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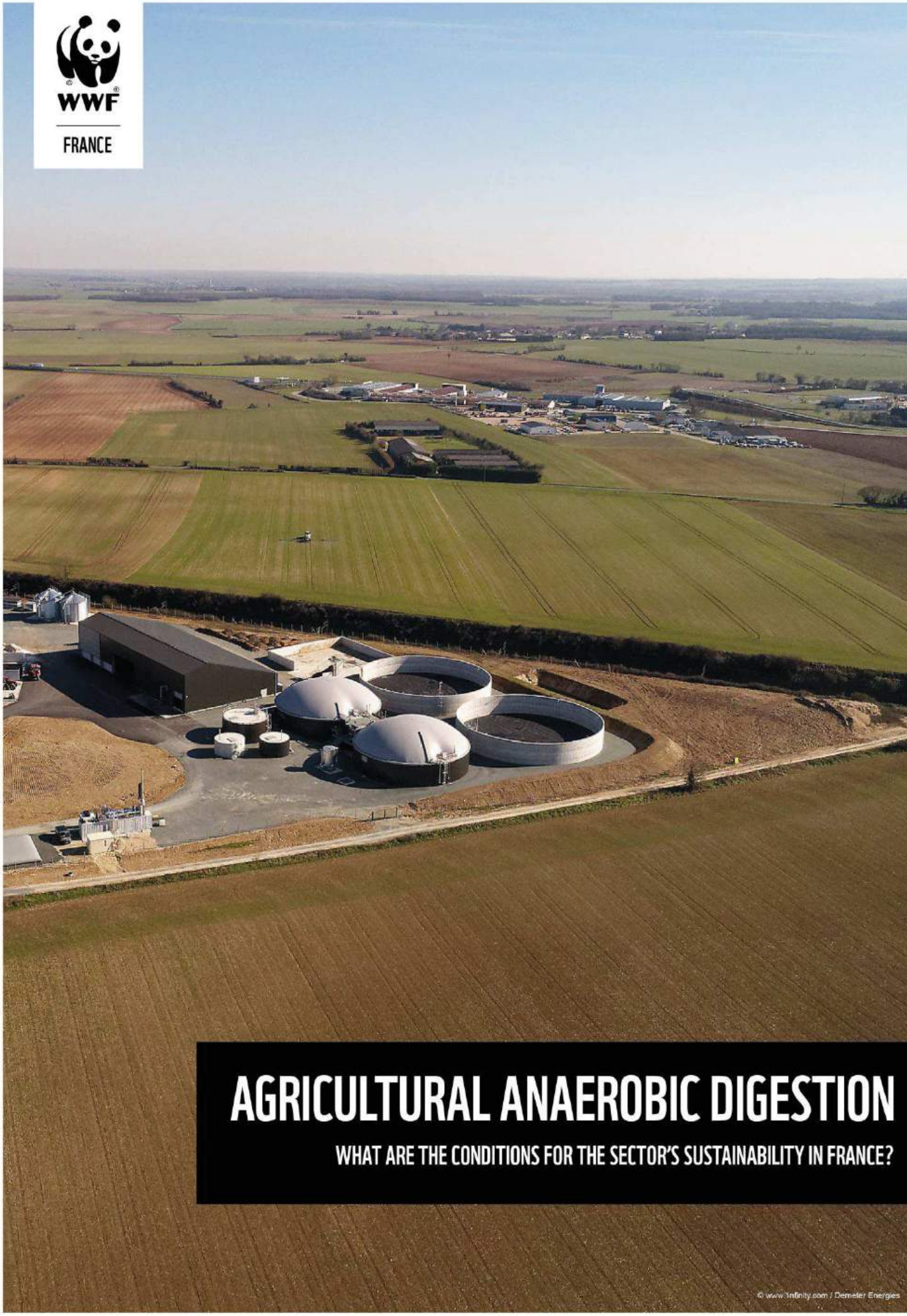

AGRICULTURAL ANAEROBIC DIGESTION

WHAT ARE THE CONDITIONS FOR THE SECTOR'S SUSTAINABILITY IN FRANCE?

WWF

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The document "**Agricultural anaerobic digestion: what are the conditions for the sector's sustainability in France?**" was produced through a collaborative process conducted jointly by WWF France and GRDF.

We would like to thank everyone who has contributed, taken part or shown an interest in this approach and agreed to share their experience throughout the process presented in this document. The series of workshops organised with GRDF on the conditions for sustainability in agricultural anaerobic digestion would not have been possible without their practical and technical knowledge. We are particularly grateful to the contributors who have proofread the document and cast a critical eye over its contents.

Finally, we want to thank the teams at GRDF, WWF France's partner, for their active help in preparing this document.

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EDITORIAL

Developing renewable energy while contributing to sustainable agricultural production systems – that's the challenge of anaerobic digestion. Currently the most mature source of renewable gas, it seems to provide responses to many different priorities since it emerged in France in the 1970s. Supported by the potential of agricultural biomass (livestock effluent, crop residues, etc.), it contributes to the development of the bioeconomy, which is now seen as a solution for decarbonising the economy and preserving biodiversity.

Like many solutions that aim to contribute to the ecological and solidarity transition, agricultural anaerobic digestion relies on industrial infrastructure that is faced with major issues of environmental and territorial integration. Incorporating it into food production methods can affect how they work in a variety of ways. Given the importance of the agroecological transition on which our resilience and our future food security partly depends, anaerobic digestion has to be compatible with the principles of agroecology. This is why WWF France, in partnership with GRDF, decided to take a closer look at the conditions for the sector to contribute to sustainable development and respond to major environmental, agronomic and energy challenges.

Future energy and agricultural scenarios that focus on containing global warming within 1.5°C rely on the large-scale use of agricultural biomass to expand anaerobic digestion. This document aims to highlight the conditions in which anaerobic digestion can provide leverage for the agroecological transition in our production systems. Though it currently appears to promise better nitrogen management on farms and an opportunity to limit climate change through carbon storage, the overall impact of the changes in practice induced by agricultural anaerobic digestion is not known. This document proposes to review the current state of scientific knowledge and identify areas where more research is needed to provide the answers. Areas that require particular attention include the effects on soil biodiversity and adaptation to different soil and climate conditions, the source of France's agricultural wealth.

Arising from a year's collaborative work with various stakeholders from across the industry, the sustainability framework presented here lays the foundations for a debate about how biomass can be mobilised to develop sustainable anaerobic digestion.

It makes no claims to be exhaustive, but aims to help project coordinators, decision-makers and local authorities by highlighting new research topics and identifying needs. The ultimate goal is to promote the widespread adoption of practices that will make anaerobic digestion a virtuous sector.

Véronique Andrieux, Chief Executive of WWF France

FOREWORD

In 2018 and 2019, WWF France and GRDF, as part of their partnership on the sustainability of the agricultural anaerobic digestion sector in France, organised a consultation of the sector's stakeholders. The aim of this process was to identify a sustainability framework that could be used by the various stakeholders in the agricultural and energy sectors. At the same time, this work was meant to determine whether the sector was compatible with the agro-ecological transition.

In pratical terms, the work took the form of:

- A preliminary study to understand the current challenges of agricultural anaerobic digestion in France, through bibliographic research and individual interviews ;
- A series of workshops bringing together stakeholders in the sector (public authorities, research institutes, representatives of the biogas sector, representatives of the agricultural community, associations), with whom the issues addressed were framed and prioritised for further work
  - The drafting of a report presenting
  - The sustainability framework resulting from this work
  - The consistency of certain practices (intermediate crops and digestates spreading) with this framework on the basis of the state of the art at the time of writing
  - Recommendations for the development of the sector to be compatible with the agro-ecological transition.

The conclusions drawn from various research studies or discussions with stakeholders in the sector are specific to the French agricultural and energy context from an agricultural, energy and regulatory point of view. Our results are therefore not exportable to other contexts.

While the methodology used in this work may be a source of inspiration for countries wishing to undertake similar approaches, it must be based on data from these countries and assessed in the light of the organisation of the sector in these countries.

This document proposes, at the end of a joint process with GRDF, a common and shared vision, with the actors who participated in our process, of the overall conditions in which the methanisation sector can develop in a sustainable manner in France. The reader should also take into account the following areas of attention:

- The work carried out is intended to provide guidelines and recommendations at the national level. It does not take into account the territorial specificities of the French agricultural and energy landscapes; the work carried out in 2018 and 2019 is now being pursued within the framework of coalitions of stakeholders at the territorial level;
- The work carried out focuses on the agricultural angle of methanisation, targeting its environmental issues first and foremost, although social and economic issues have been integrated into the reflection; no discrimination of the size of projects has been taken into account in the analysis;
- The work carried out on the accounting of practices focuses primarily on the issues prioritised by the stakeholders, linked to the return of digestate to the soil and intermediate crops for energy purposes, without looking in depth at the mobilisation of dedicated crops or the problems identified with the mixing of inputs (with slurry, manure, green waste, etc.).

SUMMARY

In its vision for a future world with greater respect for the environment, France is now **betting on the bioeconomy**. As well as reducing its dependence on fossil fuel resources, the sustainable use of biomass presents an opportunity for the country to achieve the climate goals adopted at COP21.

Recent uses of biomass resources include agricultural anaerobic digestion, which has developed strongly due to its potential as a means of decarbonising the energy sector. As with any solution that can contribute to the ecological and solidarity transition, special attention must be paid to the conditions for its sustainable development. Specifically, because of its integration into agricultural production systems, the sector's compatibility with the agroecological transition is an essential condition for this sustainability.

Arising from a year's collaborative work with various stakeholders in the industry, **this publication proposes a definition of sustainability in agricultural anaerobic digestion** that is intended to serve as a basis for consideration of how to manage agricultural anaerobic digestion projects and, at a more macroscopic level, for the development of public policy. The definition encompasses three conditions:

- **The implementation of agroecological practices at the level of both individual parcels and whole farms**: production systems that incorporate agricultural anaerobic digestion must be tailored to an area’s specific soil and climate conditions. They must preserve natural resources (soil, water, air and biodiversity), as well as ensuring fair additional revenue for the farmer;
- **Territorial integration of projects**: with their eminently local character, involving multiple stakeholders and priorities, anaerobic digestion projects need to consider local provision of biomass and competition between different uses, local governance, societal ownership and the creation of shared local value;
- **The scalability required to address global societal challenges**, helping to achieve national targets in terms of greenhouse gas emission reductions and the resilience of agricultural systems.

The series of workshops organised by WWF France and GRDF in 2019 sought to identify the degree to which two issues identified as priorities by the sector from an agricultural viewpoint - namely the **management of intermediate energy crops and the return of digestates to the soil** - are compatible with this sustainability framework. Knowledge and mastery of these practices, which represent a shift away from current production methods, is still partial. However, national and local research projects as well as field experience have provided insights into their benefits for the agricultural system and identified the conditions under which they can be optimised from an environmental viewpoint. **Both these practices can thus align with certain principles of the agroecological transition.**

These practices are still recent, and a need for more detailed analysis has been identified, particularly with regard to their impact on biodiversity and their adaptation to each area’s specific soil and climate conditions. **Continued research and experimentation** are thus essential to clarify and develop scientific knowledge and practices suited to local contexts. The sector will then be able to draw on a **common operational framework** that promotes compliance with the sustainability conditions. To support the implementation of such a framework, **agricultural and energy policies must be aligned with each other.**

Achieving the deployment goals underlined by the prospective scenarios for 2030 and 2050 will require stakeholders' **skills to be developed.** By strengthening professional development and the spread of existing knowledge, the sector will be able to ensure

greater integration of its sustainability issues and best practices at national, regional and local levels.

Territorial integration of projects is also identified as a key to the success of these projects. By involving all the direct and indirect stakeholders, anaerobic digestion helps to strengthen links within local areas, recover waste locally, create local jobs that cannot be offshored and create economic value that stays in the area.

This publication aims to initiate the development of a common core of knowledge within the sector, building on existing tools and based on a shared vision of the conditions for sustainability in the development of agricultural anaerobic digestion and its associated practices.

INTRODUCTION

Agricultural anaerobic digestion, where the energy and agricultural transitions meet

To ensure the long-term viability of our societies, preserving the climate and biodiversity are crucial challenges across the globe. The Intergovernmental Panel on Climate Change (IPCC) regularly sounds the alarm about the speed with which climate change is occurring and the inevitable consequences. The Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services[1] (IPBES) published a report in 2019[2] that underlined the urgent need for action to address accelerated biodiversity erosion.

How can we respond to these challenges? One of the primary levers is for various sectors of activity to transition towards a more sustainable model. France has responded to the international effort by setting a number of targets. The 8 November 2019 Energy and Climate Act[3] enshrines carbon neutrality and the urgency of environmental and climate action in law. Forthcoming international gatherings in 2020, such as the UN Biodiversity Conference (COP15) in October, are key opportunities to strengthen the commitment of countries and the business world to addressing these issues.

The pressure on resources, ecosystems and the climate from power generation and agriculture make these two sectors priorities for the transition[4]. From an agricultural perspective, several potential future scenarios for agriculture and food production have been developed[5], revealing possible pathways towards more sustainable food and agriculture models in France. One lever for this transformation is agroecology, which aims to enable farms to combine economic and environmental performance with social benefits. This avenue is now essential for a sector facing significant challenges – food security and sovereignty, impact on the environment and human health, contribution and adaptation to climate change, fair pay for farmers, attractiveness of farming etc. From an energy perspective, though energy savings and efficiency remain the priorities of the energy transition, developing sources of renewable energy is equally essential. Anaerobic digestion is one of these sources, and its key feature is its integration into agricultural production systems through the materials it digests and then returns to the soil.

Opportunities for developing anaerobic digestion in France

Anaerobic digestion is not a new process in France. However, its development was eased by the National Renewable Energy Action Plan (*Plan national d'action en faveur des énergies renouvelables*) in 2010. This was followed in 2013 by the Energy, Anaerobic Digestion and Nitrogen Autonomy plan (*Plan Energie Méthanisation Autonomie Azote*, EMAA), which aims to increase France's nitrogen autonomy and resolve problems such as green algae in Brittany.

[1] Millennium Ecosystem Assessment (2005). The benefits (tangible or intangible) people obtain from ecosystems
[2] IPBES (2019). Global Assessment Report on Biodiversity and Ecosystem Services
[3] French law no. 2019-1147 of 8 November 2019 on energy and climate
[4] Department of the Commissioner-General for Sustainable Development (*Commissariat Général au Développement Durable*) Datalab Climate (2019): energy use is the primary source of GHG emissions in France (70.3%), followed by agriculture (16.7%)
[5] Afterres 2050–Solagro (2016), ADEME's Energy and Climate Scenario for Agriculture (*Scénario Energie-Climate pour l'agriculture*) (2018) and the French Agriculture and Food Ministry's application of the national low-carbon strategy to the agricultural sector

The 2015 Energy Transition for Green Growth Act (*Loi de Transition Energétique pour la Croissance Verte*) set a 10% target for renewable gas from all sources as a proportion of gas consumption in 2030. This target was renewed in the 2019 Energy and Climate Act (*Loi Energie Climat*). Forward-looking work has sought to determine the potential for renewable gas production by 2030 and 2050 and its technical feasibility. Depending on the breakdown of biomass consumption by different sectors of the bioeconomy, this potential could – under certain conditions – cover 100%[6] of final gas demand by 2050, with one third coming from anaerobic digestion. The hypotheses underlying these scenarios are a determining factor in the sustainability of the anaerobic digestion sector, which requires plentiful supplies of agricultural biomass. The widespread adoption of intermediate energy crops, the use of agricultural residues and waste or the gradual replacement of chemical fertilisers with digestates could all have a transformative effect on current agricultural systems.

In practice, the country had nearly 700 anaerobic digestion units in 2018, with 442 of them using agricultural resources[7]. Applications to build new projects are rising fast[8]. This growing number of installations in operation or in construction is enabled by a framework of financial support based on renewable energy generation. The model of anaerobic digestion with biogas injection into the gas grid[9] is gradually taking its place alongside the historic model of anaerobic digestion with co-generation integrated into livestock systems. It is currently the model showing the strongest growth in terms of installed power, making significant use of intermediate energy crops. The initial goal of reusing agricultural waste and co-products has thus been supplemented, or even replaced, by the goal of generating energy[10]. This shift, together with high production costs and competitiveness constraints, could overshadow the agronomic benefits associated with introducing anaerobic digestion into agricultural systems. Regulatory changes such as France's Multi-Annual Energy Plan (*Programmation Pluriannuelle de l'Energie or PPE*) suggest that there will be less support for the sector and economic conditions will become more difficult. These signs are likely to call the sector's compatibility with the agroecological transition into question by limiting its development to the most profitable projects.

As with any solution that can contribute to the ecological and solidarity transition, special attention must be paid to the conditions for agricultural anaerobic digestion to be developed sustainably. The sector's development must contribute effectively to the transition towards a model of agroecological production that is economically viable in the long term while improving environmental performance. This has been the ambition of the partnership between WWF France and GRDF. They formed a working group involving a variety of stakeholders to propose an approach to defining sustainable terms for the anaerobic digestion sector.

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[6] ADEME (2018). A 100% renewable gas mix in 2050?
[7] SINOE (2018)
[8] GRDF (2019). 759 projects were pending, representing reserved capacity of 16.1 TWh
[9] This model is based on heavier use of both intermediate crops and dedicated energy crops
[10] ADEME (2016). *Opinion on anaerobic digestion*: "Due to better energy performance, ADEME recommends injecting biomethane into the natural gas network when possible"

A PARTICIPATORY APPROACH

What conditions will enable anaerobic digestion to contribute to both the energy transition and the agricultural transition? How can it generate renewable energy while also increasing the autonomy of agricultural production systems and preserving ecosystems?

To help answer these questions, WWF France and GRDF brought together research institutes, farming and biomethane representatives, institutions and associations working for the environment or active in the field of renewable energy. The contributors worked together to consider:
- the conditions that will ensure agricultural anaerobic digestion is developed sustainably;
- practices compatible with these conditions;
- and the resources and guidelines needed for these conditions and practices to be rolled out and adopted widely.

This work took the form of a series of four workshops between December 2018 and October 2019.

… To identify the priorities for the sector's sustainability

Defining the sustainability of an activity involves examining its contribution to the three priorities of sustainable development: maintaining a liveable environment, economic and social development and fair social organisation. The working group considered all three of these dimensions.

During the first workshop (view the summary here), the participants were asked to identify environmental, economic or societal issues likely to challenge anaerobic digestion's compatibility with a sustainable agricultural model (see box):

Societal challenges

- Societal ownership of anaerobic digestion units by neighbours and citizens (acceptance, impact on nearby residents, changes to landscapes etc.)
- Competition for biomass resources (food, energy etc.) and changes in land use
- Joined-up public policy (energy, agriculture, waste)
- Assistance in changing agricultural practices
- Anaerobic digestion's compatibility with virtuous agricultural models, and especially organic agriculture

Environmemental challenges

- Contribution to climate change (greenhouse gas emissions from the sector, carbon storage in the soil)
- Impact of anaerobic digestion and associated agricultural practices on biodiversity and water, air and soil
- Development of intercropping for energy use and returning digestates to the soil (agronomic benefits and impact on natural environments, carbon storage in the soil and biodiversity)

Economic challenges

- Economic balance of anaerobic digestion units as support mechanisms evolve over time
- Highlighting the sector's positive externalities
- Impact of changes in the energy markets on agricultural markets

Figure 1. Principal sustainability challenges of agricultural anaerobic digestion identified during the first workshop

A sustainable agricultural model ?

A set of agricultural systems and practices with the common goal of :
- Ensuring the quality of terrestrial and aquatic habitats and protecting soil quality, organic content and fertility ;
- Protecting or developing existing biodiversity ;
- Guaranteeing food security ;
- Enabling fair, sustainable rewards for farmers.

This work led to a shared vision of the conditions for the sector's sustainability (see the section "Conditions for the sustainability of agricultural anaerobic digestion").

… To share scientific knowledge and agricultural practices

Among the environmental issues raised, intermediate energy crops[11] and returning digestates to the soil[12] emerged as having a major role in the sector's sustainability. As a result, the decision was taken to devote a workshop to each of these issues. The workshops aimed to review scientific knowledge about the environmental impacts of these practices and share field experience (*see the section "intermediate energy crops and digestate recovery: how do they respond to the sustainability conditions?"*).

Each workshop took place in three stages:

1. Presentations by scientific experts to share the results of research work and consolidate a common framework of knowledge
2. Sharing feedback highlighting sustainable agricultural practices and the benefits observed at the level of individual farms
3. Work session to identify remaining questions and prioritise the work needed to answer them

… To formulate recommendations on scaling up

A fourth workshop examined the resources and roles that would be needed for the sustainability conditions and sustainable agricultural practices shared throughout the series of workshops to be propagated, adopted and implemented. It highlighted recommendations to ensure a sustainable model of anaerobic digestion can be scaled up successfully (*see the section "Priorities and recommendations for scaling up anaerobic digestion"*). Scaling up is taken to mean establishing the sector on a large enough scale to meet the targets for its development and for renewable gas production in France.

This publication summarises the most important lessons learned from this participatory approach.

Note for readers

The developments presented in this document apply to **anaerobic digestion**. As defined by France's Rural and Marine Fishing Code[13], this refers to units processing material sourced primarily from farms and majority-owned by farmers.

The analysis does not discriminate on the basis of project size or feedstock mixture, and the document presents the subjects identified by the working group as the highest priorities. Certain issues are not covered, such as the use of dedicated crops or problems with particular feedstock mixtures.

This document does not constitute WWF France's position on agricultural anaerobic digestion. Based on a programme conducted jointly with GRDF, it presents the conditions for the sector's sustainability and recommendations on how they should be communicated to the stakeholders concerned, as identified by the organisations that contributed to the workshops.

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[11] Read the summary of the workshop on intermediate energy crops here

[12] Read the summary of the workshop on digestates here

[13] Articles L.311-1 and D.311-18

CONDITIONS FOR THE SUSTAINABILITY OF AGRICULTURAL ANAEROBIC DIGESTION

At the point where the energy and agricultural transitions meet, the development of agricultural anaerobic digestion must contribute to resolving the interwoven economic, environmental and social challenges of these two transitions. A year's collaborative work with various stakeholders in the industry has led ***to a proposed definition of sustainability in agricultural anaerobic digestion****. The definition involves* ***three conditions*** *and takes an integrated approach at several levels: the individual farm, the territory and the national or global scale.*

First condition: Encouraging the use of agroecological practices at farm level

Agroecology is an approach to designing production systems based on the functions offered by ecosystems[14]. It seeks to amplify these functions while reducing pressures on the environment and preserving natural resources. It involves a set of techniques that help to **make the farm less dependent on external inputs** (pesticides, fertilisers, irrigation water etc.), **more economically sustainable and more environmentally friendly.** Care must therefore be taken to ensure that the agricultural practices introduced by anaerobic digestion, including supplying digesters with biomass and using digestates for agronomic purposes, contribute to both environmental and economic performance.

In environmental terms, these practices must **help to maintain or improve:**

- The regulation of elements that are essential for plant growth or habitat preservation: carbon (C), nitrogen (N) and phosphorus (P);
- The biological activity of the soil, to guarantee its function and maintain its fertility;
- The physical soil fertility (structure and porosity) essential for effective water circulation, solid plant rooting and the maintenance of aerobic conditions[15] in the soil;
- Chemical soil fertility, including the chemical properties of soil needed for plants to grow;
- Water, air and soil quality;
- Biodiversity in the agricultural environment.

Adapting these practices to suit local soil and climate conditions and diversifying crop rotations are key elements in ensuring farms' autonomy and maximising these services.

In economic terms, integrating anaerobic digestion into production systems must represent an **opportunity to increase the farm's autonomy by reducing its dependence on inputs and energy and its costs**. As well as this cost reduction, agricultural anaerobic digestion must provide a new source of revenue for the farmer, who can use the renewable energy generated or sell it. The sector must take care that this additional revenue both **improves the farmer's quality of life and finances the farm's transition towards agroecology** while also giving the farm a more robust foundation for the long term.

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[14] The French Agriculture and Food Ministry's website. Though no single definition currently predominates, the field involves a set of principles guided by the alignment between agronomy and ecology.
[15] Presence of oxygen

Second condition: Integration into the context of the territory[16]

The dynamism of an anaerobic digestion project's backers is a crucial element in its integration into the surrounding territory, as they define the content of the project and hold the capital. But they are just one element. Agricultural anaerobic digestion projects are eminently local, involving multiple stakeholders and priorities. Within its territory, each project involves multiple dimensions – agriculture, waste management, the circular economy and the energy transition.

Therefore each stage of the project, from the first steps to the full operation of the anaerobic digestion unit, must involve all the stakeholders: local authorities, farmers, agri-food companies, chambers of agriculture, technical experts, investors, building contractors – and of course neighbouring residents and citizens. This approach ensures that the project is adapted as closely as possible to local environmental, social and economic characteristics, bringing all these stakeholders on board by ensuring the resulting benefits are shared. **Agricultural anaerobic digestion projects should help to create social bonds, solidarity between territories** (e.g. urban–rural)**, shared value and a circular economy.**

More specifically, the sector must ensure that agricultural anaerobic digestion projects contribute to **sustainable biomass management across the territory** and follow the hierarchy of uses[17], especially if the anaerobic digestion unit imports biomass from outside the farm. By coordinating with all the stakeholders, it should be possible to harmonise the different uses for biomass and ensure feedstocks are available for anaerobic digestion without creating competition for biomass resources, which could threaten food security[18]. Specifically, the use of dedicated crops, currently capped at 15% of feedstock by weight[19], must be kept as low as possible. Where agricultural anaerobic digestion units are used for the treatment and recovery of organic waste from the territory, and from the agri-food industry in particular, this value creation should not be an obstacle to efforts to prevent the waste being produced in the first place.

Finally, anaerobic digestion must address the priority of reintegrating farms into their surrounding territory. This includes helping to reduce the specialisation of agricultural regions that have previously responded to the demands of globalisation and competitiveness. On a larger scale, it means helping to improve the **resilience of production methods** against climate and economic risks.

This systemic vision should enable **the design of an agricultural anaerobic digestion project to result in a positive overall environmental footprint for the territory**. This will depend on thinking collectively about feedstock transport, the local use of digestates and biogas (as vehicle fuel, for example) and how to reconnect the farm to its territory in terms of both its supply chain and the distribution of its products.

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[16] The notion of "territory" is applied broadly here, covering various geographical areas defined by different political, economic, social and cultural realities. The territorial approach to anaerobic digestion will be addressed by specific additional work.
[17] MTES. French National Biomass Strategy (*Stratégie Nationale de Mobilisation de la Biomasse*), p. 29
[18] IDELE (2015). Survey on the benefits of using co-products in anaerobic digestion and competition with animal feed concluded that farmers can use products destined for animal feed when faced with difficulty in obtaining co-products. The farmers and livestock breeders surveyed also expressed anxiety about competition in the future, given the rapid growth in other anaerobic digestion units and the potential for them to be managed by industrial companies based on the German model, using dedicated bioenergy crops such as maize.
[19] Decree no. 2016-929 of 7 July 2016 applying article L. 541-39 of the French Environment Code

Third condition: Helping to solve global societal challenges

The world is facing ecological and social challenges on a scale that has never been seen before – climate change, biodiversity loss, fossil resource depletion, food security. **The solutions we choose to help us through the transition must demonstrate that they can address these challenges and scale up sustainably.**

The greenhouse gases emitted by agricultural anaerobic digestion throughout its life cycle[20] are thus a crucial factor in its sustainability. Anaerobic digestion must **significantly reduce greenhouse gas emissions compared to power from fossil fuels and help reduce the emissions of the agricultural sector**. Its overall environmental performance must be better than the total of the practices it replaces (organic waste incineration, direct manure and slurry spreading etc.). The practices used to supply digestion units with biomass and spread digestates must limit the farm's greenhouse gas emissions.

Agriculture is recognised as having a vital role to play in fighting climate change – including carbon storage in the soil – and preserving biodiversity. All the processes that go hand-in-hand with the establishment of an anaerobic digestion unit on a farm or in a territory must therefore **promote this carbon storage in agricultural soil and maintain biodiversity in farm habitats**.

[20] From feedstock production to digestate spreading

Without claiming to be exhaustive, the three conditions for sustainability emerging from the consultation process highlight the key priorities for the agricultural anaerobic digestion sector. Addressed to all its stakeholders, they provide a **basis for a common frame of reference to support the sector's sustainable development as a lever for the energy and agricultural transitions**.

What we already know about the carbon footprint of anaerobic digestion

Studies seeking to measure the carbon footprint of anaerobic digestion have focused particularly on the footprint of biomethane injected into the gas grid.

The study conducted by ENEA Consulting and Quantis in 2017 concluded that the greenhouse gas emissions associated with biomethane production, injection and consumption amounted to 23.4 g CO_2 eq per kWh LHV (Lower Heating Value), which is nine times lower than the figure for a kWh of natural gas. This average value corresponds to a prospective mix of French biomethane production in which the agricultural and territorial sector represents about 80% of the biomethane produced.

The calculation methodology took avoided emissions into account. Biogenic CO_2 emissions were not included. The study thus quantifies all the impacts of anaerobic digestion, including feedstock production (intermediate crops), local collection, anaerobic digestion, purification of the resulting biogas, biomethane injection and consumption and the storage and agronomic use of the digestate. It also covers the greenhouse gas emissions avoided through anaerobic digestion, due for example to improved management of certain feedstocks (digesting livestock effluent prevents direct methane emissions) and the use of digestate rather than fertiliser. The study did not consider the sector's impact on carbon storage in the soil.

In 2018, INRAE Transfert produced a European benchmark for life cycle analyses (LCA) of anaerobic digestion, focusing primarily on studies of injected biomethane produced from agricultural substrates. The analysis highlighted several points requiring closer examination among the 20 studies analysed. These included the impact of upstream agricultural processes (including the use of intermediate crops), replacing chemical fertilisers with digestates and carbon storage in the soil. A further INRAE Transfert study is in progress to account better for these parameters in the LCA of biomethane.

Life cycle analyses are a global impact analysis methodology. Consequently, environmental assessments of agricultural practices based on these analyses are subject to certain hypotheses and limits in relation to the complexity of living systems and the variability of soil and climate conditions. They require additional work to define relevant indicators and stable hypotheses as a basis for the calculations. For example, the scientific community is working to improve field emission models and refine environmental indicators (including coverage for the damage to ecosystems associated with water, air and soil pollution indicators). They are also seeking to improve calculation hypotheses consistent with the agricultural systems being studied (viewing cultivation systems holistically, soil conditioning power).

<u>References</u>

ENEA, Quantis, 2017. Evaluation des impacts GES de l'injection du biométhane dans le réseau de gaz naturel *(Assessment of the impact on GHG emissions of injecting biomethane into the natural gas grid), Antoine Esnouf and Doris Brockmann, 2019, on behalf of GRDF.* Etat de l'art et benchmark des ACVs portant sur la méthanisation et le biométhane (State of the art and benchmark of LCAs of anaerobic digestion and biomethane).

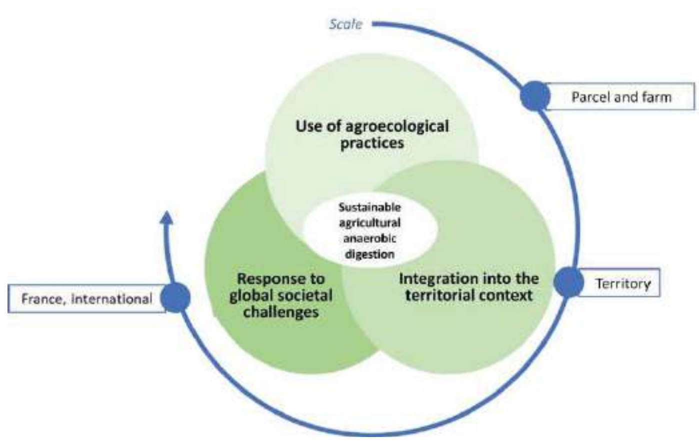

Figure: Conditions for the sustainability of agricultural anaerobic digestion

INTERMEDIATE ENERGY CROPS AND DIGESTATE SPREADING: HOW DO THEY RESPOND TO THE SUSTAINABILITY CONDITIONS?

Preface

This part of the document aims to identify whether the practices of growing intermediate energy crops and returning digestates to the soil meet the sustainability conditions described above from an environmental viewpoint. These are the practices identified as priorities by the participants of the workshops, but **they are not the only agricultural issues in the sector.** Specifically, the broader question of other sources of feedstocks for anaerobic digesters – the types of resources used, including dedicated crops[21] and crop residues, mixture types etc. – is crucial. Given that a number of deviations from best practice have been seen on the ground, this issue will have a decisive impact on the sector's future. Further work will examine this point in greater detail.

The following sections also mention the socio-economic issues. Although these are part of the sustainability framework, they were not specifically examined in detail during the series of workshops.

A few definitions

Ecosystem services : Benefits (tangible or intangible) people obtain from ecosystems

Intercrop period : The time between the harvesting of one main crop and the sowing of the next

Nitrate leaching : Nitrate ions being carried away due to the vertical transfer of water within the soil. This transfer occurs during periods of heavy rainfall and exceptionally due to irrigation

Crop cycle : All the stages in a plant's development

Labile carbon : The fraction of organic matter that breaks down most quickly. This is the fraction that is partly consumed in the anaerobic digester to produce biogas

Stabilised carbon : The more stable fraction of the organic matter, which breaks down slowly (woody compounds, organic matter that is not transformed in the anaerobic digester)

Catch crop : Fast-growing intermediate crop used mainly as forage for animal feed

Weed : Any non-cultivated plant that competes with cultivated plants

Crop management plan : Describes different ways of managing a crop based on objectives decided in advance

Humus : Top layer of the soil, created, maintained and modified through the decomposition of organic matter

Intermediate energy crops

Intermediate crops: from agroecology to renewable gas production

Intermediate crops are crops sown between two main crops within a crop rotation. By covering soil that would otherwise be bare, they provide a number of **agroecosystem services** during the intercrop period – improving soil structure, recycling mineral

[21] In 2018, ADEME estimated that the area of crops grown specifically for anaerobic digestion in France was 14,850 hectares, 0.05% of all French agricultural land in use and 0.08% of arable land

elements, storing carbon in the from of organic matter in the soil, reducing erosion due to water and/or wind, maintaining biodiversity and controlling weeds[22].

The concept of intermediate crops is not new (1970s[23]). **Several terminologies now coexist depending on the main purpose for which they are planted.** Cover crops have long been grown during the intercrop period, primarily to **protect the environment**. In response to the Nitrates Directive[24], cover crops are a means of limiting the leaching of agricultural nitrates into vulnerable areas. These are known as nitrogen-fixing cover crops[25]. The 2010s saw the concept of **multi-service cover crops** emerging – crops that are not harvested and provide a number of ecosystem services[26]. They are now **recognised as one of the levers of the agroecological transition[27]**.

Recently, intermediate crops have also been a crucial element of potential future scenarios for the energy transition. Additionally, they have been used on the ground at farms developing the use of anaerobic digestion. We describe these as **intermediate energy crops**. The goal is to produce three crops in two years – two food crops and one intermediate crop as a feedstock for anaerobic digestion. In the ADEME study *A 100% renewable gas mix in 2050*, published in 2018, the potential renewable gas production for injection into the grid identified as coming from intermediate crops represents 51 TWh GCV[28], which accounts for almost **40% of the potential production** of biogas from anaerobic digestion by this date.

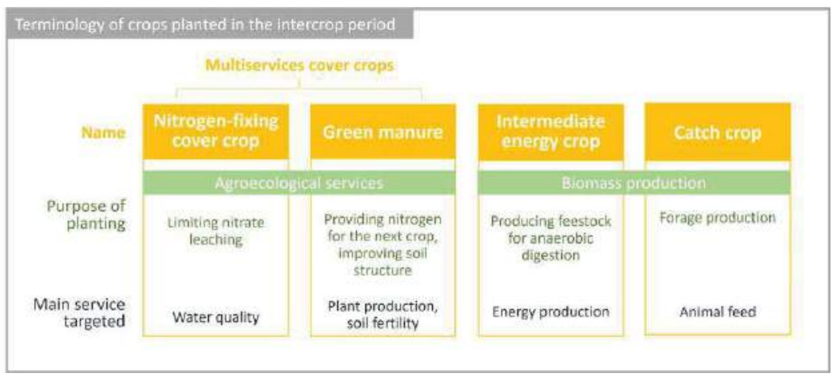

Figure 2. Terminology and purpose of crops planted during the intercrop period (Source: E Justes, G Richard. Contexte, concepts et définition des cultures intermédiaires multi-services (Context, concepts and definition of multi-service cover crops).

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[22] Eric Justes, Guy Richard. *Contexte, concepts et définition des cultures intermédiaires multi-services* (Context, concepts and definition of multi-service cover crops). Innovations Agronomiques, INRA, 2017, 62, pp.1-15. hal-01770348 / Eric Justes, Nicolas Beaudoin, Patrick Bertuzzi, Raphaël Charles, Julie Constantin, et al. (2012). *Réduire les fuites de nitrate au moyen de cultures intermédiaires : conséquences sur les bilans d'eau et d'azote, autres services écosystémiques* (Reducing nitrate losses with intermediate crops – Consequences for water and nitrogen levels and other ecosystem services), INRA / Julie Constantin, Nicolas Beaudoin, Nicolas Meyer, Romain Crignon, Hélène Tribouillois, et al. *Concilier la réduction de la lixiviation nitrique, la restitution d'azote à la culture suivante et la gestion de l'eau avec les cultures intermédiaires* (Combining reductions in nitrate leaching, supplies of nitrogen for the following crop and water management with intermediate crops). Innovations Agronomiques, INRA, 2017, 62, pp.1-12. <hal- 01770351> / Burgundy Chamber of Agriculture, 2012. *Cultures intermédiaires (Intermediate crops)*

[23] Eric Justes, Nicolas Beaudoin, Patrick Bertuzzi, Raphaël Charles, Julie Constantin, et al. (2012). *Réduire les fuites de nitrate au moyen de cultures intermédiaires – Conséquences sur les bilans d'eau et d'azote, autres services écosystémiques* (Reducing nitrate losses with intermediate crops – Consequences for water and nitrogen levels and other ecosystem services), INRA

[24] 1991 European directive aiming to protect water from pollution with agricultural nitrates

[25] By using the available nitrogen for their growth, plants limit the spread of the nitrates that cause environmental pollution

[26] Eric Justes, Guy Richard (2017). *Contexte, concepts et définition des cultures intermédiaires multi-services* (Context, concepts and definition of multi-service cover crops). Innovations Agronomiques, INRA, 2017, 62, pp.1-15. hal-01770348

[27] Agronomic innovation seminars (Carrefours de l'innovation agronomique): "Multi-service cover crops for high-performance agroecological production", 4 October 2017

[28] Gross Calorific Value

What are the differences between dedicated energy crops and intermediate energy crops?

In the specific context of anaerobic digestion, so-called **dedicated crops** are food **or energy crops** grown primarily to supply an anaerobic digestion unit. French decree no. 2016-929 of 7 July 2016 caps their use at "15% of the total gross tonnage of feedstocks per calendar year", averaged over three years.

Intermediate energy crops are not included in this category, because they are planted in soil that is unused during the intercrop period – it is left bare or sown with a cover crop not intended to be harvested. They are thus sown and harvested between two main crops. The intercrop period is often too short to produce crops for human food.

Main crops are crops that are either:

- Present for the longest time over an annual cycle;
- Identifiable on a parcel between 15 June and 15 September, either growing or from their remains;
- Sold under contract.

As they are not covered by decree no. 2016-929, there are currently no limits on the use of intermediate energy crops. When choosing their crops, farmers can be heavily influenced by the economic conditions governing agriculture/livestock on one hand and bioenergy on the other. Conditions specific to a territory, such as local specialisations, can also play a part. These varying priorities lead to a risk that intermediate energy crops may compete with food crops.

First condition: do intermediate energy crops help to establish agroecological practices across the farm?

Intermediate energy crops are grown in order to **recover the economic and energy value of the biomass produced**. Unlike multi-service cover crops, they are **harvested from the parcel** to be fed into an anaerobic digestion unit and produce renewable energy in the form of biogas. Do intermediate crops still provide agroecological services in this context?

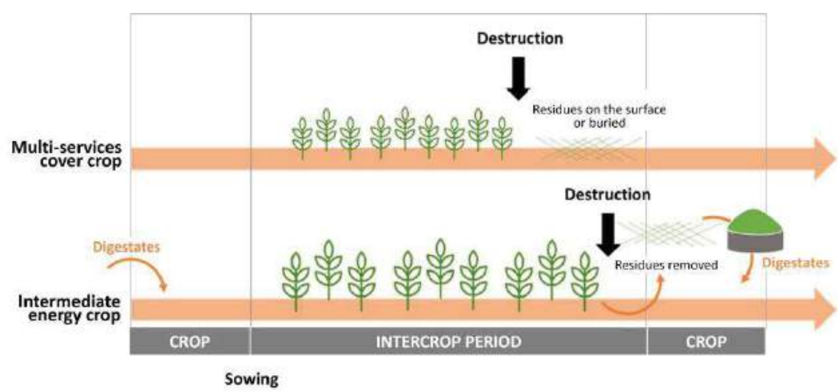

Figure 3. Comparison between multi-service cover crops and intermediate energy crops (source: after INRAE – J Constantin)

- **Ecosystem services are maintained or maximised, as long as crop management is adapted to local soil and climate conditions**

Current scientific knowledge based primarily on the work of INRAE[29] and Arvalis[30], suggests that **the services provided by a harvested intermediate crop can be maintained or even maximised**, as they generally develop for longer than a multi-service cover crop.

> ***Limiting water and air pollution****:* the research suggests that the services of nitrogen fixing and runoff limitation can be maintained, depending on the chosen species and crop management plan. Intermediate energy crops can help to limit water and air pollution due to nitrate leaching, which occurs when the fertilisation of the previous crop was not adequately controlled. However, these crops reduce drainage, especially since the amount of biomass produced is high, and could lead to a slight increase in nitrous oxide (N_2O) emissions. Care must be taken to ensure that the quest to produce biomass does not lead to inappropriate fertilisation of the intermediate energy crop, which would enrich the environment with nitrogen and cancel out the nitrogen management services provided by the intermediate crop[31]. Fertilisation management using digestates produced by anaerobic digestion is recommended.
>
> ***Limiting soil erosion:*** covering the soil during the intercrop period (before the intermediate energy crop is harvested) limits water and wind erosion. The plants give the soil physical protection against the rain, the ground cover obstructs water flow and the root system gives structure to the soil.
>
> ***Maintaining soil fertility****:* According to tests carried out by the OPTICIVE project, although the above-ground biomass is harvested as a feedstock for anaerobic digestion, organic matter is returned to the soil by the stubble and roots of the plants, together with the digestates (2 tonnes of dry matter (tDM) per hectare for each fraction returned to the soil, compared with 6 tDM/ha harvested). Spreading digestates reinforces this return of carbon to the soil. The tests are still limited in terms of their representativeness of different cropping systems, but the scientific literature agrees that intermediate energy crops increase the provision of carbon (via the roots and non-harvested crop residues) compared with leaving the soil bare between crops. Intermediate energy crops can thus help to maintain stores of organic matter and minerals in the soil, as long as digestates are returned to the parcel. Without the digestates, there would be a net export of minerals (nitrogen, phosphorus etc.) from the parcel via the biomass, requiring the shortfall to be made up with fertiliser in some cases.

The biomass production and ecosystem services that **intermediate energy crops can provide depend directly on the species, the variety, the crop management plan and the territory's soil and climate conditions, as well as on the digestates being returned to the soil**. Several projects are currently seeking to define the "best" crop management plans to maximise biomass production and agroecological services. **The impacts of an intermediate energy crop must be**

[29] INRAE's work has so far focused on multi-service cover crops, and not specifically on intermediate energy crops
[30] The OPTICIVE project run by the GAO economic interest group (Arvalis, Terres Univia and Terres Inovia) with Euralis, supported by ADEME
[31] If fertilisation is not properly controlled, the nitrogen left unused by the intermediate energy crop could intensify the problem of water contamination

evaluated across a whole rotation, and not just over the period of the dedicated intermediate crop.

> "In conservation agriculture, cover crops are vital for their root systems. But the above-ground biomass can make it more difficult to sow the next crop and manage pests (mice, slugs etc.), so harvesting is possible. Anaerobic digestion is a virtuous circle, because the digestate helps to stimulate both above-ground and root growth in intermediate energy crops."

A member of AAMF, the French association of farmers operating anaerobic digesters

- **Economic opportunities, but variable yields must be anticipated**

Introducing an intermediate crop into a production system has **several effects on the economic balance of the farm**.

***Reduced operating costs and increased autonomy for the farm*:** by recycling nitrogen and limiting annual weed growth through direct competition, intermediate energy crops help to limit the use of synthetic inputs (fertiliser, crop protection products) and improve the farmer's autonomy, especially when digestates are returned to the soil as an organic fertiliser.

Additional revenue for the farmer: farmers can sell the intermediate energy crop to an external anaerobic digestion unit or use it as a feedstock for their own digester. Selling the intermediate energy crop or the resulting renewable energy provides an additional source of revenue. However, this must be balanced against the costs associated with integrating an anaerobic digestion unit to be sure whether the financial outcome is positive for the farmer[32].

***Loss of main crop yield*:** a loss of yield due to sowing being delayed or a lack of water availability in summer has been observed on some farms[33]. In the current economic climate, the margins achieved by the sale or self-consumption of the intermediate energy crops, together with cost savings, can make up for the opportunity cost associated with the loss of production for the farmer. However, the impact of the intermediate energy crops must be controlled to avoid disrupting the main food crops and changing the land use, which could lead to economic costs. More knowledge is needed about the impact of intermediate energy crops on water availability for the following crop in order to manage the intermediate energy crops as effectively as possible. This need is all the more pronounced in the context of climate change, which will intensify water resource pressures.

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[32] The PRODIGE study of the technical and economic performance of anaerobic digestion units in operation, conducted by APCA and ADEME, was unable to reach a conclusion on the benefits of intermediate energy crops, because not enough farms had developed them (sampling based on a model processing livestock manure, mostly for cogeneration).

[33] The OPTICIVE project run by the GAO economic interest group (Arvalis, Terres Univia and Terres Inovia) with Euralis, supported by ADEME: this loss is due to a combination of factors (delayed sowing, changes to variety earliness etc.), not just to the intermediate energy crop consuming a non-negligible proportion of the soil's useful water reserves. The frequency of rain when winter intermediate energy crops are harvested often replenishes these reserves for the following crop. / INRA, 2008. Collective scientific expertise (ESCo) on "Agriculture and biodiversity" – chapter 3. Incorporating biodiversity targets into agricultural production systems

***Potential fluctuations in intermediate energy crop yields to be anticipated*:** while intermediate energy crops represent a way for farmers to secure supplies for their anaerobic digestion units against variations in the organic waste market, fluctuations in production yields need to be taken into account. Climatic conditions, combined with the crop management plans chosen, will have a direct effect on plant growth. This high level of variability from one year to the next (between 1 and 10 tDM/ha, depending on the source and the tests conducted) determines the activity's cost-effectiveness – the yield must be high enough to justify the harvesting cost. **These variables must be included in the business model and the anaerobic digestion project's secure feedstock plan.** There may be techniques that could limit the level of variability, such as planting **mixtures of species**, but this has yet to be proven. Leaving each species to develop according to the climatic conditions could stabilise overall yield from one year to the next.

Second sustainability condition: intermediate energy crops and their integration into the territorial context

- **Helping to maintain a territory's agricultural identity**

The aesthetic appearance of the landscape is one of the intangible services provided by intermediate crops[34]. By covering the soil during periods when it is usually bare, and by choosing species with rapid growth cycles that favour flowering, intermediate energy crops can **help maintain the diversity of the agricultural landscape**.

- **Strengthening links between agricultural operators**

On the scale of a territory, farmers' production of intermediate energy crops, either for self-consumption or for sale, helps to diversify their revenue while providing feedstocks for anaerobic digestion units. Aside from this purely financial aspect, these exchanges of biomass can **balance returns of organic matter to the soil across the territory**. In exchange for their intermediate energy crops, farmers can receive a proportion of the digestate produced by the anaerobic digestion unit in line with their needs for fertiliser and organic amendment. The logistics of these exchanges must be considered when contracts are signed between agricultural operators to limit the overall environmental impact.

- **Vigilance about how intercrop periods are managed and possible competition in biomass use**

Although intermediate energy crops can strengthen links between agricultural operators within a territory, using their biomass for energy purposes must not compete with existing uses of biomass, such as animal feed if the intercrop period was previously used for producing catch crops. The effects of intermediate energy crops on the crops that follow them, and the potential extension of the intercrop period to produce biomass, may also compete with food production, and this should also be monitored (see below).

Third condition: do intermediate energy crops help to solve global societal challenges?

- **Potential contribution to carbon storage in agricultural soil**

[34] Eric Justes, Guy Richard (2017). *Contexte, concepts et définition des cultures intermédiaires multi-services* (Context, concepts and definition of multi-service cover crops). Innovations Agronomiques, INRA, 2017, 62, pp.1-15. hal-01770348

As we have already seen, the stubble and roots of intermediate energy crops can return organic matter to the soil, though the final amount of carbon stored may be less than with a nitrogen-fixing cover crop[35].

Carbon storage has not yet been measured in the field over a long enough period for results to be observed, but it has been modelled mathematically with AMG[36] using the CHN-AMG tool (Arvalis). The study compared the evolution of organic carbon content in the first 30 centimetres of the soil[37] between an intermediate energy crop with oats, an intermediate energy crop with digestate returned to the soil and a control. Different controls and resulting models were used based on different tests conducted by Syprre, an agricultural research project. These included a monoculture of grain maize with the soil left bare between crops and a rotation of wheat, winter barley and maize. The model showed an increase in soil organic carbon resulting from intermediate energy crops, which was higher still when digestate was returned to the soil[38]. These observations need to be replicated with other production models and extended to a variety of other contexts.

The carbon storage potential of planting intermediate crops[39] identified by the "4 per 1000" initiative[40] could still be present with intermediate energy crops even if the biomass is removed. **Incorporating intermediate energy crops into agricultural production models could thus contribute to carbon storage in agricultural soil, helping to offset greenhouse gas emissions and fight climate change[41].**

- **Intermediate energy crops and biodiversity: an interaction requiring further study**

The impact of integrating intermediate energy crops on biodiversity, particularly in the soil, remains little-studied, though initial research has been carried out. As part of the Agrifaune programme set up by ONCFS[42], FNC[43], APCA[44] and FNSEA[45], the intercrop technical group looked closely at the intercrop variables that could promote biodiversity. The programme evaluated the criteria that determine how an intermediate crop can balance agronomic and environmental priorities while benefiting wild animal life. This work resulted in the labelling of species mixes that support these criteria. The right choice of species for producing intermediate energy crops can thus balance these priorities while encouraging local wildlife.

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35 However, a situation consisting of an intermediate energy crop combined with digestate would need to be compared with a situation with a nitrogen-fixing cover crop alone.
36 Clivot, Hugues, Jean-Christophe Mouny, Annie Duparque, Jean-Louis Dinh, Pascal Denoroy, Sabine Houot, Françoise Vertès et al. 2019. "Modeling Soil Organic Carbon Evolution in Long-Term Arable Experiments with AMG Model". *Environmental Modelling & Software* 118 (August): 99-113. https://doi.org/10.1016/j.envsoft.2019.04.004.
37 The data integrated into the model are territorial data from Béarn
38 The long-term carbon storage of these digestates (see below) requires further study, as current results are based on modelling
39 The 4 per 1000 initiative has highlighted the fact that intercropping and intermediate crops can represent 35% of the total carbon storage potential in this type of system
40 The international "4 per 1000" initiative was launched by France on 1 December 2015 at COP21. It involves bringing voluntary public and private-sector stakeholders together under the Lima–Paris Action Agenda. The initiative aims to show that agriculture, and especially agricultural soil, can play a vital role in ensuring food safety and fighting climate change. It builds on concrete actions that can be put in place to encourage carbon storage in the soil.
41 Life cycle analyses in progress at INRAE Transfert should reveal the carbon balance of this practice in comparison with other potential emissions (including NH_3 and N_2O)
42 ONCFS: French National Hunting and Wildlife Agency
43 FNC: French National Hunting Federation
44 APCA: Permanent Assembly of Chambers of Agriculture
45 FNSEA: French National Federation of Farmers' Unions

- **Intermediate energy crops and food security: practices must be monitored as they become more widespread**

As we have already seen, planting intermediate energy crops can sometimes delay the sowing of the following crop or affect water availability in summer[46]. This can influence the yields of the following crops, and thus have a direct impact on the production of human or animal food. For example, the results of the OPTICIVE project show a yield loss of one tonne per hectare for a grain maize/intermediate energy crop system, due to the two-week delay in sowing the next main crop. Current research to optimise crop management plans should characterise this impact more generally and suggest solutions to mitigate it. In a context where the use of biomass offers a solution for decarbonising several activity sectors, **coordination with main crop production** must remain a focus for the roll-out of intermediate energy crops. Apart from the additional research required, the current regulatory framework for defining intermediate energy crops remains vague and needs clarification. Excluded from the 15% cap on dedicated crops as anaerobic digestion feedstocks, they may constitute a large proportion of the supply, encroaching on the food use of agricultural land, which must remain the highest priority.

> "The purpose of an intermediate energy crop is to maximise the services provided during the intercrop period, including adding new economic and environmental functions. Its position in the rotation is vital in enabling productivity while also controlling costs and limiting the impact on the following food crop."

Sylvain Marsac, Arvalis

[46] The OPTICIVE project conducted with Euralis, the GAO economic interest group, Terres Univia, Arvalis and Terres Inovia

Returning digestates to the soil

One digestate, many digestates

Every tonne of waste fed into an anaerobic digestion unit produces an average of 930 kg of digestates, which are usually considered a waste product[47]. Most of these digestates are currently spread on agricultural land for their agronomic benefits.

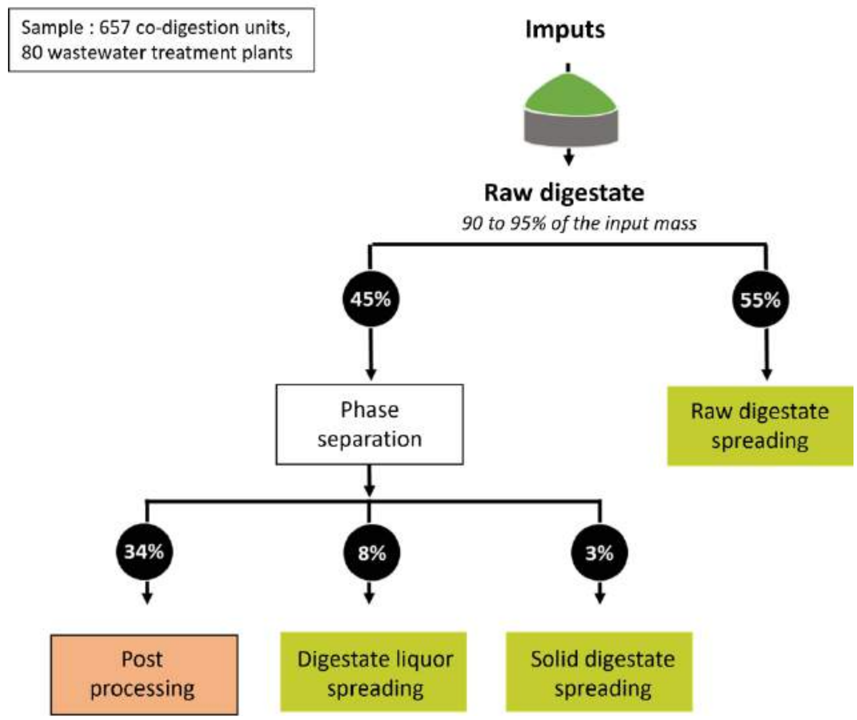

Figure 4. What happens to digestates in France (source: after ATEE Club Biogaz, 2019)

The agronomic value of materials returned to the soil depends on three components – their **fertilising value**[48] (presence of nitrogen, phosphorus, potassium and trace elements essential for plant growth), their **soil-conditioning value**[49] (capacity to maintain the organic matter in the soil, the stability of the soil structure and its pH) and finally their **impact on the environment** (greenhouse gas and other atmospheric pollutant emissions) **and on health** (biological, organic and chemical contaminants and trace metals).

The characteristics of the digestate depend heavily on the **quality of the waste and the feedstock** used in the anaerobic digestion unit (origin and composition), together with the **process conditions** (temperature, time spent in the digester) and **any post-processing** (aerobic maturation, drying etc.). The **spreading** process can influence the digestate's effectiveness and efficiency in the field. Consequently, there is **not one digestate, but many digestates**.

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[47] Club Biogaz
[48] The fertilising value of a product can be expressed by the nitrogen fertiliser replacement value (NFRV), which measures short-term fertilising value as a function of apparent nitrogen recovery (ANR), the ratio of the nitrogen found in the crop to the total nitrogen added.
[49] The soil conditioning value can be expressed with an organic matter stability index

First sustainability condition: does returning digestates to the soil help to establish agroecological practices across the farm?

- **Digestate, an effective substitute for mineral fertilisers**

The anaerobic digestion process is conservative – all the fertilising elements (nitrogen, phosphorus, potassium and trace elements) fed into the process are present in the output, sometimes in a different form[50]. Separating the phases of the raw digestate produces a liquid phase and a solid phase. The fertilising elements (N, P, K) and organic carbon are divided unequally between these two phases. This unequal distribution and the properties it provides mean **the liquid phase is comparable to an organic fertiliser with a high fertilising value, and the solid phase is comparable to an organic soil conditioner[51].**

Scientific research confirms the fertilising value of digestates[52]. They can **replace mineral fertilisers.** In particular, nitrogen that has been mineralised by the anaerobic digestion process can be taken up more directly by plants, though it is also more easily leached in water or volatilised in the air than a non-digested input[53]. Feedback from farmers shows that the replacement is gradual, and many have used mineral fertiliser to boost the intermediate energy crop initially before being able to rely directly on the digestate.

- **Management practices necessary to protect the environment**

As with the management of livestock waste (slurry, manure) and mineral fertilisers, **nitrogen losses can occur via several mechanisms during the digestate storage, post-processing and spreading phases.**

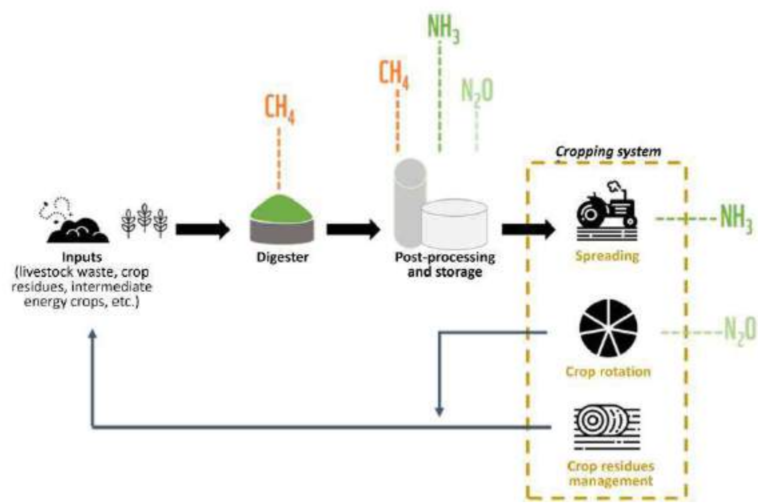

Figure 5. Impact of digestate post-processing strategies on gaseous emissions across the sector (after Girault et al. 2017)

[50] For example, the breakdown of nitrogenous materials in the absence of oxygen results in the formation of a nitrogenous compost in reduced form, ammonia

[51] A number of tests identified in the summary published by GERES in 2018 have shown that the nitrogen fertilising behaviour of raw digestate is comparable with that of pig or poultry slurry, with an average effectiveness (expressed as an NFRV) of 40 to 60% for cereals. Meanwhile, the organic matter stability index has been measured for various digestates produced from different feedstocks with different degrees of post-processing. This processing affects the stabilisation of the organic matter in the digestate.

[52] Sources: INRAE, MéthaLae (Solagro), GERES literature review conducted in 2018

[53] GERES, 2018. *Valorisation agricole des digestats : quels impacts sur les cultures, le sol et l'environnement ?* (Agricultural use of digestates: what are the impacts on crops, soil and the environment?)

They depend directly on several known factors: digestate quality (concentration of ammonium nitrogen N-NH4, dry matter percentage, pH), storage conditions and the technical, soil and climate conditions of the spreading process. During spreading, a number of conditions favour nitrogen losses: low soil porosity/roughness, warm temperatures (spreading in late summer) and dry, windy conditions[54]. The variability of the digestate makes it essential to know its composition in order to adjust spreading practices and limit losses.

Volatilisation releases a gas into the atmosphere, ammonia (NH_3), which **affects the quality of the air** (ammonia is a precursor of fine particles), **water and soil** (acidification after resettling) **and contributes to climate change** (transformation into nitrous oxide N_2O after resettling).

Best practice for limiting or eliminating the risk of ammonia volatilisation is well-known:

- **Airtight covers on digestate storage areas** reduce nitrogen losses by 90% compared with a situation with no covers, for digestates produced from slurry for example[55].
- Using **the right spreading equipment and spreading at the right time** are essential. Both must be adapted to the nature of the soil (bearing capacity, pH, presence of stones), the crop type and the climatic conditions[56]. They must also help the digestates to be incorporated into the soil quickly, because half to 90% of total nitrogen losses occur within six to eight hours after spreading[57]. Using drag hose booms or incorporators reduces volatilisation but requires high-quality phase separation[58].

Like any fertiliser, applying digestate **may cause water pollution through excess nitrates and phosphates** if too much is applied or if spreading takes place at an unsuitable time. The digestate quantity must be adjusted to the needs of the plants to limit this pollution, taking into account their mineral nitrogen absorption period and the remaining mineral nitrogen already available, as with any fertiliser. Precision agriculture, which a number of farmers operating anaerobic digesters now seem to rely on, can help with this.

Other losses may be caused by microbial reactions in the soil once the digestates have been spread or injected, leading to emissions of **nitrous oxide N_2O**[59]. These emissions are influenced by soil pH, temperature and humidity and by the nitrogen content of the digestate. It is not currently possible to generalise from the conclusions of tests on digestates.

Losses of methane (CH_4) can also occur during the anaerobic digestion process and during digestate storage before spreading.

- **Effects on the soil that require further study**

The soil conditioning value of digestates has so far been studied less than their fertilising value. The organic matter content of soil influences its physical, chemical and biological properties and thus its fertility. This means that maintaining soil organic matter content and producing humus, its stable fraction, are a priority in all types of agriculture. As the

[54] Sources: GERES (2018), Grégory Vrignaud (2019), INRAE (Sabine Houot, Romain Girault – 2019)
[55] Source: IRSTEA, 2019
[56] The weather conditions that limit losses are cloudy, cool weather with no wind or rain in the 24 hours after spreading. The soil should not be saturated with water and spreading should take place at the end of the day when temperatures are lower, as close as possible to the period when crops absorb mineral nitrogen.
[57] Sources: Arvalis, 2019 (EVAPRO test 2016) – GERES (2018)
[58] MéthaLAE programme, Solagro, 2019
[59] N_2O has a global warming potential 265 times higher than CO_2.

anaerobic digestion process breaks down some of the labile fractions of organic matter, the digestates returned to the soil are richer in stable carbon, which breaks down more slowly[60]. With anaerobic digestion, part of the dynamics of organic matter breakdown no longer takes place in the soil. The impact of this transfer, particularly on the potential redistribution of microbial populations in the soil, needs to be studied. By breaking down labile organic matter, micro-organisms are responsible for forming aggregates that create soil stability.

INRAE has begun looking at the issue and should undertake work in the short term on the impact of returning digestates to the soil on the soil's biological quality, including microbial activity. The environmental research laboratory working on Organic Waste Products (SOERE PRO)[61] is also conducting long-term field tests that include issues relating to digestates.

- **Digestate sanitary safety: biomass inputs must be qualified**

The **sanitary quality of digestates** can also affect **water and soil quality.** Contaminants, whether biological (bacteria and other pathogens), organic or chemical, pesticides and trace metals and minerals may all be present in the feedstock. Input and output materials may be hygienised[62], a step that can reduce the risk of these contaminants being present in digestates.

Some bacteria may be eliminated by the process temperature, with the level of reduction varying (Orzi et al. 2015, Solagro), but some are resistant (*Clostridium perfringens*[63]), even after hygienisation. The persistence of trace metals in the soil (copper, zinc, chrome, nickel etc.) depends directly on their concentration in the digestate, but also on the form of the digestate (liquid, solid, dried or composted). Work is in progress on what happens to pesticides and pharmaceutical products[64].

The literature review conducted by AILE (the French association of local energy initiatives) and AAMF (the French association of farmers operating anaerobic digesters) shows that the overall sanitary quality of digestates is better compared to raw effluents, and highlights the parameters that can reduce pollution risks. As the presence of these contaminants depends directly on their presence in the materials processed by the digester, the risks of environmental contamination can be limited by at least the following:

- A good knowledge of the nature and source of the waste and effluents digested,
- Combined with good management practice at the anaerobic digestion site (including site organisation and layout, transport disinfection),
- And good spreading practice.

These three phases must be given special attention to reduce the presence of contaminants at source.

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[60] GERES (2018). Anaerobic digestion mainly breaks down hemicellulose-type compounds and volatile fatty acids. More complex compounds such as lignins and complex fats are not broken down by the micro-organisms in the digester. The output material is thus more stable.
[61] https://www6.inrae.fr/valor-pro/SOERE-PRO-Presentation-de-l-observatoire
[62] Hygienisation is essential for all category 2 and 3 animal by-products – see regulation EC 1774/2002, replaced by regulation EC 1069/2009.
[63] GERES, 2018. *Valorisation agricole des digestats : quels impacts sur les cultures, le sol et l'environnement ?* (Agricultural use of digestates: what are the impacts on crops, soil and the environment?)
[64] The DIGESTATE programme[64], recently completed, sought to develop an environmental assessment of organic waste processing (composting, anaerobic digestion) and agricultural recycling. It studied what happens to various substances in digestates, including pharmaceutical products, but the conclusions are not yet available. This initial work will be supplemented by research in progress at INRAE.

- **Savings achieved by replacing mineral fertilisers**

By replacing mineral fertilisers, digestates can reduce the associated costs. The multi-partner MéthaLAE programme coordinated by Solagro, which surveyed 46 farms over three years before and after the introduction of anaerobic digestion, highlighted an **average reduction in synthetic fertiliser purchases of 20% at over half the farms**. The farmers questioned during the series of workshops presented similar or even better results.

Introducing good practice to avoid nitrate losses may require the farmer to invest in equipment (drag hose, disc or shoe for meadows, tine cultivator behind the tank before maize etc.). For projects involving a whole territory, these costs can be shared between the farmers, perhaps through agricultural equipment cooperatives, limiting the need for individual investment.

These savings should thus be seen in the context of additional costs for the farmer, relating particularly to working time, equipment and practices to be introduced alongside anaerobic digestion.

"At *Haut-Village Farm*, we have been spreading digestate on our fields for four years now. We have seen the fastest results in the meadows.
The meadows or pastures are fertilised with digestate liquor during winter and at the beginning of spring. Not only has this digestate enabled us to bypass all other "non-organic" inputs; it has also increased yields by a third. It offers a better balance between the elements than other fertilisers, and it is richer in various minerals and organic elements. We have gone from six to eight tones of grass dry matter in these meadows, even though the weather has been less favourable in recent years (very hot, dry summers). We have seen better root tissue growth in the meadows fertilised with digestate. We get both the ammonium nitrogen, which is taken up quickly, and the organic nitrogen, taken up more or less quickly, which limits losses and feeds the plants gently. We have maximised the biomass produced in the meadows, increasing photosynthesis activity and thus exchanges between the roots and the soil.
The result is an increase in the soil organic matter content. A study is in progress to determine how organic matter storage is evolving in our parcels."

Florian Christ, SAS Méthachrist - Haut-Village Farm

Second sustainability condition: returning digestates to the soil and integration into the territorial context

As well as being used directly by their producer, digestates can contribute to the development of a circular economy across a territory. Produced through the processing of one farmer's waste, they can be recycled agriculturally by others, as long as traceability, safety and agronomic benefit criteria are met. Like existing exchanges of straw and manure, recorded in exchange receipts issued by the producer and the receiving farmer, they can contribute to recycling and complete biogeochemical cycles.

By making farms less dependent on external inputs, digestates help **increase their resilience and maintain agricultural activity within territories**.

Extract from the results of the MéthaLAE program

Some projects bring livestock and cereal farmers together, setting up triangular systems of exchange – straw to livestock farmers, manure to anaerobic digesters and digestate to arable farmers. Another collective benefit is having a uniform digestate across the whole territory, with a constant composition throughout the year, analysed regularly. In some territories, several dozen different qualities of manure and slurry can be found, depending on management method, age and livestock population. Digestate from an anaerobic digester, on the other hand, has a constant composition, even if feedstocks vary continuously over the year. This makes fertilisation advice much simpler. The exchange systems introduced with collective anaerobic digestion make it possible to share supplies between all the farms in the territory.

Finally, from a social viewpoint, managing livestock waste with anaerobic digestion can help **improve the acceptability of farming**, which is sometimes viewed with suspicion. When the anaerobic digestion process is well controlled (time, temperature etc.), the volatile compounds in livestock waste responsible for unpleasant smells are broken down. Although feedback from farmers during the workshops clearly supported this view, little work has been done on the potential reduction of odour molecules[65]. Depending on the author, the odour disappears within 30 hours of the digestate being applied, compared with 60 hours without anaerobic digestion. These results vary depending on the nature of the materials processed and the digestate fraction observed.

Third sustainability condition: does returning digestates to the soil help to solve global societal challenges?

- **Controlling GHG emissions**

Digestate management can be a source of greenhouse gas emissions (nitrous oxide and methane), and work is in progress to quantify this precisely. So far there is little data on the subject. According to Holly et al. (2017)[66], the main greenhouse gas emissions occur when digestate is stored (CH_4) and after spreading (N_2O). The performance of the anaerobic digestion unit and the post-processing applied may increase or reduce these emissions[67]. But by comparing different stages in the management (storage and spreading) of non-digested raw materials and digestates, the authors showed that the balance of greenhouse gas emissions is lower for digestates than for raw materials. In reality, as these results do not include the avoided emissions associated with synthetic mineral fertiliser production[68], the actual result is even more positive.

- **A theoretically favourable impact on carbon storage in agricultural soil according to modelling**

Few studies have examined the soil conditioning value of digestates and the potential for carbon storage in the soil following repeated digestate applications. Most of these were carried out on the basis of computer models and simulations (AMG).

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[65] GERES, 2018. Valorisation agricole des digestats : quels impacts sur les cultures, le sol et l'environnement ? (Agricultural use of digestates: what are the impacts on crops, soil and the environment?)

[66] M A Holly et al. (2017). *Agriculture, Ecosystems and Environment*

[67] GERES, 2018. Valorisation agricole des digestats : quels impacts sur les cultures, le sol et l'environnement ? (Agricultural use of digestates: what are the impacts on crops, soil and the environment?)

[68] According to Solagro (2014), producing 1 kg of ammonium nitrogen consumes 1 kg of natural gas and releases 3 kg of carbon dioxide

Field trials carried out over 25 years in Germany on how digestates from manure/slurry evolve after spreading show that, in the long term, the soil stores **a quantity of carbon equivalent** to that resulting from spreading the same manure/slurry directly[69][70]. The nitrogen enrichment caused by returning digestates to the soil, but also by planting intermediate crops, would enable primary biomass production to be increased as a whole while enriching the soil with organic carbon through the roots.

- **Impact on biodiversity requiring further study**

The impact of digestates on biodiversity, and soil biodiversity in particular, has not so far been covered by many studies. There are a few references in Germany, but they concentrate on earthworm populations, which are not necessarily representative of agricultural soil. However, work in progress in France, conducted through MétaMétha trials at INRAE Nouzilly, has already shown that although a degree of mortality in anecic earthworms was seen after spreading, this only represented a few percent of the total worm population and the population grew in the medium term due to rapid resilience and additions of organic matter.

[69] Wentzel S, Schmidt R, Piepho HP, Semmler-Busch U, Joergensen RG, 2015. *Response of soil fertility indices to long-term application of biogas and raw slurry under organic farming*. Applied Soil Ecology 96,99–107
[70] Thomsen IK, Olesen JE, Møller HB, Sørensen P, Christensen BT (2013). *Carbon dynamics and retention in soil after anaerobic digestion of dairy cattle feed and faeces*, Soil Biol. Biochem., 58, 82-87

In summary

- **Current scientific knowledge highlights the benefits to the agrosystem of intermediate energy crops and returning digestates to the soil.**
  - Though the crop is removed from the parcel, the ecosystem services provided by an intermediate energy crop can be maintained or even maximised by biomass production that is often higher than with a "conventional" intermediate crop such as a nitrogen-fixing cover crop (reducing the risk of nitrate pollution, limiting erosion and maintaining soil fertility);
  - The fertilising value of digestates is confirmed: they can replace mineral fertilisers;
  - According to existing modelling, returning digestates and intermediate energy crop residues to the soil are two practices that can maintain or encourage carbon storage in the soil.

- **These benefits can only be observed under specific technical conditions, which may alter current agricultural practices.**
  - There are operational practices (including equipment choice and spreading period in particular) that can limit the environmental impact of digestates (volatilisation and nitrogen leaching) and optimise their agronomic value. Depending on their form and any treatment they may have undergone, dosing the digestates as accurately as possible to meet the plants' needs limits the transfer risk, as long as specific management practices are followed (limiting ammonia volatilisation and loss of fertilising capacity through the use of appropriate equipment);
  - Cropping systems that incorporate intermediate energy crops must be reviewed in their entirety to avoid disrupting food production, improve their resilience and their ecosystem functions (e.g. by extending the rotation, improving soil structure etc.) and provide a source of biomass with high methanogenic potential for digesters;
  - These new practices must be suited to the local soil and climate conditions.

- **Additional research and experimentation work is either already in progress or required to guarantee that these practices are fully compatible with the agroecological transition:**
  - To deepen knowledge about certain environmental impacts and identify the sustainable practices associated with them (e.g. the impact of intermediate energy crops and digestates on biological activity in soil);
  - To adapt practices to the soil and climate conditions of each territory: choosing intermediate energy crop seeds, rotation time and digestate spreading conditions to limit nitrogen volatilisation, for example;
  - To assess the environmental benefits in terms of carbon footprint offered by anaerobic digestion compared with other forms of gas production;

- **The implementation of these practices still depends on how their application is encouraged, supported and controlled.** Non-virtuous anaerobic digestion units or sites have been identified in some territories under the current context of support. Without adequate monitoring or supervision, certain practices can be implemented despite being agronomically incoherent or ill-judged from a food security standpoint. In these situations, anaerobic digestion supports an agricultural model that makes no contribution at all to the agroecological transition.

PRIORITIES AND RECOMMENDATIONS FOR SCALING UP AGRICULTURAL ANAEROBIC DIGESTION

How can we ensure these sustainability conditions are enforced on a large scale? The series of workshops highlighted priorities for scaling up anaerobic digestion and led to the collective formulation of recommendations to support its development sustainably.

The need for a shared, consistent frame of reference

Agricultural anaerobic digestion is covered by French and European regulations in fields such as renewable energy, agriculture and waste management.

By confirming a minimum target of 10% for renewable gas as a proportion of gas consumption by 2030, the French Energy and Climate Act of 8 November 2019 supports the development of renewable gas production sectors, including anaerobic digestion. The challenge is to ensure that this encouragement from the energy side, notably economic, also benefits the transition towards agroecological practices. Any weakening in public financial support mechanisms could threaten the economic balance of anaerobic digestion units and stimulate practices that undermine the sector's environmental sustainability.

To guarantee that agricultural anaerobic digestion can be scaled up sustainably, **sector-specific policies and regulations (energy, agriculture, waste management) must be consistent with each other. This requires an analysis of their mutual and interrelated effects on all the environmental, social and economic dimensions.**

> **"While synergies exist between the goals of biogas development in the agricultural, energy and waste sectors, it is also crucial to identify areas of conflict. Anaerobic digestion can only be part of this sustainability framework under economic and political conditions that must be established precisely, clarifying the possible compromises/judgements to be made between the goals of renewable energy production, biodiversity improvement and diversification of agricultural production systems, sustainable management of territorial resources (water, soil etc.), improvements in equality (between sectors, territories etc.) in agricultural revenues etc. The deployment of the biogas sector will not necessarily align the transformation of agricultural structures (reallocation of agricultural inputs) with the goals of the agroecological transition established by the États Généraux de l'Alimentation forum (conclusion of Workshop 11). Setting out the agronomic, economic, social and environmental issues at the level of individual farms and at territorial level is thus essential for the development of a sustainable industry."**

IDDRI

To make it easier to achieve this consistency, **a common vision of the sustainability conditions for the sector must be shared with all its stakeholders.** It would clearly be useful to have a common frame of reference incorporating the criteria and the expected levels of performance, for the practices themselves but also for territorial integration and methods of consultation. This type of framework could ultimately lead to shared reference systems for project evaluation or even labelling.

There are several voluntary initiatives that could provide a helpful basis:

- ***The Méthascope***, a tool for helping to evaluate anaerobic digestion projects developed by France Nature Environnement with support from ADEME and GRDF. This consists of a booklet and a multi-criteria evaluation grid, and helps territories to take hold of the issues involved in anaerobic digestion.
- ***The Qualimétha® label****:* Developed in 2019 by Club Biogaz with support from ADEME and GRDF, this label covers companies that design and build anaerobic digestion units. Consisting of 84 evaluation criteria, it aims to guarantee the quality of an installation by capitalising on good design and construction practice. Starting from 1 January 2021, this label should be required for projects to be eligible for ADEME grants and meet the selection criteria for calls for proposals issued by regional authorities.
- ***The "Unis pour innover et progresser" (united for innovation and progress) charter***[71] : : This charter, developed by the French association of farmers operating anaerobic digesters (AAMF), aims to help farmers to fully grasp the regulatory framework. It is a common system of requirements applying to all the association's members, helping farmers and providing the basis for audits. Its consists of eight main commitments that are assessed using an evaluation grid divided into ten chapters that cover the different stages of the anaerobic digestion process. The charter aims for regulatory compliance as a minimum, and goes further in certain areas such as digestate management. AAMF has set up a network of contacts to help its members implement the charter and prepare for their audits. The charter will evolve to certify the professionalism and continuous improvement of the member sites, quickly outpacing the regulations.
- ***The Énergie Partagée charter***: In April 2017, Énergie Partagée published a charter[72], working with SOLAGRO, SERGIES, ERCISOL, ELISE, CIVAM 44 and farmers, to promote anaerobic digestion projects compatible with the energy transition and the agricultural transition. It applies to units already in operation and consists of governance, agricultural, environmental and energy criteria. Compliance with the charter is a condition for Énergie Partagée's "Projet Citoyen" labelling and enables access to the participatory funding set up by Énergie Partagée.

Recommendation 1: Strengthen a common framework that promotes compliance with the sustainability conditions[73]

- Develop a shared culture within the energy, agriculture and waste sectors at national and regional level
- Evaluate the combined impacts of energy, agriculture and waste policies at all levels (national, regional and local) and ensure they are consistent with the shared objectives
- Promote clarity about the roles of different stakeholders at national and territorial level
- Establish and share a common national reference system (charter, quality label etc.) defining sustainable practices for all the conditions set out above, adapting the criteria and requirements to the specific characteristics of different territories
- Clarify the definition of intermediate energy crops from a regulatory viewpoint so that the development of the practice does not undermine higher priority uses of agricultural land or its resilience
- Put incentives in place (financial or not) to promote virtuous practices with a local economic impact. Tools such as payments for environmental services could be explored
- Intensify feedback about the sustainability criteria of existing installations

A need to supplement and disseminate knowledge, working with key operators

In recent years, stakeholders in the sector have developed their knowledge about the environmental and economic impacts of integrating anaerobic digestion units into agricultural systems. Though **further research and trials are still needed, spreading and capitalising on existing knowledge now appears to be an essential first step.** Information is still very scattered, "siloed", sometimes accessible only to a limited or very local circle of players.

The current state of scientific knowledge and practice shows that intermediate energy crops and returning digestates to the soil, when managed properly, align with agroecological principles and can act as a driver for the agroecological transition. This involves a **change of practice for farmers** (crop rotation, harvesting, processing) and **the development of new skills**, entrepreneurial as well as agricultural.

To guarantee its sustainability, the sector must therefore **ensure that farmers take ownership of these new techniques, acquire these skills and put them into practice so that the expected environmental and economic benefits are delivered. The farming profession is significantly affected by anaerobic digestion, and it is important that the direction taken should be agroecological rather than productivist**[74]**.** The spread and adoption of knowledge and sustainable practices at local level will enable projects to be created in accordance with the conditions for the sector's sustainability.

[73] In line with the work planned in the broader context of the 2018–2020 Bioeconomy Strategy for France action plan (Theme 4, Action 1)

[74] CEREQ (2016). *Transition écologique et énergétique – la filière méthanisation* (Ecological and energy transition – the anaerobic digestion sector)

Chambers of agriculture can play a central role in this upskilling process, because they have close relationships with the developers of agricultural anaerobic digestion projects, and providing information and awareness is one of their functions. Today all the chambers of agriculture are supporting the emergence of anaerobic digestion projects. However, the level of support provided when projects are being prepared can vary from one area to another.

> "The developers of anaerobic digestion projects must be able to control the constraints inherent in the management of their farm, plus the everyday running of the anaerobic digestion unit: spreading or intermediate energy crop silage, but also internal organisation, safety, communications etc. This is a whole new role for farmers. Initial training exists and is being delivered in several agricultural colleges alongside the continuing training offered by chambers of agriculture. Feedback from experience, collective discussions and visits to units are vital resources to help project developers build anaerobic digestion projects suited to the systems they operate. Putting an anaerobic digestion project together takes time and needs to be carefully considered by everyone involved.
> The role of chambers of agriculture is also to produce and pass on objective technical and economic information arising from local experience to support the implementation of these new practices and ensure the anaerobic digestion unit performs well."

Léonard Jarrige, Agriculture & Territories - French Chambers of Agriculture

Recommendation 2: Continue research and trials

- Continue to develop scientific knowledge about the agronomic and environmental effects of agricultural anaerobic digestion, the funding needed for applied research being released
- Intensify feedback (recommendation 1) and field trials to identify practices appropriate to local contexts

Recommendation 3: Support the professional development of the sector

- Promote the InfoMétha.org platform to capitalise on knowledge and practices and encourage their development and spread. The site operates collectively and evolves over time, collecting together the available knowledge about anaerobic digestion and its effects
- Identify stakeholders/channels able to distribute this knowledge and ensure it is adopted at national, regional and more local level (ADEME, APCA and chambers of agriculture, CTBM, INRAE etc.)
- Circulate the sustainability conditions to all project stakeholders and promote a framework for their adoption, perhaps involving a training programme[75]
- Strengthen mechanisms for support, skills transfer and professional development with the help of existing key territorial players (decentralised services, chambers of agriculture, AAMF, GIEE etc.) and develop the resources needed on the ground and for applied research

[75] Stéphane Michun's analysis in a Céreq Etudes publication (2016) on agricultural anaerobic digestion identifies the need to launch training programmes to moderate the wide diversity of today's training.

Strengthen key factors for success involving local governance

Agricultural anaerobic digestion projects are means of creating synergies and a circular economy approach between stakeholders within a territory. In response to the recurring problems of social acceptability[76], the most suitable level for the necessary public dialogue and communication is the local territory into which the project must integrate.

Uniting all project's stakeholders and creating forums for dialogue are essential to guarantee its territorial coherence. Experience has shown that cooperation between the territory's stakeholders around the project should be encouraged. There are many possibilities here: sharing engineering, biomass/waste flows or financial resources. A factor making it easier to put these cooperative arrangements in place is the shared motivation of these players to take advantage of the territorial benefits provided by biogas: preserving agricultural activity, the transition towards agroecology, local low-carbon energy production, a local waste processing solution, the development of jobs that cannot be offshored.

This requires local governance to be put in place, which cannot be achieved without the **participation of local citizens and people living next to anaerobic digestion units**.

Territories are already getting organised, on smaller or larger scales (see the local examples below). At a regional level, the GERES association is pursuing a number of regional structural and leadership initiatives, especially in the south of France. In Nouvelle-Aquitaine, the regional government has adopted the "100% renewable gas by 2050" scenario for application within the region. The Grand-Est region has established a charter for the development of anaerobic digestion in the territory. It is based on four themes: territorial approach; agriculture and environment; competitiveness and innovation; and training. In Hauts-de-France, the CORBI collective (regional biomethane injection steering committee) has been involved in structuring the sector since 2014. CORBI has created the Métha'Morphose brand to underscore its initiatives, and the Méthania development programme to support companies throughout the value chain across the territory.

Projects that include the public

Méthamoly is a group of twelve farmers from the Monts du Lyonnais area, who came together in 2012 to establish an anaerobic digestion project following a study conducted by the municipal waste processing agency. They quickly obtained support from the agency as they took their first steps.

The farmers are driven by a desire to involve the local community, which they do by communicating with the public and reassuring them about their project. The group also decided to make this a formal part of the project's design by issuing shares to SEM Soleil (a semi-public energy company in the Loire district), the local population (102 citizens saving through Énergie Partagée) and the regional renewable energy fund OSER. Farmers remain the majority shareholders with 51% of the stock, and the industrial company Engie Suez Méthabio Développement is also represented. The local stakeholders' participation in the project's stock creates a real sense of trust and dialogue within the project. The alliance has proved a win-win proposition throughout its development, and now during its operation. Each stakeholder contributes their own vision, skills and resources to the project, which is stronger as a result.

Energie Partagée – Suzanne Renard

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[76] CEREQ (2016). *Transition écologique et énergétique – la méthanisation agricole* (Ecological and energy transition – agricultural anaerobic digestion)

Successful inter-territory cooperation : Tiper Méthanisation

Tiper Méthanisation arose from global thinking about diversifying renewable energy generation (wind, solar and anaerobic digestion) in the Thouarsais group of municipalities. As soon as the project was first considered, various stakeholders were brought to the table (farmers, the agrifood industry, local authorities, cooperatives, the water agency, the chamber of agriculture) to define each party's needs, with the shared goal of converting biomass to energy locally and returning it to the territory in the form of digestate. After six years of development and many technical committee meetings, the work resulted in the construction of a 75,000 t combined heat and power unit, sourcing biomass from 50 farms and a dozen agrifood companies and generating steam for a local agricultural company. The unit has been operating for seven years, and its local partners are working alongside the anaerobic digestion activity to develop agricultural practices, waste collection and the production of natural gas for vehicles.

ACE Méthanisation – Grégory Vrignaud

Recommendation 4: Promote the integration of anaerobic digestion projects within each territory

- Create spaces for exchange between multiple stakeholders to share experience and spread good practice, both locally and nationally
- Create local forums for dialogue and consultation that include citizens, with the aim of making it easier for anaerobic digestion projects to integrate into their territories and the existing systems (district waste management plans, regional development, sustainability and equality plans and territorial climate, air and energy plans), taking inspiration from the experience of territories where this type of action is already in progress
- Give greater visibility to the tools available to local authorities that wish to develop anaerobic digestion (including those listed by CERDD, CNFPT and Énergie Partagée)
- Encourage farmers and their advisers to have the courage to truly integrate their anaerobic digestion project into their territory, using the tools available to local authorities and citizen funding

"*France Gaz Renouvelables* welcomes the work carried out by everyone who took part in the workshops. The development of anaerobic digestion to produce renewable, storable, local gas is a major contributor to the energy transition in rural territories. It goes hand-in-hand with the development of agroecological practices, which, along with the involvement of all the stakeholders in project construction, are a driver of local acceptability. Local consultation in the early stages of projects will make it easier to develop this new source of energy, which helps to establish the circular economy. Maintaining national support for the sector is vital to enable projects to emerge and guarantee that virtuous practices are put in place."

France Gaz Renouvelables

CONCLUSION

This publication sets out a vision of the conditions for the sustainability of agricultural anaerobic digestion. The sector can develop sustainably by **respecting the principles of agroecology** in the renewal of production systems, **establishing territorial roots** and demonstrating its ability to scale up sustainably to provide a solution that can **address global societal challenges.**

Helping to **improve the management and recycling of organic matter** by relocating flows, anaerobic digestion provides **renewable energy** and contributes to the energy transition in territories. Looking more specifically at two priorities identified as major for the sector – **developing intermediate energy crops to supply digesters and returning digestates to the soil** – we have reviewed the existing knowledge and the questions that remain to be answered. As long as good management practices are adopted, intermediate energy crops and digestates are compatible with several of the conditions set out. Anaerobic digestion and the agroecological transition seem to be compatible, depending on the production system in question. But although the agronomic, environmental, economic and social opportunities generated are very real, more research is needed to examine the remaining questions and ensure that all the conditions are fulfilled.

Safeguards must be put in place against practices that undermine the sustainability of anaerobic digestion. Examples of such practices have been reported by the national and local press and observed at grassroots level by stakeholders involved in this consultation process. In the quest for profitability, anaerobic digestion must not lose sight of the need for agriculture to produce food and the issue of agrosystem resilience. **A balance must be struck between agricultural and energy interests**, with conditions favourable to maintaining this balance. At the same time, a shared vision of sustainability in agricultural anaerobic digestion must provide the basis for capitalising on and spreading existing knowledge, developing skills in the sector and thinking about the territory as a whole. The sector's development must also be integrated into more global thinking about uses of biomass for all the relevant fields of activity.

The approach used in this process aims to initiate the establishment of a common sustainability framework within the sector, based on a shared vision of the conditions for sustainability in the development of agricultural anaerobic digestion and its associated practices. The goal is to give the sector's development an agroecological direction. Further development work could be done to list the **principles of successful territorial governance** from an operational viewpoint on one hand, and to specify the **conditions** for **sustainable feedstocks** for digesters from a more systemic viewpoint on the other.

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Expert presentations

Workshop 1: definition of the issues

(1) **Solagro** – Presentation of the ADEME study "A 100% renewable gas mix in 2050?"

(2) **INRAE Transfert** – Evaluation of the environmental impacts of the biomethane sector

(3) **INRAE Toulouse** – The ecological services provided by intermediate crops

(4) **Arvalis** – Intermediate energy crops: presentation of the results of the OPTICIVE project

(5) **Agryfil's Energie** – Operational experience

Workshop 2: Returning digestates to the soil: what are the environmental issues and best practices?

(1) **APCA** – Good practice for digestate spreading: obstacles and levers

(2) **AAMF** – The agronomic benefits of using liquid digestates properly: the experience of GATINAIS BIOGAZ

(3) **ACE** – Choosing spreading systems and equipment to limit volatilisation

(4) **IRSTEA** – The impact of management practices before digestates are returned to the soil

(5) **Arvalis** – Fertilising and soil conditioning value of digestates

(6) **INRAE** – Fertilising and soil conditioning value of digestates based on their origin, issues relating to soil biology

(7) **AILE** – Sanitary issues in agricultural anaerobic digestion

(8) **ATEE Club Biogaz** – Regulatory framework for digestates: end of waste status

Workshop 3: Intermediate energy crops: what are the sustainability issues and best practices?

(1) **WWF** – Proposed framework for interpreting the sustainability issues of an intermediate energy crop

(2) **INRA UMR AGIR Toulouse** – Intermediate energy crops, ecosystem services and potential for introduction into rotations

(3) **ARVALIS** – The OPTICIVE project's response to the sustainability issues of intermediate energy crops, other research perspectives

(4) **AAMF** – Feedback on the integration of intermediate energy crops into agricultural systems

(5) **SOLAGRO** – Intermediate energy crops in the METHALAE study: how can anaerobic digestion be a driver of agroecology?

(6) **SOLAGRO** – Hypotheses on intermediate energy crops in the study “A 100% renewable gas mix in 2050”

Workshop 4: Scaling up: what are the issues?

(1) **WWF France** – Feedback on lessons learned from previous workshops

(2) **IDDRI** – Evolution of agricultural and energy policy: considerations for the sector’s development

(3) **Club Biogaz** – Additional framework for anaerobic digestion activities and presentation of the Qualimétha label

(4) **AAMF** – Presentation of the AAMF Charter

(5) **ACE Méthanisation** – Tiper Méthanisation, a territorial project with multiple stakeholders: lessons and perspectives

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