VTT Technical Research Centre of Finland

Report on drivers and barriers for implementation of bioenergy technologies in rural areas

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BRANCHES

Boosting RurAl bioeconomy Networks following multi-actors' approaches

Deliverable

D3.5 Report on drivers and barriers for implementation of bioenergy technologies in rural areas, 2nd version

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Table of Contents

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1. Executive summary

This is the second version of the *Report on drivers and barriers for implementation of bioenergy technologies in rural areas*. The report summarizes the key findings related to the drivers and barriers for implementation of bioenergy and bioeconomy technologies in rural areas, elaborated in the BRANCHES project. The results are presented in a practitioner-friendly format. The final conclusions are delivered and disseminated via the National Thematic Networks (NTNs) established in the project countries: Finland, Germany, Italy, Poland, and Spain.

The methodology for formulating Practice Abstracts and collecting and analysing their related drivers and barriers in the BRANCHES project is described in the first version of this report (D3.1). The previous report also provided an example of how drivers and barriers are elaborated and synthesized for topical groups based on the themes covered in the Practice Abstracts.

In total, this report analyses drivers and barriers from 27 Practice Abstracts across the following topical groups: Biogas and biomethane production; Advanced thermochemical conversion processes; Hybrid and farm-scale bioenergy solutions; Heat (cascading) technologies and Bioeconomy solutions in rural communities. A summary discussing the key findings of the related drivers and barriers is presented at the final Chapter of this report.

2. Deliverable description

The *Report on drivers and barriers for implementation of bioenergy technologies in rural areas* is divided into two versions D3.1. (1st version) and D3.5. (2nd version). The first version of the report (D3.1) described the methodology on how the Practice Abstracts and related drivers and barriers are formulated, collected and analysed in the BRANCHES project. In addition, the report provided an example on how the drivers and barriers are synthesized for one topical group formulated based on the topics covered in Practice Abstracts.

This report is the second version of the deliverable, and it provides a short summary of the methodology on Practice Abstract elaboration, dissemination and collection of drivers and barriers, results of the analysis and the final conclusions and remarks. The report is based on the findings during the Practice Abstract (PA) elaboration in *Task 3.1 Screening of currently available mature and novel bioenergy technologies for rural bioeconomies* and discussions in the workshops organized in *Task 3.2 Active share of practical knowledge in workshops of bioenergy technologies*. In this report, the findings of bioenergy and bioeconomy related drivers and barriers are summarized in a form that is understandable for practitioners. The final conclusions are delivered and distributed via national thematic networks (NTNs) established in each project country.

3. Summary of Practice Abstract elaboration, dissemination and collection of drivers and barriers

Within the BRANCHES project, a key component involves the creation and distribution of Practice Abstracts (PAs) through country teams. In Task 3.1. *Screening of currently available mature and novel bioenergy technologies for rural bioeconomies,* over 25 PAs have been produced related to available and innovative bioenergy and bioeconomy solutions. Approximately five PAs are produced for each of the project country involved. The specific steps for generating these Practice Abstracts and their dissemination process have been outlined in the deliverable D3.1.

The project country responsible for creating the Practice Abstract collects drivers (D) and barriers (B) for the practice in question using the DEPEST approach outlined in D3.1. The DEPEST analysis stands for six categories: demographic, economic, political and legal, ecological, socio-cultural and technological aspects. The drivers and barriers are primarily sourced from discussions with practitioners and technology providers while collecting the information for the Practice Abstract. Technological and Sectorial Partners of BRANCHES projects may also add drivers and barriers based on their expertise or relevant literature references.

Additionally, insights into drivers and barriers affecting the implementation of the associated solutions are generated during the national workshops (T3.2). The information regarding these workshops and their content is elaborated in D3.1. During these workshops, the presenters (e.g., technology providers, scientists) can present currently available and innovative bioenergy and bioeconomy technologies, while practitioners can share insights into the drivers and barriers associated with the implementation of the associated solutions in rural areas. The related drivers and barriers arising from the workshops are collected. Each project country decides themselves on how the collection of drivers and barriers takes place during the workshop (survey, open discussion, virtual memo-board etc.). The project country is responsible for the data collection and analysis of drivers and barriers from the workshop. The results are integrated into the DEPEST reporting templates generated for each Practise Abstract.

When gathering information on drivers and barriers for a Practice Abstract, each project country completes a Drivers and Barriers (D&B)-table (Table 1) to identify the drivers and barriers. They also provide the corresponding data sources. After completing the D&B-tables for the PAs covered in this report, the D&B-tables are categorized into topical groups based on the respective focus of the PA. After that, individual statements from each D&B-tables are gathered, combined and synthesized with similar statements extracted from other D&B-tables. An example of this synthesis process can be found in D3.1. This report presents the synthesized findings on drivers and barriers, organized according to the topical groups introduced in the Chapter 3.1.

Table 1 A D&B-table to collect PA-related drivers and barriers.

	Source	Driver or barrier
Demographic		
Economic		
Policy & legislation		
Ecological		
Socio-cultural		
Technological		

3.1. Topical groups for drivers and barriers

In total, drivers and barriers from 27 Practice Abstracts were analyzed for this report, covering technologies such as biogas and biomethane production, advanced thermochemical conversion processes such as gasification, pyrolysis, torrefaction, hydrothermal carbonization, multiform renewable energy production methods, heat production from local side and waste streams and bioenergy and bioeconomy examples from rural communities, such as community-scale efforts for energy independence and innovative production routes from biomass.

To analyze the related drivers and barriers from the associated bioenergy and bioeconomy solutions covered in the Practice Abstracts, the PAs are categorized into topical groups, within which the key drivers and barriers are synthesized. These topical groups are established so that each PA created within the Task 3.1. of BRANCHES aligns with a specific theme. The Practice Abstracts are organized under the following topical groups, which will serve as the basis for our following analysis of drivers and barriers.

1) Biogas and biomethane production

- PA7: Manure-powered milk logistics (Finland)
- PA18: Agricultural cooperative biogas plant (Poland)
- PA19: Agricultural cooperative biogas plant (Germany)
- PA27: Farm-scale energy and nutrients circulation through an on-farm micro biogas plant (Poland)
- PA31: Climate-smart food production (Finland)
- PA35: Added value from an agricultural biogas plant (Poland)

2) Advanced thermochemical conversion processes

- PA8 An example of microgeneration in Italy (Italy)
- PA11 Olive cake gasification (Spain)
- PA14 HTC of biomass (Spain)
- PA15 Biomass torrefaction and cleaning (Spain)
- PA22 Hydrothermal carbonization of green waste to produce biocoal, carbons and biochemicals (Germany)
- PA24 Biochar from lignocellulosic and agriculture residues (Italy)
- PA37 Biochar production and heat generation through slow pyrolysis (Finland)
- PA48 Bio-oil from forest biomass through pyrolysis (Finland)

3) Hybrid and farm-scale bioenergy solutions

- PA6 Hybrid solution to ensure energy self-sufficiency in a berry farm (Finland)
- PA20 Biomass hybrid dryer (Finland)
- PA45 A heat storage device (Poland)
- PA57 Energy from miniature power plants (Finland)

4) Heat (cascading) technologies

- PA29 Self-cleaning rotary boiler for solid waste (Spain)
- PA30 Pallet valorisation system for energy purposes (Spain)
- PA44 Biological waste as a source of low-temperature heat for hotbeds (Poland)

5) Bioeconomy solutions in rural communities

- PA21 Grass factory – from meadow grass to innovative materials (Germany)
- PA33 Increasing energy independency in a rural municipality - case Barciany (Poland)
- PA34 From cereal straw to district heat: case Kisielice (Poland)
- PA39 Rasen: A district heating plant in operation for over 30 years: lessons in adaptation, survival and evolution (Italy)
- PA40 Pellerei: New old roots – from farming to power producers…and back (Italy)
- PA58 Domestic energy from nature (Finland)

4. Drivers and barriers for implementation of bioenergy technologies in rural areas

The findings in this Chapter provide an analysis of the drivers and barriers related to the implementation of bioenergy and bioeconomy technologies in rural areas. To account for statements that may serve as both drivers and barriers, we have included ambivalent factors in our analysis as well.

It is important to note that the synthesized results of drivers and barriers are not intended to be exhaustive. Instead, the represent factors that are extracted from discussions with practitioners and technology providers and from workshop discussions. They aim to capture the viewpoints of the different stakeholders. Furthermore, although these findings are categorized into topical groups based on the corresponding Practice Abstract, many of them are applicable to a broader range of technologies and are not restricted to a single category. Additionally, it is essential to recognize that these statements are presented without any particular order of importance.

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4.1. Drivers and barriers for biogas and biomethane production in rural areas

	Drivers	Ambivalent factors	Barriers
Demographic		*Biogas value chains generate employment opportunities within the community; however, it may be challenging to secure a sufficient number of trained workers to operate and maintain these value chains in rural areas*	
		Urbanization may decrease interest in rural bioeconomy solutions, but it can also lead to larger farm sizes, promoting their adoption	
Economic	*Guaranteed and stable demand for biomethane is a prerequisite to make biogas upgrading for biomethane profitable: as an example, a purchase agreement between a dairy farm and a logistic company has been made to secure the biomethane demand.*	*Local energy production potential for biogas from agricultural and livestock residues is substantial, yet local challenges can arise due to seasonal variability in the feedstock supply*	*Potential disruptions in base-load energy production from biogas due to variations in the supply of local biomass waste sources*
	Biogas and biomethane production provide a new source of income for the farmer (e.g., sold electricity, heat or biomethane)		*Chicken-egg problem: biomethane demand needed for investments to biomethane infrastructure and production, on the contrary, biomethane infrastructure and production needed to create biomethane demand*
	The farm, cooperative or municipality can increase its energy self-sufficiency by producing its own energy (electricity and heat) from biogas and thus reduce energy-related costs		*Investment cost of biogas production and upgrading units for biomethane are high, however, the profitability is affected by the rising cost of purchased energy. At the moment, the cost of fossil energy is high*
			Transportation of agricultural and livestock residues from decentralized locations to centralized location may not be cost-effective and thus reduce the benefits of economics of scale

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Policy & legislation	*Fertilizer production from manure can help farmers meet related requirements and directives to reduce agricultural nitrogen pollution from manure application to land*	*The presence or absence, as well as the complexity, of long-term financial support schemes can either facilitate or hinder investments and use in biogas and biomethane projects. Moreover, uncertainties linked to future legislation may pose a restraining barrier to potential investments*	
		Financial support for investments is often vital, but the availability of financial support schemes varies by country where the technology is applied	
Ecological	*The farm, cooperative, company, or municipality promotes the circular economy by converting own and/or collected waste streams into new products*		
	Biogas and biomethane production bring ecological benefits in heat, power and transportation fuel production (e.g., farms) and users (e.g., municipalities), contributing to reduced carbon footprints in various production chains		
	Producing biogas from livestock manure allows for the utilization of digestate as a nutrient source, reducing the need for purchased chemical fertilizers on farms. This has several advantages, including the transformation of manure nutrients into a more soluble form and the reduction of odours and potential nutrient runoffs compared to untreated manure		
Socio-cultural	*A company's image becomes more environmentally friendly when valorising waste streams into energy or using renewable energy as a fuel*		*While bioenergy producing can have long-standing traditions, biogas production may face resistance due to concerns about odours, particularly in cases where high manure storage capacity is necessary*
	The biogas value chain involves and benefits multiple local community parties, including farmers utilizing agricultural residues, local		

	employment creation through new energy production plants, and locally produced electricity and heat		
	The increase in the price of purchased energy can immediately affect farm profitability, potentially boosting interest in local, renewable energy. Environmental values can also play a positive role in the transition to renewable power and heat		
Technological	*Biogas is a versatile form of energy: can be used as a storage, operated both flexibly and as a baseload. In addition to heat and power, biogas can also be used as a transportation fuel when upgraded to biomethane*		*Liquefied biogas (LGB) would be preferred as a fuel in heavy transportation over compressed biogas (CBG) as it requires less space in the vehicles. However, liquefying biomethane is not yet economically feasible in small-scale*
	Besides own use, heat from biogas CHP can be fed to the municipal district heating network.		
	Local networks and new businesses can be created around biogas increasing also energy efficiency of the solutions (e.g., woodchip drying plant utilizing excess heat)		

4.2. Drivers and barriers for advanced thermochemical conversion processes in rural areas

	Drivers	Ambivalent factors	Barriers
Demographic		*New value chains create employment and have a positive economic impact in the community, but acquiring enough trained workers for operation and maintenance can be a challenge in rural areas*	
Economic	*Utilizing innovative technologies, such as advanced thermochemical processes, allows for the profitable use of biomass that might not have another market, such as biowaste from municipalities, industrial processes, or low-quality logs, including large-sized chips. Furthermore, employing these novel technologies for biomass treatment can offer cost savings and result in reduced CO_2 emissions compared to traditional methods of biomass disposal*	*The profitability of the investment is impacted by the currently high cost of fossil energy, with ongoing price uncertainty*	
	In some countries, the investment in a thermochemical treatment unit (e.g., gasification) can be made more affordable through support from rural development and next-generation funds. Dedicated financing programs and support measures are available for such investments although in some cases, there may be no need for additional investment funds	*Supply and transport cost(s) of the feedstock can play a key role to determine the feasibility of an initiative*	
	The investments contribute to energy self-sufficiency of the selected region	*Securing a raw material supply can be challenging due to competing uses. However, in some cases, feedstock availability is abundant, and raw material sourcing and refinement can occur on-site*	

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	Company can use potential strategies for optimizing feedstock utilization and reducing storage capacity	*Additional value can be created from side-streams or by-products, leading to various income sources beyond the primary product, including gate fees, generated heat, steam, hot water, and extracted chemicals from process water. In some cases, the profitability of production may rely on these additional income sources driven by market demand. However, these supplementary income sources may also face competition from established production routes*	
		Markets for some of the biobased products for thermochemical processes (such as torrefied biomass and biochar) are not established, however, in case a market exists, the value of the product can be high	
Policy & legislation	*Air emission limits promote uptake of new innovative technologies where these particles can be minimized*	*There is a long regulatory road to production and/or use for some of the new biobased products and by-products. The environmental advantages of the product needs to be understood and proven (e.g., certification, LCA calculations) after which supporting policies need to be enforced*	*Unclear categorisation of the new activity, facility, product and by-products when obtaining the environmental and construction licences can pose a barrier for implementation*
			Clear framework or standardization of biochar as product lacking, adopter might have to get a permit as waste manager to handle it
Ecological	*The product (bio-oil) can substitute fossil-based fuels (light and heavy fuel oil, gas) in industrial and municipal heat and electricity production*		
	Utilizing bio-based feedstock can mitigate environmental issues associated with the status quo, including fire risk, pollution, methane emissions, inefficiency, and ineffective composting		

	Utilizing local, sustainable raw materials in biochar production avoids the need for imported alternatives like charcoal and peat, which may not be sustainably sourced		
	Biochar can be used in many different applications (e.g., in soil improvement of highly degraded and infertile lands, water management, replacing fossil fuels in heating/transportation fuels, carbon sequestration)		
	The use of local wood in advanced thermochemical processes promotes an active management of the local forests		
	Biochar production not only contributes to CO2 sequestration and reduced emissions by replacing fossil alternatives but also offers a higher energy output from biomass compared to other biomass-based energy production methods		
Socio-cultural	*Local communities are generally more receptive to new industrial processes when those processes involve renewable resources, circular practices, and contribute to decarbonization and sustainability*		*Previous bad references and the absence of existing full-scale facilities can hinder replicability potential and investment interest in new technology. Sometimes, a decisive attitude and manager's interest are necessary to drive transformation*
	Production of innovative bio-based products, such as biochar or bio-oil, provides support to local businesses in forestry and agriculture while contributing to the development of rural bioeconomies through local or regional sourcing of raw materials		
	General knowledge of biochar and its benefits may be poor		

Technological	*Modularity of the technology makes it possible to adapt the solution based on the project needs*	*Innovative technologies must undergo piloting, demonstration, and scaling up to an industrial level before they can be widely adopted in the market. For example, processes like olive cake gasification, biomass torrefaction, and hydrothermal carbonization have been successfully demonstrated but now require scaling up for production*	*Depending of the country, of the possibly useful technologies lack of national providers and technological facilitators*
	Local or regional utilization of generated process heat is possible, such as selling it externally or using it for drying raw materials, to improve their quality		
	Efficient and user-friendly technologies are readily available for replication		
	Advanced thermochemical processes (pyrolysis, gasification, and hydrothermal carbonization) can exploit variety of raw materials		
	Advanced thermochemical processes enable the removal of unwanted inorganic elements from raw materials, opening up new potential uses for the material		

4.3. Drivers and barriers for hybrid and farm-scale bioenergy solutions in rural areas

	Drivers	Ambivalent factors	Barriers
Demographic			
Economic	*Investments in multiform renewable energy production methods, such as solar PV and wood gasification, enhance farm self-sufficiency and reduce reliance on grid energy prices*		*Subsidies are often the requirement for a farm-scale investment*
	On-site energy production using farm feedstock or renewables can generate additional income and savings for the farm, including selling excess electricity and reducing transmission costs		
	Profitability and losses of a hybrid solution can be optimized with flexible use of different operating modes		
	Technologies can prevent material losses by utilizing residues and drying biomass, leading to more efficient biomass utilization processes		
Policy & legislation		*Although climate policies favour production and use of biomass-based energy in some countries, uncertainties related to future legislation (e.g., sustainable energy sources, required materials) may prevent the use of certain technologies*	
Ecological	*Hybrid and farm-scale solutions promote the use of sustainable, locally-sourced fuels, reducing reliance on GHG-emitting fossil fuels for heat and power generation*		

Socio-cultural	*Operating in a sustainable manner can be beneficial for a local producer from image perspective.*	*The farmer's personal interest and motivation to enhance the farm's energy self-sufficiency can play a crucial role in promoting the adoption of new energy solutions on farms. Conversely, when personal interest is lacking, the uptake of these solutions may face greater challenge*	
	Concepts suitable for rural areas benefit the local economies in various ways (e.g., increase self-sufficiency of energy, local employment in raw material sourcing)		
Technological	*Farms can act as a small-scale source of energy system flexibility by operating during the times when a lot of cheap electricity (e.g., wind, solar) is available, since they naturally can have the electricity requirement during these times (e.g., need to freeze berries/fruits during the summer) or they can shift operations (e.g., solid fuel drying)*	*Some promising technologies need commercialization before wider adoption, while others may not be user-friendly enough for the target group, despite some being quite automated*	*Although the technology (gasification in this case) is effective, it requires homogeneous and dry fuel*
	Utilizing solar energy to enhance the heat value and quality of solid fuels through drying is beneficial for fuel management	*In some cases, the profitability of primary production (electricity) depends on value generated from additional by-products, like heat*	
	Technologies can be modular and enable on-site scaling		

4.4. Drivers and barriers for heat (cascading) technologies in rural areas

	Drivers	Ambivalent factors	Barriers
Demographic		*Workforce availability in rural regions can be challenging, even though some technologies do not require specific skills*	
Economic	*Available financial support mechanisms can enable wider uptake of equipment/facilities that enable decarbonisation, although depending on the technology, the investment cost can be low*	*The investment cost of renewable technologies may be high, but the increase of prices in fossil fuels makes the investments more profitable*	*Seasonal variability in the feedstock supply might be a challenge locally*
	The technology enables cost-effective creation of additional value from waste/biomass streams, such as energy generation, accelerated yield rates and/or improved fertilization		
Policy & legislation	*The promotion of decarbonization strategies is supported by policies in many countries*		
	In some cases, the technology itself may not entail any legal requirements, permits, or other regulatory obligations		
Ecological	*GHG emissions in rural communities can be reduced by replacing fossil-based energy sources with biomass-based alternatives*		*If the process operates improperly (composting), it has the potential to contribute to an elevation in greenhouse gas emissions*
Socio-cultural	*Social acceptance promotes the renewable technology uptake*		*Societal attitudes may reduce interest in investment when the technology is disruptive or lacks successful examples*
Technological	*The technology promotes renewable energy use, energy efficiency and efficient use of resources*	*The technological solution can be relatively simple, but it may necessitate specific site-specific pre-conditions*	*The technology's feasibility is influenced by the scale of its application, whether it's small-scale or industrial. This connection can create usability challenges when the chosen scale doesn't align with the technology's capabilities*
			The technology may require additional manual work in comparison to status quo

4.5. Drivers and barriers for bioeconomy solutions in rural communities

	Drivers	Ambivalent factors	Barriers
Demographic	*Efficient and modern energy system based on local renewable energy production can improve local air quality and decrease the amount of diseases of the upper respiratory tract promoting overall well-being of the local population*	*Structural changes in agricultural production can pose challenges in sourcing specific commodities like feedstock for certain bioenergy processes. However, innovative bioeconomy technologies have the potential to generate new income sources in regions undergoing such changes*	*The expansion of innovative technology can face limitations driven by demographic factors, such as a limited number of potential consumers for district heating or an underdeveloped transportation network for innovative products. These demographic characteristics act as barriers to the technology's broader adoption and growth*
	The development of rural communities plays an important role in demographic trends. As these communities become more modern and attractive, they may experience an increase in population, which contributes to the growth and vitality of the region		
	Engaging subcontractors in the feedstock procurement process contributes positively to local employment opportunities		
Economic	*The municipal energy independency reduces the effect of fluctuating global energy prices on the local energy price*	*Developing energy-independent municipalities creates additional income sources, such as profits for local farmers and cost reduction through the use of residual biomass. However, it may also lead to additional obligations and costs for local residents*	*Increasing costs of production (energy, labour etc.) can be a barrier for local business as they can impact the profitability and competitiveness of businesses*

	Local accessibility to various bio-based feedstock and the presence of local markets can facilitate the development of specific circular business ecosystems, creating new income opportunities for local residents. For example, the availability of residue wood and SRF, agricultural residues and side-streams, abundant forests and orchards, and cultivated meadow grass can all contribute to these opportunities	*Wood energy is a cost-effective way of heating in Finland, however, there is competition in wood fuels, driven by both energy and forest industries*	
	Economic growth can increase the local demand for combined heat and power (CHP) production, potentially creating new business opportunities for biomass-fired plants that have been in operation for decades and encouraging their retrofitting	*Sometimes exploiting all the residues (e.g., heat) of a local energy business is challenging, but can create new businesses*	
Policy & legislation		*Existence/lack of supporting climate policies (e.g., using woody biomass for energy purposes) can promote or hinder bioenergy production and use. In addition, uncertainties related to future legislation (e.g., sustainable energy sources, required materials) may prevent the use of certain technologies*	*Volatile feed-in tariffs for electricity supplied to the grid affects profitability of rural/local electricity production*
		The categorization of new activities, facilities, products, and by-products can promote or restrict their potential uses. For instance, legislation can complicate the reuse of bottom ash and fertilizer in agriculture	
Ecological	*Modern renewable energy production exploiting new technologies (e.g, filters) improve local air quality and reduce greenhouse gas emissions*	*Bioenergy production serves as a valuable outlet for sustainable biomass resources that might otherwise go to waste*	*Practicing sustainable forestry, such as preventing erosion through careful and conservative management of mountain forests, may result in higher supply costs*

	The potential to establish closed production chains (e.g., converting waste into fuel and residues into fertilizers) can serve as a driver in the development of local renewable energy systems and promote circular economy principles		
	Intensified forest management due to local forest industry augments the share of young and vital stands that are more resistant to pests and pathogens and store more CO2 during the biomass accumulation phase		
Socio-cultural	*New trends can lead to new business ideas for a local producer (e.g., construction and operation of an own charging station)*	*Modern district heating system is convenient for municipality residents and in general decreases concerns related to heating. However, worries exist related to possible fault situations due to dependence in central system*	
	The applied practices support regional farmers, local businesses and economies in forestry and agriculture thus promoting social acceptance	*The public opinion and mentality is often divided when municipality's energy system is established. On the other hand environmental awareness of citizens is rising but the mentality might be against collective/central energy production and distribution. Thus, it is important to obtain broad consensus for the goal in advance*	
		In the context of new bio-based products, there may be a high level of social acceptance, even though consumers may not be willing to pay extra for environmentally friendly products	
Technological	*The resulting product can be used to substitute fossil-based counterparts*	*Investing to new technical solutions can be costly itself but often require also employee training or external services as highly-trained personnel is not often available in rural areas. On the other hand, some of the plants are highly automated and can operate unmanned*	

	While the technology already offers environmental benefits, there is room for further development to enhance efficiency and maximize its utilization potential	*Although technologies needed for establishing a local bioeconomy might be mature and widely available on the market, they may be out of reach for smaller entrepreneurs or risk-averse businesses due to a high investment cost*	

5. Summary and final conclusions

This report presents the findings concerning the implementation of bioenergy and bioeconomy technologies in rural areas as explored in the BRANCHES project. This Chapter provides a summary of the key analysis highlights, addressing the demographic, economic, political and legal, ecological, socio-cultural, and technological drivers and barriers.

From demographic perspective, new bio-based value chains create employment and have a positive economic impact in the rural communities. As these communities become more modern and attractive, they may experience an increase in population, which contributes to the growth and vitality of the region. However, at least at first, acquiring enough trained workers for operation and maintenance of the new technologies can be a challenge. Also, the expansion of innovative technology can face limitations driven by demographic factors, such as a limited number of potential consumers for district heating or an underdeveloped transportation network for innovative products. These demographic characteristics can act as barriers to the technology's broader adoption and growth. In addition, structural changes in agricultural production can pose challenges in sourcing specific commodities like feedstock for certain processes. However, innovative bioeconomy technologies have the potential to generate new income sources for regions undergoing such changes.

As said, rural bioenergy production and bioeconomy solutions can create employment and hence foster economic growth in rural areas. For instance, farmers can obtain new sources of income and cost savings by supplying feedstock and being involved in raw material sourcing, and by producing electricity, heat and/or transportation fuels. In addition, using local biomass sources promotes energy independence in both farm-level and in rural communities, hence reducing reliance on imported fossil fuels and volatile energy markets. At the moment, the cost of fossil energy is high, which has a positive impact on the profitability of a bioenergy investments. However, despite that, investment costs for bioenergy production can be high. Financial support schemes and investment programs for these investments are often vital and can encourage wider adoption of rural bioenergy technologies.

Besides the primary product of a bio-based investment, such as electricity, biochar or bio-oil, additional value can be created from side-streams or by-products of the production process, leading to various income sources beyond the primary product. These income sources can include gate fees for processed side- and waste streams, generated heat, steam or hot water, and extracted chemicals from process water. In some cases, the profitability of the primary production may rely on these additional income sources.

Due to the high investment costs of bioenergy and bioeconomy technologies, available financial support mechanisms can facilitate and enable wider uptake of these technologies. However, the absence, as well as the complexity, of long-term financial support schemes can hinder investments on bioenergy and bioeconomy. Moreover, although climate policies favour production and use of bio-based products in many countries, uncertainties linked to future legislation may pose restraining barriers for new investments. For instance, unclear categorisation of the new activity, facility, feedstock, product or by-products when obtaining the environmental and construction licences can pose a barrier for implementation. Furthermore, certain new bioeconomy solutions may encounter extended regulatory processes before they can be applied. One approach to address this challenge is to establish and verify the environmental benefits of feedstock and products through methods such as certification or life cycles assessments, followed by the enforcement of supportive policies.

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Bioenergy and bioeconomy solutions provide ecological benefits and reduction of carbon footprint throughout the rural value chains (farmers, cooperatives, communities, companies). For instance, greenhouse gas emission can be reduced by replacing fossil-based fuels with locally sourced sustainable alternatives in heat, power and transportation fuel production. Harnessing value from agricultural waste and side products has also positive impacts on rural waste management as the new technologies serve as a valuable outlet for sustainable biomass that might otherwise go to waste. Utilizing bio-based sources as a feedstock can mitigate environmental issues associated with the status quo, including fire risk and problems related to landfilling, such as methane emissions.

Local communities are generally more receptive to new technologies and processes when those processes involve renewable resources, circular practices, and contribute to decarbonization and sustainability. In addition, operating in a sustainable manner, such as by valorising waste streams into energy or using renewable energy as a fuel, can be beneficial for a local producer or a company from image perspective. However, societal attitudes may reduce interest in investment when the technology is disruptive or lacks successful examples. Previous bad references and the absence of existing full-scale facilities can hinder replicability potential and investment interest in new technology. Yet, an important factor in promoting social acceptance is that the concept suitable for rural region can benefit the local community members in various ways, such as by boosting local employment in raw material sourcing or in the plant operations.

Various innovative bioenergy processes offer flexibility in utilizing a range of raw materials, including agricultural by products and waste streams. The modular nature of these technologies also serve as a catalyst for their adoption, allowing for customization based on specific project requirements and on-site scalability. However, there are instances where the required scale does not align with the technology’s capabilities. In addition, in many cases involving innovative technologies, a phase of piloting and demonstration is needed before widespread market adoption can take place. Even when technologies promoting local bioeconomy are mature and readily available, they may be out of reach for smaller entrepreneurs or risk-averse businesses due to a high investment cost.

While successful examples for technologies utilizing biomass feedstock as a raw material exists, ongoing research and development efforts are essential to advance the bioenergy and bioeconomy technologies. These efforts are important to address technological challenges such as maturity, scalability and cost-efficiency, ultimately fostering growth in this field.

A variety of successful bioenergy and bioeconomy examples adopted in rural regions have already been established. The BRANHCES project has collected a comprehensive database comprising a diverse combination of available and innovative bioenergy and bioeconomy solutions. These examples are readily accessible via BRANCHES project webpage.