SET4BIO

RENEWABLE FUELS AND BIOENERGY FOR A LOW-CARBON EUROPE – ACCELERATING THE IMPLEMENTATION OF THE SET-PLAN ACTION 8

Horizon 2020, Grant Agreement no. 884524

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EXECUTIVE SUMMARY

This report describes the main results of monitoring of the Renewable Fuels and Bioenergy sector conducted in the KPI Monitoring task of WP5 in the SET4BIO project. A KPI structure was developed to facilitate yearly monitoring and reporting of the relevant development in the sector. The monitoring activities were based on market analysis and information gathered in other Work Packages in the SET4BIO project. The results and knowledge were used for the yearly reporting procedure in the SET Plan and as a basis for further development of activities and corrective actions in the Implementation Plan of Area 8 of the SET plan. An overview of the reporting done during the years as well as selected results from the project are included. The overall development of the sector has been key inputs, and the main part was compiled in the work described in this report.

PARTNERS

RISE - Research Institutes of Sweden AB, Sweden	
SINTEF - SINTEF Energi AS, Norway	
FNR - Fachagentur Nachwachsende Rohstoffe e.V., Germany	
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VTT – Teknologian tutkimuskeskus VTT Oy, Finland	
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Content

1. Introduction

The monitoring of KPI´s in SET4BIO was developed to facilitate the SET Plan reporting and provide valuable input to the future monitoring within the scope of the SET Plan Action 8 Renewable Fuels and Bioenergy for transport. The monitoring in SET4BIO is based on a synthesis of project results in the Work Packages of SET4BIO as well as overall monitoring of the progress and key factors relevant in the sector. The KPI monitoring has been used as key input to the SET Plan progress reporting procedure during 2020, 2021, 2022, and 2023. The monitoring of development has also served as basis for a proposed update of the Implementation Plan of IWG8 presented in May 2023. In preparing the proposed update of the IP the current IP was assessed and relevant indicators were proposed.

The COVID-19 pandemic and later the unprovoked Russian invasion of Ukraine has challenged our societies alongside with the imminent need to put society on a pathway towards sustainability. In this new context where energy supply is central, bioenergy has been both challenged and highlighted. The overall conclusion is that bioenergy has a clear role to play but all aspects with regards to understanding and fulfilment of sustainability issues must be acknowledged and handled correctly to unlock the potential in the sector.

This report contains details on the following topics which were defined as the overall structure to monitor in deliverable D5.1 KPI proposal.

- Monetary volume of actions (public and private)
- Number of cases reaching the market
- Number of demonstrations/flagship projects
- Market pull, in terms of statistics on bioenergy demand
- Number of R&I actions
- Research infrastructure development
- The overall development in the IWG8 scope

The monitoring done under this task was adjusted during the project in order to match the needs in the SET-plan reporting. For example, details on specific projects of high importance were focused at one point.

2. Monetary volumes of actions

This monitoring activity is mainly based upon work in WP1 of SET4BIO and include the monetary volume of both publicly and privately funded actions related to the development on advanced biofuels, other renewable liquid and gaseous fuels, renewable hydrogen, bioenergy, and intermediate bioenergy carriers. The mapping in WP1, including actions relating to development, demonstration, and scale-up, identified in total 317 national RDI projects and 39 EU projects with key information on budget, linked to them. See Figure 1 for number of projects per SET Plan Implementation Plan 8 R&I activity (national and EU) from 2018 until today. All the projects cannot be connected to ETIP Bioenergy value chains as they are rather integrated value chains or focus on the end-use application.

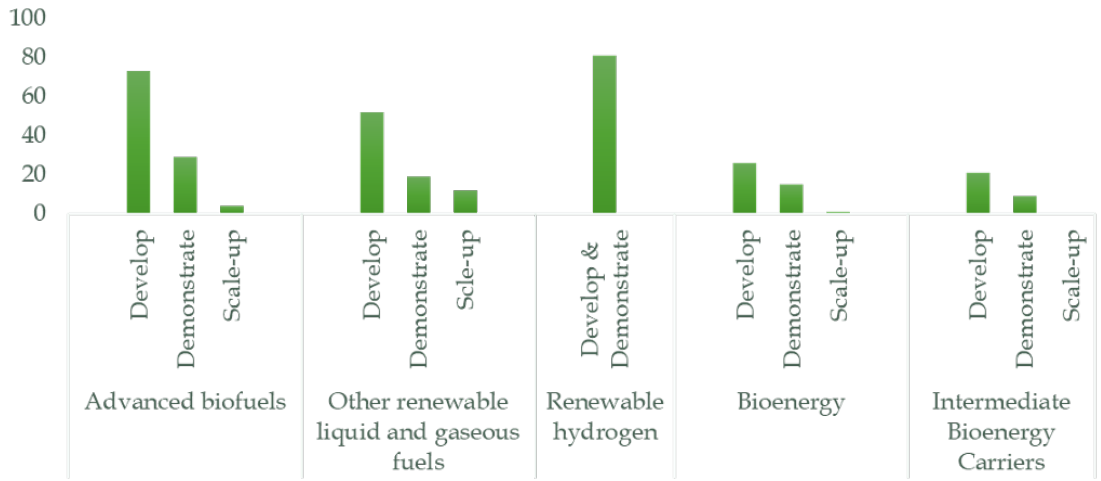

Figure 1. Number of projects in the field of renewable fuels and bioenergy.

The contribution of monitored projects to the 2030 targets of the SET Plan IP8 was analysed with data collected from 7 countries (Austria, Belgium, Finland, Germany, the Netherlands, Spain, Turkey). It was observed that more contributions are needed to fulfil 2030 targets for development set in Implementation Plan 8. Variability in the quality of data recording is high and a challenge. See Figure 2 and Figure 3 for details. It was observed that the Recovery and Resilience Facility (RRF) and Important Projects of Common European Interest (IPCEI) instruments have high impact on reported demonstration values. Countries include big bioenergy economies like Finland and Germany. EU projects collected are led by 15 different countries.

Data was provided mainly by MS representatives active in IWG8. The national funding consists of institutional funding and competitive funding.

Data gaps identified:

Typically, some of the data is missing since it was hard to obtain, e.g., relations to value chain(s) addressed in the project, TRL levels, and/or share of public/private funding. The funding situation is often not reported with respect to the different IPs of SET Plan. There is a lack of data especially at high TRL.

The list of national projects has been under continuous update and an interactive map was developed on this link: https://www.etipbioenergy.eu/set4bio/outputs-and-resources/set4bio-map

A factsheet is also available on this link:
https://www.etipbioenergy.eu/images/SET4BIO/Mapping_Bioenergy_R_I_Projects_SET4BIO_Factsheet.pdf

More detailed information is available in deliverable 1.1

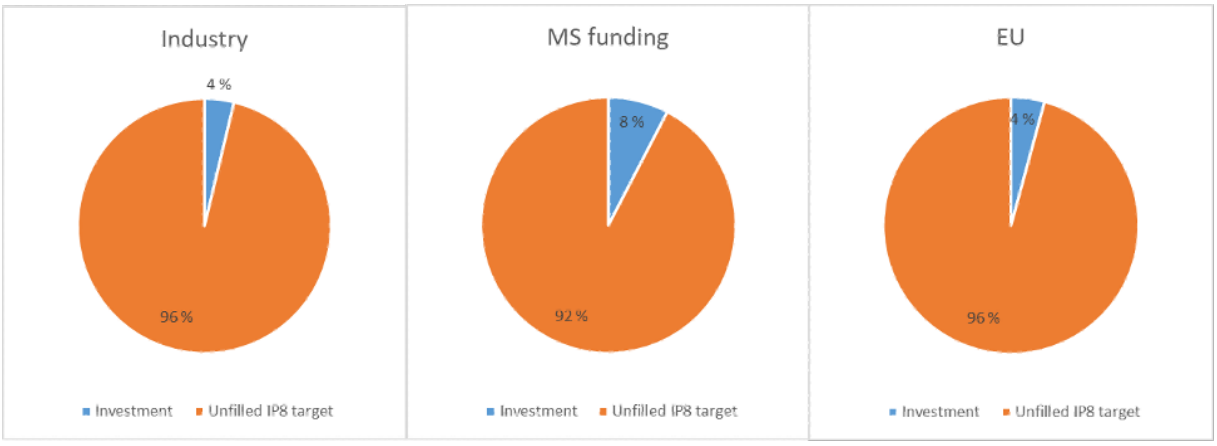

Figure 2. Contribution of monitored projects to 2030 targets of SET Plan IP8.

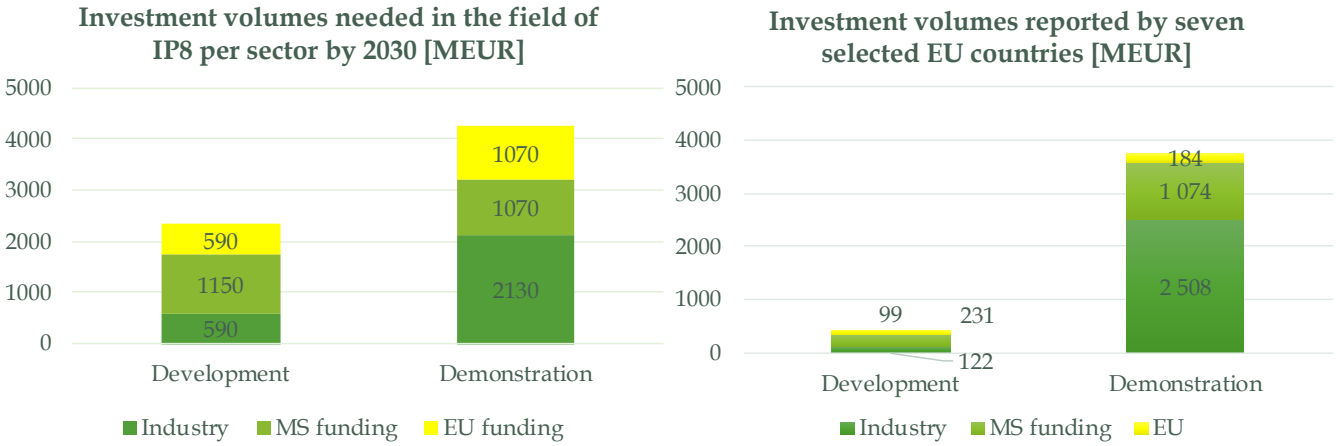

Figure 3. Investment volumes needed (left) and reported (right).

When it comes to the contribution of the monitored projects to the 2030 targets it was observed that investments in renewable hydrogen is 20-fold compared to expectations in 2018. Areas that are far from fulfilling needed contributions are Advanced Biofuels, Bioenergy, and Intermediate Bioenergy Carriers. See Figure 4 for details.

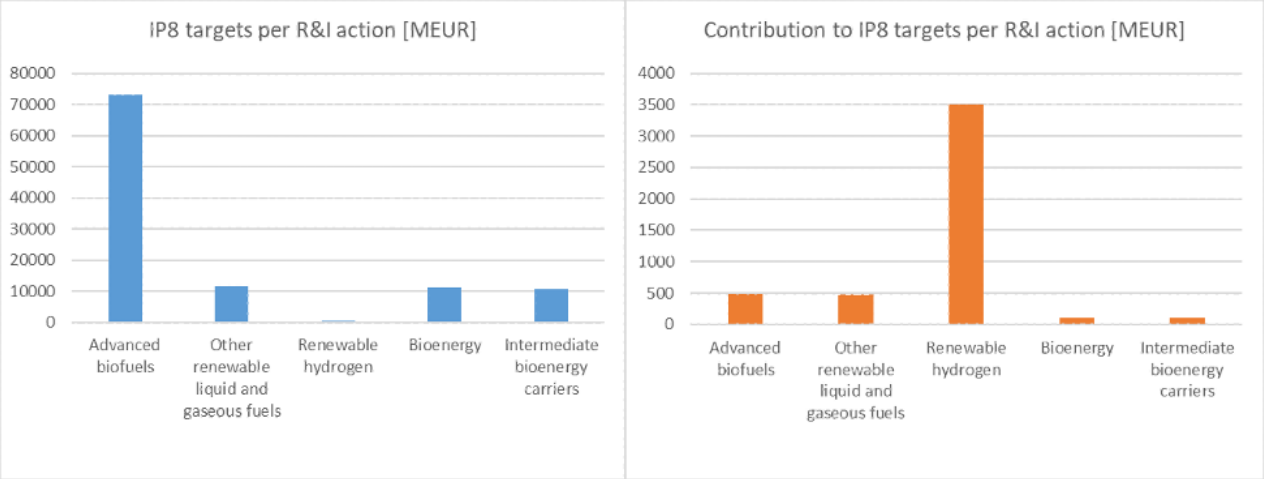

Figure 4. Contribution of monitored projects to 2030 targets of SET Plan IP8.

3. Market development

Value chain development was monitored with the aim to identify the number of cases reaching the market and the number of demonstration projects/flagship projects. It can be generally observed that several pathways are progressing positively and reaching high TRL (the market) but there is still innovation, upscaling and deployment measures needed to release the full potential of a wide range of technologies.

At the mid of 2023 there was 37 operational production plants (TRL 8-9), 4 under construction and 18 planned in the European Union (see Figure 5). The operational plants' output is the following:

- 14 HVO plants (10 producing both HVO and SAF)
- 11 Ethanol plants
- 6 Pyrolysis oil plants
- 2 SNG/Hydrogen plants
- 2 Methanol plants
- 1 Syngas/biochar plant
- 1 BioLPG plant
- 1 Isobutene plant
- 1 Diesel substitute plant

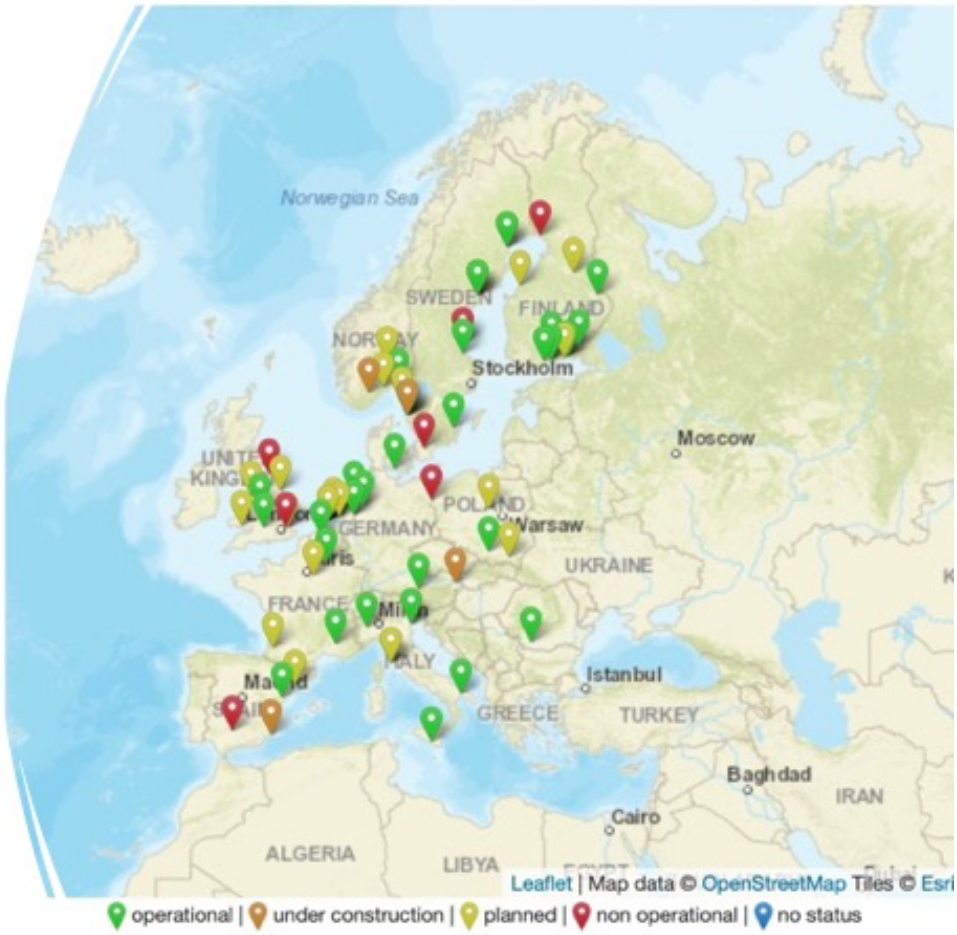

Figure 5. Production plants in EU. Source: ETIP Bioenergy.

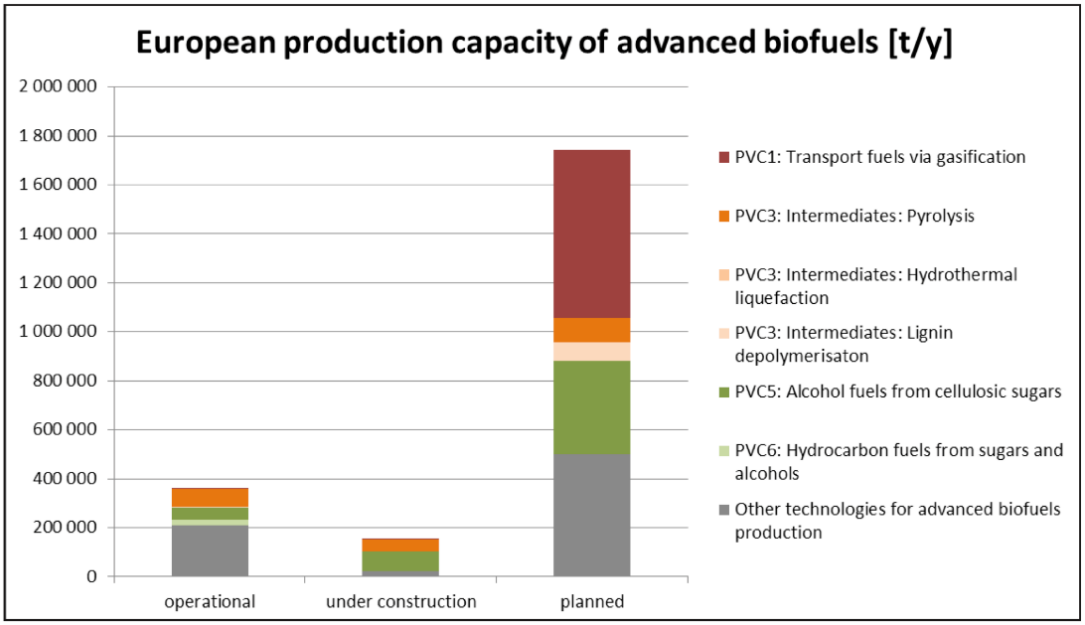

Figure 6, Production capacity for advanced biofuels in EU, ETIP Bioenergy

In general terms several technologies have progressed despite many challenges.

Factors holding back progress are mainly the following:

- Policy uncertainty on a multitude level,
- The often-unknown combined effect of the multi-layer policy initiatives,
- Feedstock, production, and end use,
- Lack of technology neutrality with unbalanced focus on single technologies such as electrification and hydrogen,
- Biomass sustainability debate – questioning of biomass in general and higher priority on other technologies,
- Market risk combined with technology risk and capital-intensive investments often represent too much risk.
- The benefits of new digital technologies are currently not combined with the technologies of the bioenergy sector. This could have significant potential going forward.

The status of value chains or so called "Strategic Areas" was reported each year in the SET Plan reporting structure. A summary is presented below.

Advanced biofuels

- Significant advancements in technology and demonstration
- Limited scale-up and market deployment
- The IP8 target for production volumes in 2020 was not fulfilled
    - 0.43 Mtoe (CETO, 2022[1]) was installed capacity compared to the 2.15 Mtoe target in IP8. ETIP Bioenergy reported 0.36 Mtoe installed capacity in March 2020 (Figure 6).[2]

[1] Advanced Biofuels in the European Union, Clean Energy Technology Observatory, European Commission, 2022
[2] Current Status of Advanced Biofuels Demonstrations in Europe, 2020, https://www.etipbioenergy.eu/images/ETIP-B-SABS2_WG2_Current_Status_of_Adv_Biofuels_Demonstrations_in_Europe_Mar2020_final.pdf

- Use was 4 Mtoe of advanced biofuels (25% of total biofuel volume). Thus, a significant amount was imported to EU
- Examples of technologies
  - BTG-BTL (TRL 9), Chemcell Ethanol (TRL 9), HTL (TRL 5-6), Methanol (TRL 8), BIOMCM and Södra, Clariant Ethanol (TRL 7-8)
- Outlook is promising but several challenges remain for scale-up and large-scale deployment
- Still challenging cost of production compared to fossil fuels

Other renewable liquid and gaseous fuels

- Several technologies are advancing in development with many projects with EU-funding and other sources
- Demonstration activities are increasing
- Limited scale-up and deployment so far
- Several technologies have reached high TRL level but still a lot to do in order to reduce cost
- Some examples
  - AUDI, Liquid Wind, CRI
- Technologies for other renewable synthetic fuels (solar fuels, microbial fuels and micro-algae fuels) are mostly at lab-scale

Bioenergy

- The technologies are developing
- Demonstration activities are planned
- Scale-up and deployment have somewhat stalled
- Potential for grid balancing with more intermittent power
- What is the relevant target? Flexibility or production?

Solid, liquid, and gaseous intermediate bioenergy carriers

- Significant advancements in development, pyrolysis oil, pellets and syngas
- Technologies are demonstrated
- Technologies have reached commercial level

The progress and status of the above-described strategic areas were assessed in SET4BIO to facilitate SET Plan reporting. The following classification was used. “GREEN” activity has been successfully carried out, projects were launched, and some finished successfully. “YELLOW” activity is ongoing, projects have been launched but have not been completed yet. “ORANGE” work is delayed, activity has started but there are project delays. “GREY” no work has been carried out for this activity. The status as of 2023 is illustrated in Table 1 below.

	GREEN Activity has been successfully carried out, projects were launched and some finished successfully	YELLOW Activity is ongoing, projects have been launched but have not been completed yet	ORANGE Work is delayed, activity has started but there are project delays	GREY No work has been carried out for this activity
* 1. Develop advanced liquid and gaseous biofuels through biochemical / thermochemical/ chemical conversion from sustainable biomass and/or from autotrophic microorganisms and primary renewable energy	◉	○	○	○
* 2. Demonstrate advanced liquid and gaseous biofuels through biochemical / thermochemical/ chemical conversion from sustainable biomass and/or from autotrophic microorganisms and primary renewable energy	◉	○	○	○
* 3. Scale-up advanced liquid and gaseous biofuels through biochemical / thermochemical/ chemical conversion from sustainable biomass and/or from autotrophic microorganisms and primary renewable energy	◉	○	○	○
* 4. Develop other renewable liquid and gaseous fuels (excluding hydrogen) through thermochemical/ chemical/ biochemical /electrochemical transformation of energy neutral carriers with renewable energy	◉	○	○	○
* 5. Demonstrate other renewable liquid and gaseous fuels (excluding hydrogen) through thermochemical/ chemical/ biochemical/ electrochemical transformation of energy neutral carriers with renewable energy	○	◉	○	○

* 6. Scale-up other renewable liquid and gaseous fuels (excluding hydrogen) through thermochemical/ chemical/ biochemical/ electrochemical transformation of energy neutral carriers with renewable energy	○	◉	○	○
* 7. Production of renewable hydrogen from water electrolysis and renewable electricity	◉	○	○	○
* 8. Develop high efficiency large scale biomass cogeneration of heat and power	◉	○	○	○
* 9. Demonstrate high efficiency large scale biomass cogeneration of heat and power	◉	○	○	○
* 10. Scale-up high efficiency large scale biomass cogeneration of heat and power	○	○	◉	○
* 11. Develop solid, liquid and gaseous intermediate bioenergy carriers through biochemical/ thermochemical/ chemical conversion from sustainable biomass	◉	○	○	○
* 12. Demonstrate solid, liquid and gaseous intermediate bioenergy carriers through biochemical/ thermochemical/ chemical conversion from sustainable biomass	◉	○	○	○
* 13. Scale-up solid, liquid and gaseous intermediate bioenergy carriers through biochemical / thermochemical/ chemical conversion from sustainable biomass	◉	○	○	○

Table 1. Status of strategic areas in IP8 from 2023 reporting.

The status of the activities in Table 1 is based on expert judgment and knowledge with regards to technology development, demonstration activities and scale-up status. The knowledge on projects, market deployment and industry insights were gathered to a large part in the SET4BIO project and in cooperation with ETIP Bioenergy. In year 2023, 10 out of 13 activities had “Green” status compared to only 5 in 2021. Overall, that illustrates positive development but the total number of projects reaching the market is still limited as shown in Figure 5. Thus, the “Green” status of technologies should be interpreted correctly and not too positively as there is still many activities needed to stimulate market uptake and wide deployment.

There is only one activity that is “Orange” in 2023 and that is the scale-up of high-efficiency large-scale biomass cogeneration of heat and power. Details were reported in the yearly reporting as follows:

Bioenergy (large-scale biomass cogeneration of heat and power) technologies are developing, and demonstration activities are planned. Scale-up and deployment have somewhat stalled due to strong competition from other power supply technologies. The technology has future potential for grid balancing with more intermittent power in the energy system.

4. Overall development in the IWG8 scope

The overall development and the important aspects/hurdles for deployment of the IWG8 scope have been monitored in the SET4BIO project through the activities in the different WPs and in particular the policy work related to WP5 and the interaction with Industry, European Commission, and the Member States during and in between the meetings in the SET Plan IWG 8 Implementation Working Group and the “Core Team” of IP8. The monitoring and reporting have been one of the major topics for discussions, dissemination, and analysis within the Implementation Working Group of IP8. Each year when the SET4BIO project was active the reporting was prepared by SET4BIO with contributions from the IWG8 Core Team and then disseminated to the Implementation Working Group Members consisting mainly of Industry, Research and Member State representatives.

The following texts summarizing the recent developments and highlights in the IWG8 scope were prepared in the SET4BIO project and submitted annually from 2020 to 2023 to SET Plan Reporting Procedure. The progress can be seen in the reporting that the project contributed with four times during the SET4BIO project (2000, 2001, 2002 and 2003). The reporting procedures changed format during the years as specific issues were raised reflecting the overall situation such as the energy crisis and the COVID-19 pandemic.

Recent developments and highlights reported in 2023 SET Plan reporting procedure

In general, the policy landscape has changed significantly from the "Fit for 55" package. The unprovoked Russian invasion of Ukraine has also changed the drivers significantly as security of supply has become acutely imminent. Renewable fuels and bioenergy can contribute significantly to energy security however it is still not understood and visible in the current policies and strategies in Europe. Activities to highlight from the ETIP Bioenergy is the process to update the SRIA which is planned to be ready after the summer. The priorities and status of the value chains have been reviewed in detail. In the CSA SET4BIO, a large number of activities have been ongoing during this period. SET4BIO has established funding and financing roadmaps to help project developers to accelerate. Projects and initiatives on EU and Member State level have been mapped and categorized in order to suggest actions and coordination opportunities. The concept of innovation challenges has been refined and described in terms of how it can contribute to the different steps of the TRL scale (see SET4BIO deliverable 3.3). A global outlook has identified plenty of different initiatives and how they could integrate and collaborate to speed up research, innovation, and deployment. Policy recommendations to the Member States and EU have been disseminated by SET4BIO at the EUBCE 2023 conference. At EUBCE 2023 in Bologna, SET4BIO also presented "The Implementation Toolbox" "SET4BIO - a framework to accelerate renewable fuels and bioenergy solutions across Europe and beyond".

Main challenges reported in 2023:

The review of investments in the Member States that is taking part in IWG8 clearly show that there is a large volume of investments for hydrogen where the recent RRP related investments resulted in a sharp increase. For the other technologies, such as advanced biofuels, which represent the largest share of the

needed investments there is still a large gap as investments have been slow. At the moment, 1% of the total investments needs for advanced biofuels have been achieved, 4% of the other renewable liquid and gaseous fuels, 854% of the renewable hydrogen, 1% of the bioenergy and 1% of the intermediate bioenergy carrier investment needs.

Recent developments and highlights reported in 2022 SET Plan reporting procedure

As reported in earlier years the sector has been hurt by lack of long-term policy frameworks and missing support and questioning of bioenergy. This has resulted in limited market uptake even though many technologies have taken several steps up in the TRL scale. The policy context has improved when it comes to policy when the Green Deal and subsequently "Fit for 55" were communicated. As the "Fit for 55" package is still under implementation/discussion it is vital to ensure that bioenergy is included with an open and transparent mindset. The role for IP8 technologies in REPowerEU is somewhat weak except hydrogen. In general targets for IP8 have been underachieved although there are exceptions. The CSA SET4BIO has passed its mid-term and a number of activities supporting the IP has been done. Some results are the finalised innovation challenge where several teams were supported to develop their ideas and concepts. Nearly all of the participants took several steps forward thanks to the challenge. In addition, an interactive map illustrating projects has been developed. The winner BIOCORE took significant steps and befitted from the expert advice on value chain potential, innovation height, business viability and scalability. In SET4BIO an industry needs, and gap assessment was done. The results showed that 52% of the respondents are familiar with the SET-Plan. The interviewees stated that they are carrying out the 13 R&I activities mainly as demonstration and development in the following categories: Advanced Biofuels, Other renewable liquid and gaseous fuels, Renewable Hydrogen, Bioenergy and Intermediate Bioenergy Carriers. There is still a lot of potential for scale-up, especially in the category of bioenergy. SET4BIO developed factsheets mapping bioenergy projects, funding roadmaps and instruments for bioenergy. SET4BIO also carried out extensive dissemination and communication activities promoting the SET plan and linked activities.

Main challenges reported in 2022:

A constant challenge is to provide a level of information and detail that attracts wide industry involvement. Industry representatives have limited time to attend meetings and sometimes activities are spread out in too many overlapping initiatives. For SME´s it is particularly hard to devote time in meetings unless there are direct business benefits. The main strategy to overcome this is to actively work in the core team and drive the different tasks in the CSA SET4BIO. For example, a number of activities in SET4BIO attracted a number of startups and smaller companies. They were supported to develop their ideas in the SET4BIO innovation challenge and in addition they were presented to potential financiers from both public and private initiatives.

An additional challenge is how the SET-plan is used and integrated into each member state. The integration in for example National Energy & Climate Plans is not uniform. In order to stimulate cooperation and streamlining as well as identifying the effective ways SET4BIO has worked on a number of tasks also interacting with the IWG members in seminars.

Recent developments and highlights reported in 2021 SET Plan reporting procedure

The policy context has been an area of continuous evolution with a degree of uncertainty for the scope of SET plan Action 8. As a fact the renewable energy directive (RED2) is being implemented at the same time

as a new version is developed (RED3). As the European Green Deal strengthens the ambitions towards sustainability in all areas several existing policy frameworks are under update and new ones are under development. The Green Deal will guide all policies going forward. This should in principle improve the market potential for sustainable bioenergy but the discussions relating to sustainability for bioenergy has not been driven by facts but more on emotions and a lack of systems perspectives. The Commission will review several pieces of legislation such as the EU Emissions Trading System, the Effort Sharing Regulation, the Land Use, Land Use Change and Forestry Regulation, the Energy Efficiency Directive, the Renewable Energy Directive, the Alternative Fuels Infrastructure Directive, and the Regulation on the Governance of the Energy Union and Climate Action.

As policy measures are updated and extended the investors in technology may become wary that the direction could change in favour of other technologies than bioenergy. Nevertheless, it is widely expressed that sustainable bioenergy will play a key role in the transition as well as a permanent solution in a sustainable society. Integration aspects and synergies have been highlighted as an importance aspect.

The 2020 reporting did not focus in detail on recent developments and highlights and is therefore not included here.

5. Conclusions and Outlook

During the years monitored, the policy context has been an area of continuous evolution with a degree of uncertainty and significant complexity for the scope of SET Plan Action 8. As a fact, the renewable energy directive (RED2) was under implementation in the Member States at the same time as a new version was developed (RED3). As the European Green Deal strengthens the ambitions towards sustainability in all areas several existing policy frameworks were and are still under update when it comes to the details. The Green Deal will guide all policies going forward. This should in principle improve the market potential for sustainable bioenergy but the discussions relating to sustainability of bioenergy have unfortunately not been driven by facts but often more by emotions and a lack of system perspectives.

As policy measures are updated and extended the investors in technology may become wary that the direction could change in favour of other technologies than bioenergy. Nevertheless, it is widely expressed that sustainable bioenergy will play a key role in the transition as well as a permanent solution in a sustainable society. Integration aspects and synergies have been highlighted as an important aspect to strengthen the market deployment potential. Integration of bioenergy has also been highlighted in the position paper of IWG8 prepared for the Berlin SET Plan conference in November 2020. The paper is available here:
https://www.etipbioenergy.eu/images/SET4BIO/SET4BIO_Bioenergy_for_a_green_economy.pdf

SET4BIO also compiled separate policy recommendations which are found in Deliverable 5.3.

A focus and interest for bioenergy and biofuels for aviation and shipping has gradually increased during the period. The main reason is that other solutions such as electrification and hydrogen are less suitable and further away in the future for these areas of transport. Most of the development and research that has been conducted in relation to the production of biofuels for the road sector is fully applicable also for aviation and shipping. As electrification and later hydrogen grows for road transport there will be less need for liquid fuels. However, the need for sustainable biofuels is expected to be significant for the foreseeable future due to the inertia in the system and the long lifetime of the existing vehicle fleet.

The National Climate and Energy Plans (NECPs) have been central to the work and discussion in IWG8. Country representatives have presented their respective NECP in the IWG8 meetings, to discuss synergies and inform on progress and plans. A special review of hydrogen in the NECPs was also presented in one of the meetings during the period. SET4BIO analysed these NECPs as well as RRF instruments in the Member States. For NECPs the following observations were made. A shift from bioenergy towards advanced liquid biofuels and biomethane, and bio-based products; focus on use of residue and waste streams. Trends: circular economy, energy storage, PtX, biofuels, energy efficiency, H2 synthesis and integration. Importance in heating and cooling sector will further increase. Updated NECPs to be published in June 2023, taking into account RED recast, REPowerEU, REFuel Aviation and FuelEU Maritime. The NECPs describe the national plans in different ways, and the plans have diverse levels on putting the planned activities into practice. Almost all countries advance the use of biomass for heating and cooling. However, they encourage paying attention to particulate emissions and efficiency of heating appliances, and therefore regulate heating with incentives and restrictions on heating devices.

A shift from power-only plants to efficient CHP plants was noticed, especially if large domestic resources are available – it was observed that feed-in tariffs and market incentives are in place. Several countries have decided to phase-out coal in power plants. Decarbonization of the transport sector is expected with alternative fuels, including biofuels, electrification and hydrogen. There is a quota obligation for biofuels in the transport sector set by many countries. Feed-in tariffs for biogas are present in Austria, France, Germany, and Portugal. Though only Poland and Portugal give explicit targets for hydrogen, several countries mention hydrogen for vehicles, development of refuelling infrastructure, and hydrogen injection in the natural gas grid. For RRP: Renewable hydrogen production and infrastructure development and strengthening of value chains are strategic areas. Clear acceleration between NECPs and RRFs. Barely any dedicated funding for bioenergy and biofuels was included. Dedicated funding (EUR 1.92 bn) for biogas development was identified.

A significant push for hydrogen has increased the activities and many projects are under development linked to industry applications and transport. Hydrogen is one of the important building blocks that will help achieving the ambitions in the Green Deal and a specific strategy for hydrogen has been presented by the European Commission. For IWG8 the recent development for hydrogen is central, and hydrogen has a role to play in transport both on its own and integrated into bioenergy value chains as well as CCS and CCU linked to biomass and non-biogenic origin. As the use and deployment of hydrogen increases, the number of potential synergies will increase.

For preparing this report, the following deliverable/s have been taken into consideration:

D#	Deliverable title	Lead Beneficiary	Type	Dissemination level
1.1	Funding and financing roadmap and investments	SINTEF	Report	Public
1.2	Report on institutional and competitive public funding opportunities	SINTEF	Report	Public
1.3	Report on private financing opportunities to support the realisation of the SET Plan IP8	CIRCE	Report	Public
2.4	Report and documentation on commitment reached by industry stakeholders	FNR	Report	Public
3.1	Innovation Challenge in SET4BIO	RISE	Report	Public
3.2	Experiences from the SET4BIO Innovation Challenge	RISE	Report	Public
3.3	Consolidate Innovation Challenge Schemes	RISE	Report	Public
3.4	Innovation Challenge in SET4BIO	RISE	Report	Public
5.1	KPI Proposal	RISE	Report	Public
5.3	Summary for policy makers	VTT	Report	Public