opportunity for networking, for new partnerships and to gather new information about innovations and technologies.

1. What is for you a marginal land?

Scenario:

Where we are now, there are several types of grasses. These grasses are located in an area in which, due to unfavorable natural and economic conditions, food and feed crops are not grown. Thus, the area has been traditionally dedicated to nature conservation and tourism.

This plant will use the grasses as its main input to provide several outputs, including (i) biomethane, which is mainly sold to the transport sector, (ii) organic animal bedding for large and small livestock farming, (iii) biochar, which can be used as fertiliser and soil improver for agriculture, (iiii) natural fibers as building material and for packaging, (iv) organic protein concentrate as soy substitute for feeding monogastric animals (pigs and poultry).

These grasses will now be harvested and used as feedstock for the biorefinery in order to generate the outputs mentioned above.

With this this in mind, we kindly ask for your opinion on the following questions.

1. What could be your possible contribution in this scenario?
2. What is your experience in this area? What technical or social skills would be advantageous for such a project?
3. With which external partner would you need to work more closely with?
4. What type of contract would you prefer with your partner, e.g. in terms of contract duration, payment, division of labor, machine sharing?
5. By what form of communication and interaction would you prefer to negotiate with your partners? How would you like to communicate and negotiate?
6. Do you know about laws that make this new business possible or the regulations that hinder this development?
7. From whom could you expect resistance from?

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Social Expectations

How could this business have an impact on local communities?

- Social engagement
- Competing interests
- Existing and new partnerships
- Public acceptance
- Diversity and equal opportunities (gender equality)
- Health and safety
- Land rights (additional land rent required)
- Tourism
- Further education/training and innovation (development of new qualifications)
- Continuity of young people in the region
- Community pride

Economic Expectations

(Farmers)

1. How likely do you think it will be that your income from farming will increase in the next 5y?
2. How likely do you think it will be that your yields will increase in the next 5y?

(All)

How could this business line contribute to the local economy in terms of :

- Job opportunities
- Employees from the region/abroad
- New investments
- Land prices
- Competitiveness of the domestic economy

Environmental Expectations

1. What effects do you expect regarding biodiversity (fauna, flora), water quantity, and soil quality of the area? Why?
2. What technical and environmental considerations must be taken when harvesting the grasses? (fertilization regimes, harvesting frequencies, vegetation periods) Why?

What would be your motivation to engage in such a project?

In which processes of the business line would you concentrate, and how can you optimise them?

After this discussion, would you consider the harvested areas as a marginal land?

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