FlexSNG

Deliverable D7.1

Determination of KPIs for the proposed process concepts

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Document Control Sheet

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Disclaimer

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Abbreviations and acronyms

KPI Key Performance Indicator

SNG Synthetic Natural Gas

1 Executive summary

The present deliverable primarily aims to the identification of the Key Performance Indicators (KPIs) of the whole FlexSNG concept. Bearing in mind the FlexSNG concept and requirements, a specific methodology was chosen for the deliverable implementation. This methodology includes the conduction of a literature review as well as exchange opinions and experiences among the partners. Even if the details of the stakeholders identification and analysis is not a core activity of Task 7.1, the four stakeholders categories that were already agreed upon at the project proposal stage and some of their potential subcategories, are also roughly analyzed in this deliverable in order to better clarify the needs of the content of KPIs. The presented four stakeholder target groups are: key players, defenders, context setters and bystanders, while some of the identified significant subcategories are policy makers, producers and suppliers of feedstock, technology providers and manufacturing companies, gas suppliers, end-users and consumers etc. The selected KPIs were divided into four categories: technical, environmental, economic and social. For each of the four categories, a detailed list of subcategories and relevant indicators were agreed by all partners. The total number of the selected KPIs is 48. The description of each indicator, its respective unit and target value, if available, are also included in the deliverable. The final list of KPIs, which will be updated throughout the whole project duration, is designed to be used as a roadmap for the general FlexSNG assessment.

2 Introduction

The overall objective of the FlexSNG project is to develop and validate a flexible and cost-effective gasification-based process for the production of pipeline-quality biomethane (bio-based synthetic natural gas, bio-SNG), high-value biochar and renewable heat from a wide variety of low-quality biomass residues and biogenic waste feedstocks. The combination of gasification process development and feedstock supply chain optimization is expected to lead to significant cost reductions that allow lowering biomethane production costs by more than 30% compared to state-of-the-art biomass-to-SNG technologies. The FlexSNG concept and the primary development goals of the project are illustrated in Figure 1.

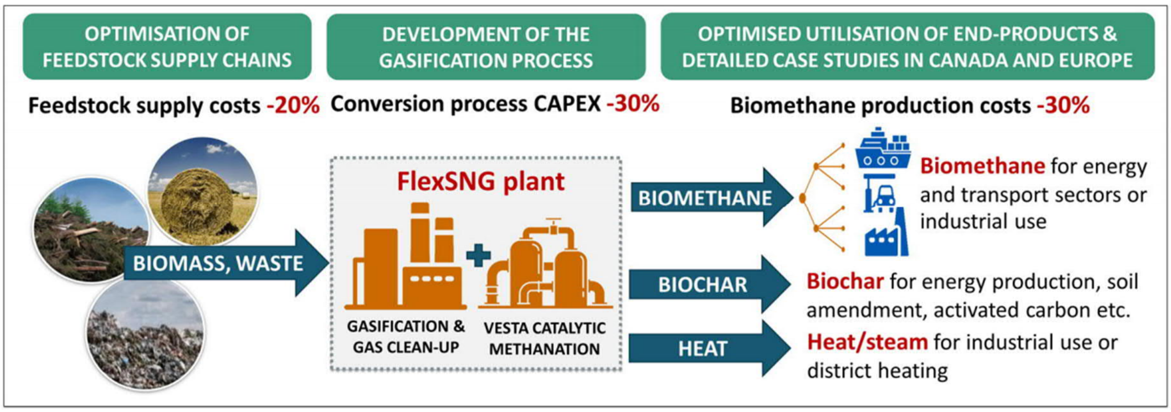


Figure 1. FlexSNG concept - Flexible production of intermediate bioenergy carriers (biomethane and biochar) and heat.

This deliverable is related to Task 7.1 - “Identification of Key Performance Indicators (KPIs)” where the overall objective was to establish a list of Key Performance Indicators that will be used in overall system evaluation and impact assessment of the FlexSNG concept. The aim was to form a coherent insight into the diverse benefits that can be delivered via the proposed FlexSNG concept. Already from the project proposal stage it was decided that the KPI list will include four different categories, which are technical, economic, environmental and social metrics. In order to select KPIs that are most relevant for the FlexSNG project, a preliminary analysis and identification of the most important stakeholders, an analytical literature review and last but not least the exchange of experiences and opinions between project partners were conducted. The data used and methodology and the final results of this approach are outlined in this report.

3 Methodology overview

For the identification and analysis of relevant KPIs for the FlexSNG project, a simple but important methodological framework was established to guarantee the best possible results. CERTH, as the leader of this task, had the responsibility of coordinating the necessary activities in order to conclude to the final lists of KPIs. The selected methodology is shown in Figure 2.

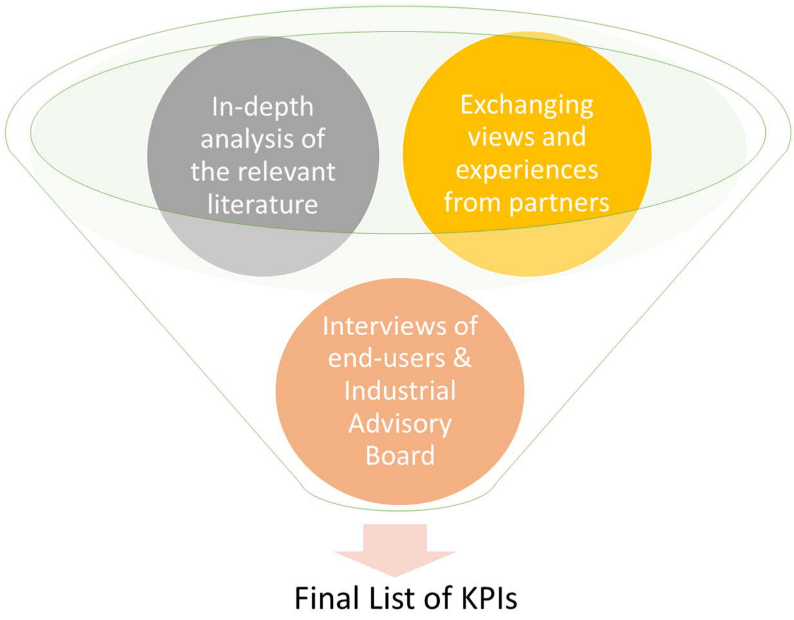


Figure 2. Elements of the methodology used to identify KPIs.

To be more specific, CERTH has developed the respective KPIs based on:

- Data collected from relevant literature, part of which is presented in the next section of this deliverable.
- Exchange of views and experiences between the FlexSNG partners (VTT, SFW, WOOD, EIFER, SF, CREAT, UL, PM, CANM, JM).
- Interviews of likely end-users, including the Industrial Advisory Board of the FlexSNG concept.

As essential part of KPIs definition was the cooperation between FlexSNG partners in exchanging views and experiences from previous projects that have similarities with FlexSNG and sharing the partners' general cognitive background. Virtual meetings were organised and datasheets shared to facilitate effective information exchange within the consortium. Moreover, although the Industrial Advisory Board was not officially established when this document was prepared and it was not possible to obtain feedback from its members, their valuable contribution will be assessed in the future. So, the list of KPIs presented in the current version of this report will be re-evaluated and updated throughout the development of the project once new experimental data and other relevant information is received. This makes the KPIs list a dynamic and constantly evolving document.

4 Literature review on KPIs identification methodologies for biofuel technologies and concepts

Biofuels production and utilization has a complex background and has broad impacts on many fields and sectors, such as the environment, economics and society.

Therefore, a sustainable biofuel development strategy that may contribute to sustainable society is possible only if established by analysing the complex features of biofuels in a comprehensive manner. In the field of public policy analysis, the concept of “stakeholders” has been widely applied to a variety of policy-making efforts. The application of stakeholder perspective to analysing the sustainable deployment of biofuels, the way of defining stakeholders can vary significantly. In order to achieve a robust strategy, it is necessary to have a long-term stakeholder perspective [1].

The biofuel policy impacts are still highly uncertain being neither linear nor proportional while depending on local, national and international contexts. Defining a set of relevant sustainability criteria is necessary for the planning of the stages for renewable energy deployment, especially for biofuels. The sustainability assessment of biofuels requires dealing with a wide range of criteria, whether economic, social, environmental or legal issues. Depending on the problem characteristics, stakeholder participation can take many forms and different degrees of involvement ranging from informing the public to co-producing knowledge and policy plans. According to Baundry et al. (2017), the selection of the set of indicators for the assessment of biofuel sustainability should be based on the following criteria:

- Completeness: through the participatory process, completeness requires that all the relevant points of view be captured;
- Operationality: the set of criteria should be measured on an appropriate scale while ensuring both data and information availability;
- Non-redundancy: within each stakeholder group, sustainable criteria should not measure the same thing;
- Homogeneity: within each stakeholder group, an agreement about the set of criteria group can be reached [2].

According to Stephan Gold (2010), when competition evolved from an inter-firm to an inter-supply-chain, the concept of supply chain management gained more and more momentum and was also already related to sustainability management. Supply chain cooperation may be defined as “two or more companies working together to create a competitive advantage and higher profits than can be achieved by acting alone”. Hence, this refers to distinct goal-oriented partner-focused interaction among supply chain actors. At the same work, Gold identified and classified the most relevant stakeholders of bio-energy production systems, and used the basic distinction between:

- the members of the supply chain themselves (thus representing a very narrow view of stakeholders), and
- external stakeholders (thus representing a medium or broad view of stakeholders).

The latter have been inductively subdivided on basis of the analysed material into three groups: (1) governmental bodies, (2) non-governmental organisations (NGOs) and associations, and (3) residents, consumers and citizens. Figure 3 summarises the three structural dimensions and their analytic categories applied for this analysis: challenges of bio-energy, supply chain actors, stakeholder groups and benefits of bio-energy[3].

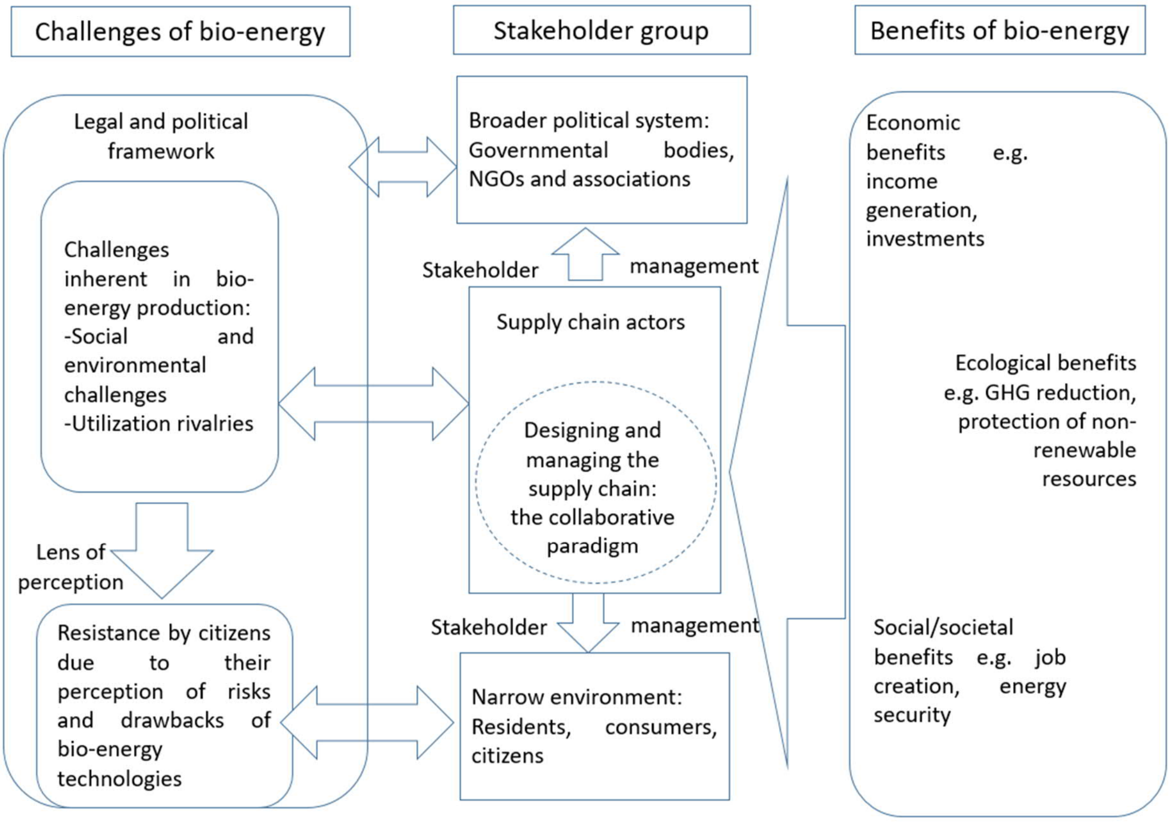


Figure 3. Conceptualizing supply chain actors and other stakeholders between challenges and benefit of bio-energy.

Another work carried out by Dale et al. (2018) also investigated stakeholder perspectives across the biofuel value chain in the context of bridging biofuel sustainability indicators and ecosystem services through stakeholder engagement. Stakeholders in the biofuel systems discussed in this paper include anyone that is affected positively or negatively by changes in the provision of ecosystem services and socioeconomic conditions associated with the production of feedstock or biofuels. Stakeholders across the biofuel supply chain are diverse and range from rural feedstock suppliers and farmers to the final consumers of renewable fuel. Developing some agreement on the key issues around biofuel production and use is important for identifying paths toward biofuel sustainability. Deploying systems that can monitor effects on indicators is challenging but necessary to maintain support and guide decisions that result in the long-term sustainable management of feedstocks used in biofuel production. The key elements of the questions asked from the key players of the feedstock production, feedstock logistics, conversion to biofuel and biofuel logistics processes of this paper are shown in Figure 4. The individual and the group perspective have been taken under consideration [4].

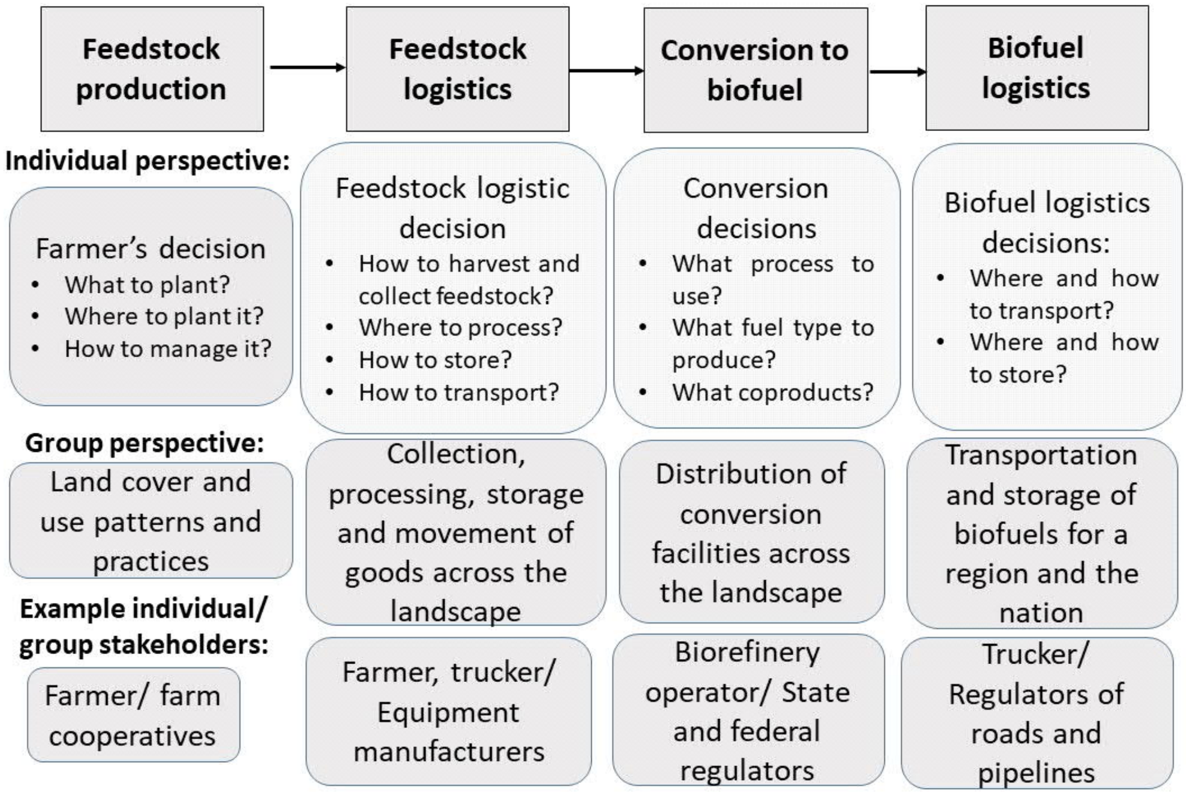


Figure 4. Stakeholder perspectives across the biofuel value chain.

Fawzy et al. (2015) also considered the use of stakeholders' perspectives and mentioned that researchers in biofuels also note requirements from contracts and regulations, raw material sources, as well as social, cultural, and political sources. In this work, a map initially suggested by Youngs in 2012 is presented. This map, shown in Figure 5, indicates the stakeholders' perspectives and their influence on biomass source selection. The arrows indicate the direction of stakeholder influence and the number on each link indicates the degrees of separation between the stakeholder and the feedstock source. Dashed lines denote the role of academia in biofuel research that should not be underestimated [5].

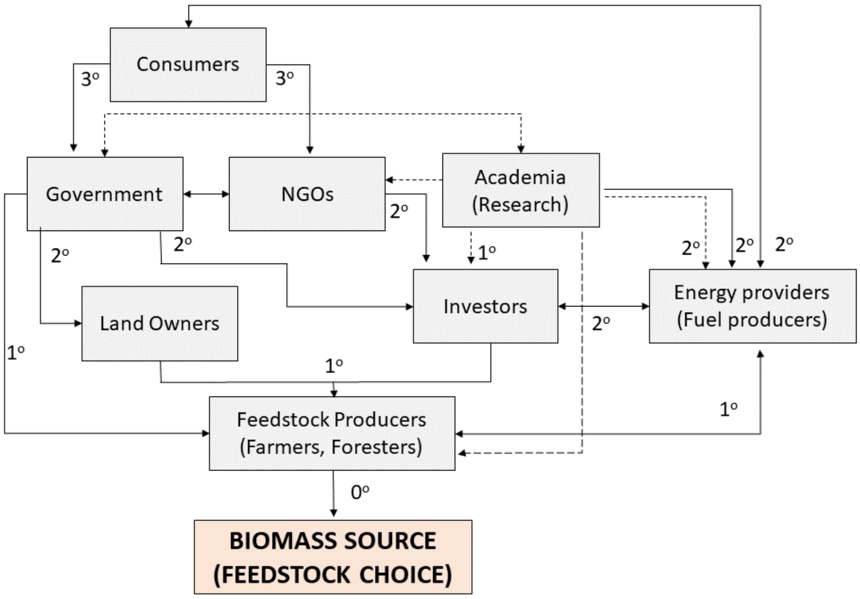


Figure 5. Map of stakeholders' interactions that influence biomass feedstock choices.

The most significant part of this deliverable is the final identification of the key performance indicators that will be used for the evaluation of the whole FlexSNG concept. In a review of key environmental and energy performance indicators for renewable energy systems, Kourkoumpas et al. (2018) proposed a methodology for KPI definition that is illustrated in Figure 6. This work indicates that KPIs are used to measure, quantify and evaluate the performance of a system/component/technology in relation to the scope, targets and objectives, this was designed to achieve during its demonstration and application. The indicators are not merely data; rather, they extend beyond basic statistics to provide a deeper understanding of the main issues and to highlight important relations that are not evident using basic statistics. The classification of the KPIs could be divided into three steps:

- Before the first step towards building up and selecting the most appropriate repository of KPIs, it needs to be clear what purpose the KPIs are expected to serve. In general, the available different types of indicators can be classified into four major domains, i.e. (a) the Social, (b) the Economic, (c) the Environmental and (d) the Technical, depending on the type and role they are selected and formulated to serve.
- The second step is the in-depth understanding of the process to allow for the proper collection of the inputs needed for the KPIs calculation.
- The third step of KPIs classification, after their selection, is putting in place the verification measures to ensure that the KPIs meet the quality expectations in terms of decision-making. By using the appropriate KPIs, it is feasible to achieve the need for scalability and replicability of the assessment results, and in that way increase the impact and the benefit of the assessment [6].

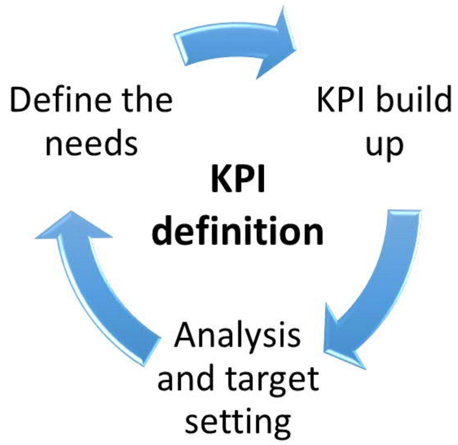


Figure 6. Methodological elementary approach for KPI definition.

Dale et al. (2015) designed and presented a framework to facilitate decision-making about which indicators are useful for assessing sustainability of bioenergy systems and supporting their deployment. Recognition of the need for comparable bioenergy sustainability indicators and associated measures has resulted in efforts to establish a standard suite of indicators. A suite of indicators can serve as a reservoir from which to compose subsets of indicators that meet specific goals. General agreement exists about the relevance of soil and air quality, water quality and quantity, GHG emissions, productivity, and biodiversity as categories of indicators of environmental sustainability. However, some indicators focus on management practices even though there is limited knowledge about which practices are 'sustainable'. Furthermore, most existing approaches use indicators that are too numerous, costly, broad, or difficult to measure. Their work reviewed some existing approaches and then presented a framework for the indicator selection as shown in Figure 7. It should be mentioned that steps for the framework are shown in blue and supporting components of the assessment process are in green. Furthermore, steps 1, 2, and 3 interact and occur concurrently. The framework allows stakeholders to articulate their priorities and values and hence to narrow the long list of potential indicators to those most useful in a particular situation, while represents an interdependent relationship among goals, context, and stakeholder values [7].

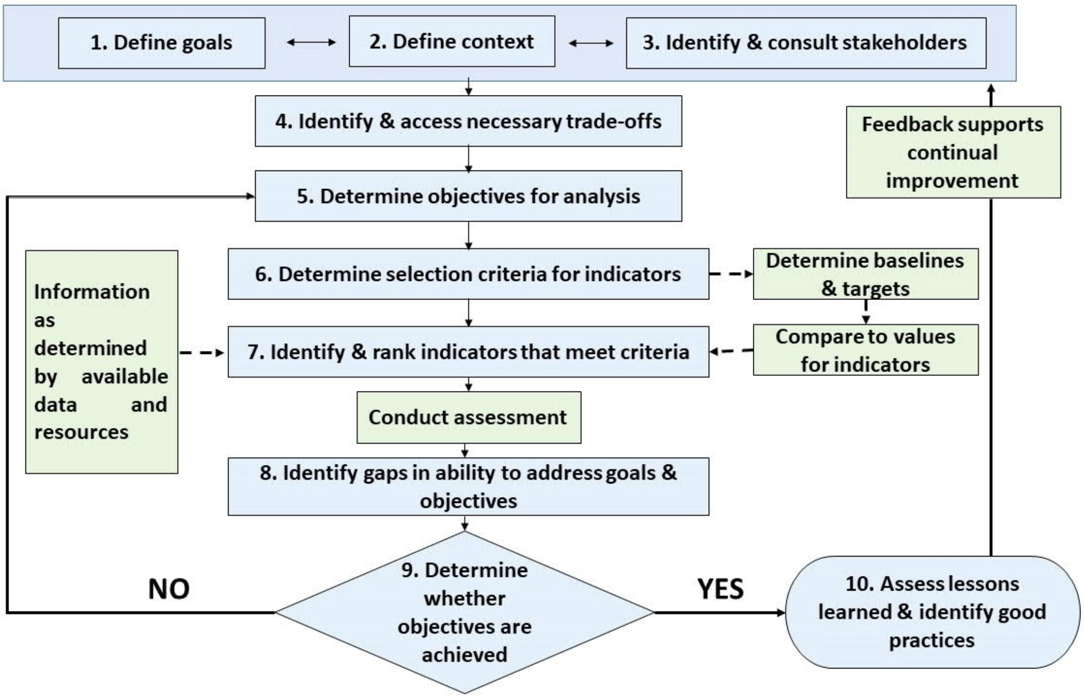


Figure 7. A framework for selecting and evaluating indicators of bioenergy sustainability.

Efroymson et al. (2013) wanted to put some light specifically on the context of the environmental of biofuel sustainability. This work stated that the purpose of a sustainability assessment determines which indicators are needed and how they are measured or modeled. Indicators can be used to assess and communicate the status of the environment, sometimes with respect to a target; to monitor trends; to provide early warning signals of changes; to provide evidence concerning causes of observations; or to compare (e.g. water quality for biofuel systems as compared with another fuel source, feedstock, or land use). Indicators may be used to measure changes in the environment when best management practices are implemented. Definitions, goals, and priorities for sustainability must be clearly stated so there can be a strong relationship with what is measured. Comparative decision contexts influence the choice of potential environmental sustainability indicators. Some decision contexts require the comparison of biofuel systems with reference scenarios, different energy sources (such as fossil gasoline), alternative land uses, or more specific siting alternatives. For example, feedstock, pipeline, or refinery siting decisions may require comparisons among alternate locations. The before mentioned are summarized in Figure 8 [8].

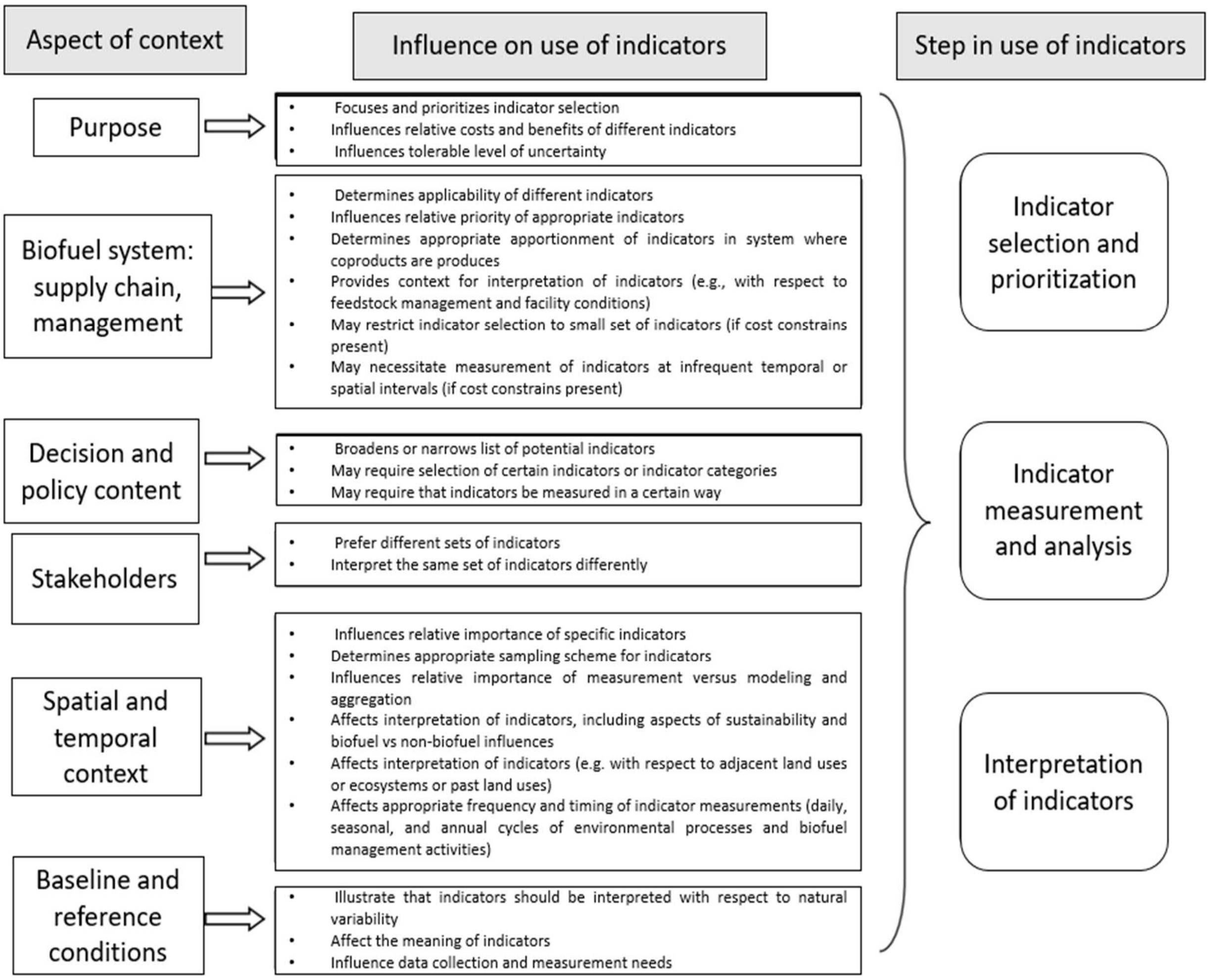


Figure 8. Aspects of the context of a resource-management question that influence selection, measurement, and interpretation of environmental sustainability indicators for biofuels.

In the work performed by Fawzy M. et al. (2015), the stakeholders' requirements were essentially split into five categories (Figure 9): environmental, economic, technical, social and legal. A similar approach could potentially be adopted in FlexSNG to categorize the key performance indicators. [5]

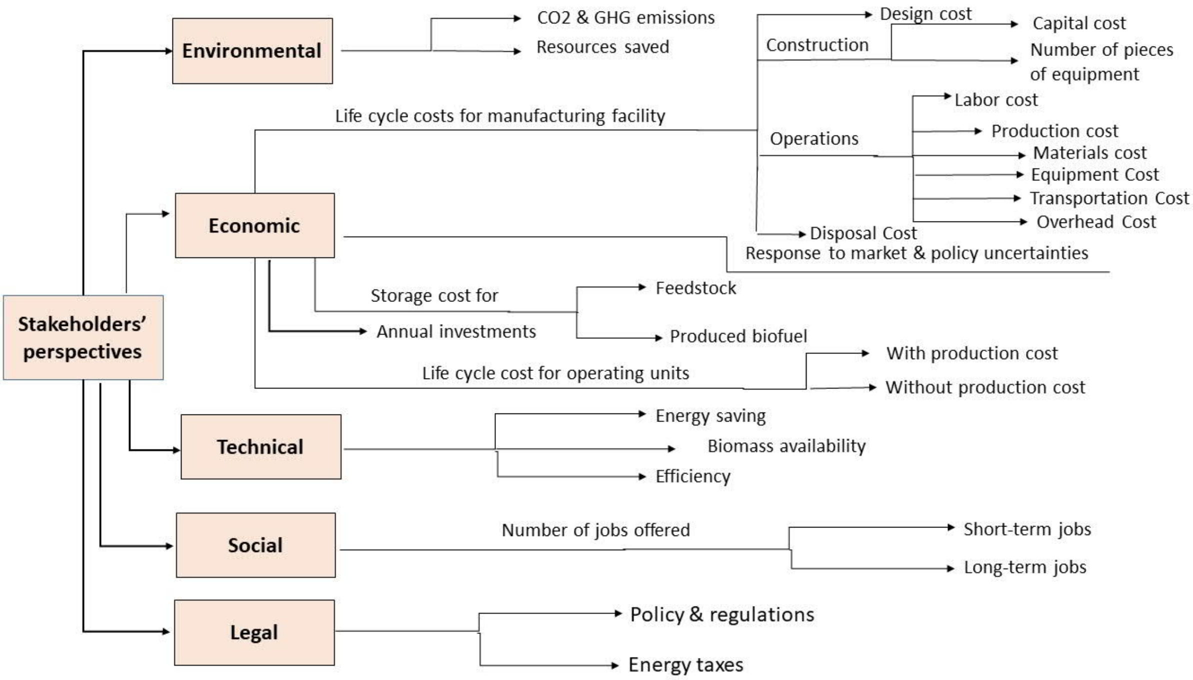


Figure 9. Indicator categories of stakeholders' perspectives.

5 Initial overview of stakeholders

Even from the preparatory phase of the FlexSNG project, the importance of identifying the most significant groups of stakeholders was evident. In the proposal stage, the project partners already defined the most relevant stakeholders and divided them into four different categories depending on their influence and interest on the project (Figure 10): key players, context setters, defenders and bystanders. During project execution, dissemination actions aim at spreading the generated knowledge widely throughout the scientific community, stakeholders and potential users. The Communication and Dissemination Plan (C&DP) to be implemented in WP9 will analyze in-depth the different stakeholders groups and will define the dissemination and communication activities that are needed to engage them during and beyond the project lifespan. Although detailed analysis of the FlexSNG stakeholders will be performed in WP9, a rough analysis of the potential subcategories of each target group is considered valuable also for this deliverable to better understand how and why the KPIs presented in this report were selected. Therefore, the pre-defined stakeholder categories and their subcategories are briefly described below.

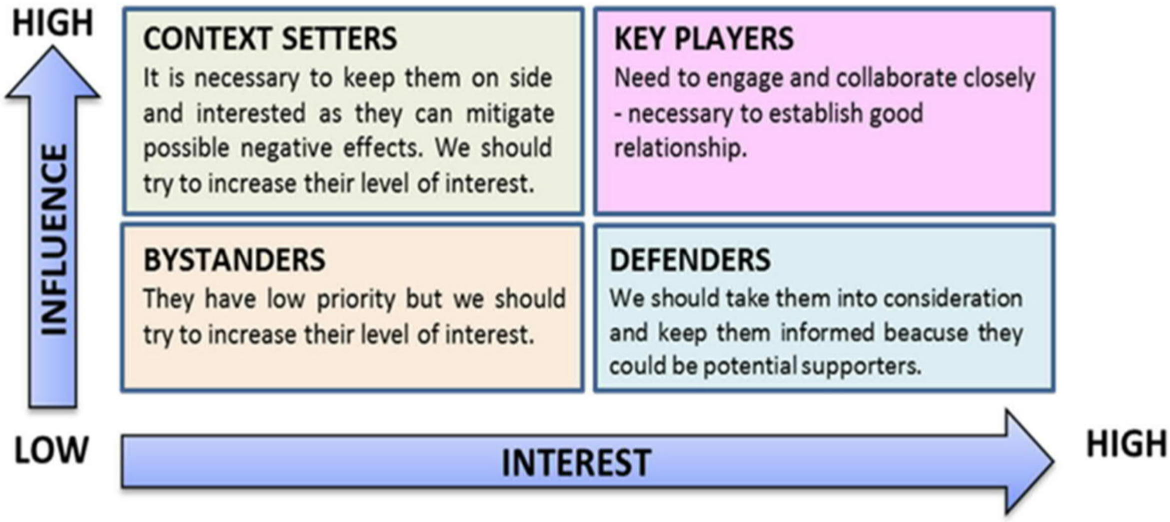


Figure 10. Initial target group categorization of FlexSNG stakeholders.

5.1 Key players

Key players are organizations that have both a high interest in FlexSNG solutions and a high level of influence on the project and follow-on demonstration. These players are engaged to build a relationship for use during and after the project. For example, decision makers within the participating industrial companies and members of the Industrial Advisory Board (IAB), energy and environmental authorities (local, national, and EU level), potential financial bodies for demo plants, technology and equipment providers, selected companies from heat, power and gas industry, chemical industries and companies with a clear policy towards renewable energy and/or fuels, feedstock providers from the agro-forestry sector and municipalities (wastes). Potential subcategories within the "Key players" target group are shown in Table 1.

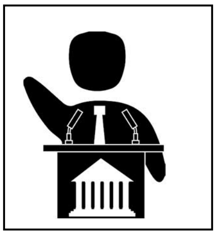
Table 1. Subcategories of "Key players".

Subcategories of Key players
Producers/distributors/suppliers of feedstock
 One of the major issues associated with the use of any biomass resource is its supply chain management. Within this target group, there are subgroups such as farmers, landowners, transporters, distributors, and suppliers of raw material. Regional and seasonal availability of biomass as well as storage problem are key parameters that could potentially affect the economic efficiency and the environmental sustainability of the project and will be examined in detail. The suppliers have been identified as the subgroup which is mainly responsible to plug in the gap between biomass resource availability and demand.

Technology providers & manufacturing companies

This group includes technology providers as well as manufacturing companies. Some of the relevant technology providers are already included in the FlexSNG consortium and have a technological contribution to the FLEXSNG concept.

Governmental/policy makers

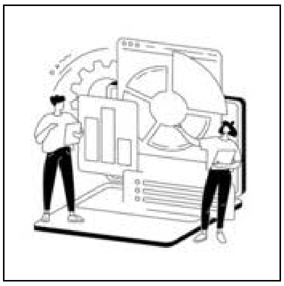


Governmental actors influence each of the previously mentioned stakeholders as this group contains the strategy and the policy which is followed to strengthen biofuel production and establish guidelines for the development of the sector. Biomass exploitation, fuel quality requirements and blending percentages are all matters that lie in legislative obligations and prohibitions that may also vary from country to country. The need for an enabling governmental framework with clear legislative signals that will create market incentives and trigger the grow-up of sustainable technologies for alternative fuel production, is evident.

Potential financial bodies

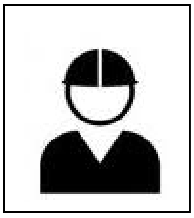
Potential financial bodies of such projects are the European Union itself, other international, European or national "green" funds, companies from different industrial sectors through their R&D departments etc.

5.2 Defenders



Defenders are organizations that have a high interest in FlexSNG, but lack high level of influence on the project or its follow-on industrial demonstration phase. Such entities will be regularly informed to keep their interest active. Members of this group could potentially become key players after the demonstration has been completed and the technology is ready for commercial deployment. For example: European Natural Gas Vehicle Association, engineering and consulting companies from different industrial sectors, representatives from the energy, material and agricultural sectors as potential users of biochar as well as selected representatives of the transport sector as potential users of bio-SNG (maritime and heavy-duty road transport). Potential subcategories in the "Defenders" target group are shown in Table 2.

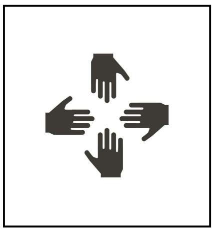
Table 2. Subcategories of "Defenders".

Subcategories of Defenders
Gas suppliers
 This important target group includes gas distribution and transmission operators who are in fact the "'intermediate" suppliers of the final FlexSNG products to the final end-users, and consumers.
End users and consumers
 They are the targeted final recipient of the products of the FlexSNG project. This group is actually represented by two different subgroups: the end-users and the consumers. The first reflects more the needs of the biochar chain and could consist of steel, cement, and fertilizing companies. It is maybe the most vulnerable stakeholder group since every aspect of the selected fuel must comply with the user demands concerning prices, performance, supply chains, storage ability, and existing infrastructure compatibility. Some members of this group could possibly be willing to proceed to partial retrofitting of their infrastructure either because a new fuel could offer a more favorable balance among the other mentioned demands or because of obligations derived from policies.

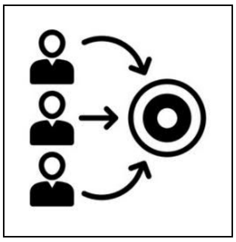
5.3 Context setters

Context setters are organisations that have a high level of influence in the context of renewable energy and fuels but a low interest in the FlexSNG project itself. Communication with this stakeholder group is aimed at increasing their interest towards the project by providing information on the potential benefits of FlexSNG. For example: Biogas and Bioenergy Associations, European Biofuels Technology Platform, Waste-to Energy Research and Technology Council and the scientific community. Potential subcategories within the "Context setters" target group are shown in Table 3.

Table 3. Subcategories of "Context setters".

Subcategories of Context setters	
Innovation and Research Centers/Institutions	
	This is a group that will be investigated mainly internally, as some key research centers and institutes are already members of the consortium and will take part in the FlexSNG project activities. These parties are expected to offer added value regarding process integration, optimization, and scale-up standards as well as project dissemination and exploitation. They will also prepare the ground and act as a support for the technology providers.
Biogas, Bioenergy and Biofuels Associations	
	Biogas, Bioenergy and Biofuels Associations on an international, European or national level could have a significant contribution to the policy framework that concerns projects like FlexSNG. Moreover, such associations are pressure levers for possible funding and means of knowledge dissemination activities of projects like FlexSNG.

5.4 Bystanders



Bystanders will receive the lowest priority and intensity in communication, as they do not play a decisive role in the initial development nor in the demonstration phase. However, they may become important at later stages of commercialization. For example: cities and regions in Europe and North America, large multinational industries in the area of oil refining, forest energy and chemical industries and the Confederation of European Waste-to-Energy Plants "CEWEP". Potential subcategories within the "Bystanders" target group are shown in Table 4.

Table 4. Subcategories of "Bystanders".

Subcategories of Bystanders	
Non-Governmental Organizations (NGOs)	
	Nongovernmental organizations are generally considered as key external stakeholders. The pressure they usually exert on government and state agencies in combination with the fact that they are often sources of information and awareness of citizens, make this stakeholder a key role in the penetration that a project can have in society. Especially in projects relevant to the energy and environment sector, NGOs are a necessary ally.
Citizens	
	Every citizen, whether he/she lives near a project site or not, whether he/she is an employee of the project or not, whether a consumer or not, can have any opinion or influence (direct or indirect) from the project implementation and development. This makes society as a whole a potential stakeholder of the project.

6 Key Performance Indicators

After thorough analysis of relevant literature, exchange of valuable views and experiences between the FlexSNG partners and careful consideration of the stakeholders' perspectives, the initial list of Key Performance Indicators was established for the FlexSNG project and divided into four categories: technical, environmental, economic and social. It should be again emphasized that the indicators presented in the following paragraphs will be re-evaluated and updated if needed as new data becomes available during the project.

6.1 Technical Key Performance Indicators

Technical KPIs, as shown in Table 5, have been divided into five different subcategories as follows:

- Handling of raw material,
- Gasification process,
- Gas cleaning,
- Final production, and
- Oxygen transport membrane (OTM) technology.

Table 5. Overview of Technical Key Performance Indicators.

TECHNICAL KEY PERFORMANCE INDICATORS				
S/N	NAME	UNIT	DEFINITION	TASK REFERENCE
Handling of raw material				
1	Feedstock supply	MWh/year	The quantity of biomass residues and wastes that can be secured and supplied at the FlexSNG plant gate.	2.2
Gasification process				
2	Feedstock flexibility of the gasification process	No of types of feedstocks	Number of different types of biomass residues and biogenic wastes that are effectively tested for gasification during the project.	4.2, 5.2
3	Biomass or waste gasified	%	Percentage of biomass/waste effectively gasified in order to obtain the biofuel product.	4.2, 5.2
4	Carbon conversion in the gasifier	%	Fraction of carbon in the feedstock that is transferred to gas during gasification.	4.2, 5.2
5	Carbon conversion to biochar	%	Fraction of carbon in the feedstock that is converted to biochar in co-production mode.	4.2, 5.2
6	Reduction in gasifier oxygen demand	%	Reduction in gasifier's oxygen demand (co-production mode) in comparison to state-of-the-art steam/oxygen-blown gasification technology.	4.2, 5.2, 7.2
7	Cold gas efficiency	%	Fraction of the chemical energy in the feedstock (LHV-based) that is converted to syngas in the gasifier.	4.2, 5.2, 7.2

It should be pointed out that the FlexSNG project aims at:

- ✓ Maximised production of biomethane and heat: over 99% carbon conversion is achieved in gasification
- ✓ Co-production of biomethane, biochar and heat: 20% of biomass carbon converted to biochar, and 20% reduction in gasifier's oxygen demand achieved compared to state-of-the-art steam/oxygen-blown gasification

Gas cleaning				
8	Hot gas filtration	Particulate removal (%)	Percentage of particulates removed in the filter.	4.2, 5.2
9		Removal of alkali and heavy metals (ppm-wt)	Concentration of alkali and heavy metals in the gas after filtration.	
10	Catalytic reforming	Conversion (%)	Conversion of tars, benzene and light hydrocarbons (incl. methane) in the reformer.	4.2, 5.2
11		H_2/CO molar ratio (mol/mol)	H_2/CO molar ratio in syngas obtained after reforming.	
12	Removal of ammonia and HCl via water scrubbing	Concentration (ppmv)	Concentration of ammonia and HCl in syngas after water scrubbing.	4.2, 5.2
13	Bulk sulphur removal	Concentration (ppmv)	Concentration of H_2S in syngas after bulk sulphur removal (activated carbon bed).	4.2, 5.2
14	Final removal of syngas impurities	Concentration (ppmv)	Concentration of syngas impurities after guard beds (H_2S, COS, NH_3, HCN, HCl, tars, benzene).	4.2, 5.2

It should be pointed out that the FlexSNG project aims at:

- ✓ Filtration: > 99.9 % removal of particulates, content of alkali and heavy metals < 0.1 ppm-wt at filter outlet
- ✓ Catalytic reforming: > 99 % conversion of tars and benzene, > 99 % conversion of C_2-C_5 hydrocarbons, < 30% methane conversion, and H_2/CO molar ratio in the range of 2-3 after reforming
- ✓ Bulk sulphur removal: < 1 ppmv of H_2S in syngas after bulk sulphur removal
- ✓ Final gas polishing: concentration of syngas impurities after final gas cleaning in ppb-level

Final production				
15	Conversion efficiency to biomethane (mass basis)	%	Fraction of feedstock that is converted to biomethane (mass basis).	6.3, 7.2, 7.3, 7.4
16	Conversion efficiency to biomethane, biochar and renewable heat (energy basis)	%	Fraction of the chemical energy in the feedstock (LHV-based) that is converted to biomethane, biochar and renewable heat.	6.2, 7.2, 7.3, 7.4
17	Total carbon utilization factor	%	Fraction of carbon in the feedstock that is converted to final products biomethane and biochar.	5.2, 7.2
18	Quality of biomethane	Density (kg/L)	Characteristics and properties relevant to the end-use of biomethane and distribution via existing natural gas infrastructure. Wobbe Index (WI) is used to describe the interchangeability of fuel gases by comparing the combustion energy output between the different compositions of fuel gases.	6.3, 7.4
19		Sulphur content (wt-%)		
20		Wobbe Index (MJ/m^3)		
21	Quality of biochar	Carbon content (%)	Characteristics and properties relevant to the end-use of biochar product.	6.1, 6.2
22		LHV/HHV (MJ/kg)		
23		Surface area (m^2/g)		
24		Ash content (%)		
25	Total electricity consumption	kWh consumed /kWh of produced biofuel	Electricity consumed in the FlexSNG process to produce 1 kWh of final biofuel.	3.3, 7.2, 7.3, 7.4
26	Total water consumption	tonne water/tonne biofuel	Water consumed in the FlexSNG process to produce 1 tonne of final biofuel.	7.2, 7.3, 7.4
27	Reduction in energy consumption	%	Reduction in energy consumption by making use of the FlexSNG process instead of the state-of-the-art (fossil fuels).	7.2, 7.3, 7.4

28	Potential productivity	kWh/year	Potential production of biofuels in the FLEXSNG plant.	7.2, 7.3, 7.4
It should be pointed out that the FlexSNG project aims at: ✓ Medium-scale conversion plants of 50-150 MW thermal input ✓ Producing pipeline-quality biomethane with a methane content of 96-98 vol-% ✓ Co-production of biomethane, biochar and heat: 45% of the feedstock energy converted to biomethane, 25% to biochar and 10% to usable heat. ✓ Maximised production of biomethane and heat: 70% of the feedstock energy converted to biomethane and 15 % to heat.				
Oxygen transport membrane (OTM) technology				
29	Improvement in oxygen production rate	%	Oxygen production rate improvement compared to the latest EU project where OTMs were optimized for use in biomass gasifiers.	3.1, 3.2, 3.3
30	Energy consumption in oxygen production	kWh/tonne O_2	Energy consumption per tonne of oxygen produced.	3.1, 3.2, 3.3
31	Oxygen purity	%	Purity of oxygen delivered via OTM technology.	3.1, 3.2, 3.3
It should be pointed out that the FlexSNG project aims at: ✓ Oxygen purity >99.5 % ✓ Energy consumption of 160 kWh per tonne of oxygen produced				

6.2 Environmental Key Performance Indicators

Table 6 shows a list of the seven environmental Key Performance Indicators that were selected for the FlexSNG project. The main pillars are the life-cycle GHG emissions and their reduction, the ozone depletion reduction and the energy efficiency demands. Taking into consideration the climate crisis, the identification of the environmental key performance indicators is considered as a very significant attempt towards the implementation of sustainable strategies. As stated in the proposal of the FlexSNG project, Task 8.2 will focus on the environmental assessment of the proposed concept, according to the international standards and guidelines (such as ISO 14044). An integrated environmental analysis that is based on the scenarios examined in WP7 will be carried out by CERTH for all considered concepts (biorefinery/cityrefinery/hybrid plant) and both examined modes of operation (co-production and biomethane-alone production). The utilization of biomethane and biochar will be investigated based on a GHG savings performance analysis.

Table 6. Overview of Environmental Key Performance Indicators.

	ENVIRONMENTAL KEY PERFORMANCE INDICATORS			
S/N	NAME	UNIT	DEFINITION	TASK REFERENCE
1	Life-cycle GHG emissions	kg CO2eq./ MJ	GHG emissions from the production of 1 MJ of biofuel, including all the life cycle stages from the feedstock supply chain to catalytic methanation and production of end-products.	8.2
2	GHG emissions reduction	kg CO2eq./ MJ	Reduction in GHG emissions by the investigated FlexSNG concept in comparison to conventional biomass-to-SNG technologies and fossil equivalents.	
3	Cumulative Energy Demand (CED)	MJ	The direct and indirect energy use throughout the whole life cycle of biomethane production, including the energy consumed during the extraction, manufacturing and/or disposal of the raw and auxiliary materials.	
4	Heavy metals contaminants reduction	kg/kg biomethane	Reduction in heavy metals contaminants through their capture in the investigated gasification and gas clean-up processes.	
5	Reduction in respiratory inorganics potential	kg PM2.5eq./kg biomethane	Reduction in inorganic particles released into the air by substituting fossil transport fuels with biomethane.	
6	Ozone formation reduction	kg NOx/kg biomethane	Reduction in NOx released into the air by substituting fossil transport fuels with biomethane.	
7	Energy Returned on Energy Invested (EROEI)	MJ/MJ	Ratio of energy produced to energy required (based on life cycle approach).	

6.3 Economic Key Performance Indicators

The economic Key Performance Indicators are listed in Table 7. The techno-economic assessment of the FlexSNG concept is conducted in WP7 and further in WP8 where the implementation potential of the FlexSNG concept in terms of techno-economic performance as well as socio-economic and environmental impacts will be analysed in different case study scenarios both in Europe and Canada. WP8 will also assess the business potential and the advantages of the FlexSNG concept over competing technologies in each case study region both qualitatively and quantitatively, taking into account also system integration aspects.

Table 7. Overview of Economic Key Performance Indicators.

ECONOMIC KEY PERFORMANCE INDICATORS				
S/N	NAME	UNIT	DEFINITION	TASK REFERENCE
1	Specific capital cost (CAPEX)	€/kW of biofuel produced	Specific capital cost of the commercial-scale FlexSNG plant per kW of biofuel produced. The full value chain and costs related to the main functions of the FlexSNG concept (incl. gasifier and gas clean-up vessels, synthesis reactors and peripheral units, etc.) are considered.	7.2, 7.3, 7.4, 8.1
2	Operational costs (OPEX)	€/L	Total costs related to the operation of the FlexSNG process, including labor, maintenance, electricity and consumables etc, per litre of final fuel.	7.2, 7.3, 7.4, 8.1
3	Reduction in feedstock supply costs	%	Reduction in feedstock supply costs achieved by optimization of feedstock supply chains and logistics (to be verified by optimization models).	2.4, 2.5, 8.1
4	Total cost estimation	€/L	Total production cost (CAPEX+OPEX) per litre of biofuel produced.	7.2, 7.3, 7.4, 8.1
5	Reduction in gasification plant investment cost	%	Reduction in gasification plant investment cost compared to biomethane production route via state-of-the-art steam/oxygen-blown gasification.	7.3
6	Gasifier specific cost	€/kWh	Specific investment cost of the gasification unit per kWh of biofuel produced.	7.2, 7.3
7	Financial benefit of GHG emission saving	€/kg CO_2 equivalent	Final cost correlation to the amount of GHG emissions saved for the FlexSNG proposed technology in comparison to similar ones.	7.2, 7.3, 7.4, 8.1, 8.2

8	Minimum estimated product selling price	€/m^3 or €/kg or €/kWh	Cost of biomethane production considering revenues from sales of byproducts (biochar and heat).	7.2, 7.3, 7.4, 8.1

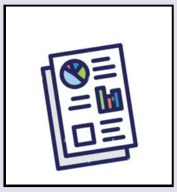
It should be pointed out that the FlexSNG project aims at:

- ✓ 30% reduction in biomethane production cost compared to biomass-to-SNG designs that are based on state-of-the-art steam/oxygen-blown gasification
- ✓ 20% reduction in feedstock supply costs through optimization of the feedstock supply chain

6.4 Social Key Performance Indicators

FlexSNG partners took into consideration a certain amount of potential social impacts that a project like this could probably present. However, based on the project needs, features and possibilities, the consortium decided to emphasize the social impact of job creation. The two selected social key performance indicators are listed in Table 8.

Table 8. Overview of Social Key Performance Indicators.



SOCIAL KEY PERFORMANCE INDICATORS

S/N	NAME	UNIT	DEFINITION	TASK REFERENCE
1	Employees hired in FlexSNG plant (direct job creation)	No/year	The number of direct jobs created during industrial implementation of the FlexSNG concept. Jobs created in different sectors (feedstock procurement, plant operation and maintenance, transport etc.) and at different stages of project implementation (plant construction, operation) will be considered.	8.1
2	Employees hired in feedstock procurement (direct job creation)	No/year		

7 Conclusions

This report established the first list of Key Performance Indicators for the FlexSNG project based on its needs, features and potentialities. To conclude to the FlexSNG KPI list, the literature review conducted, the valuable cooperation between the project partners and the rough understanding of the most evident stakeholders' perspectives were taken into consideration. KPIs that are 48 in total were divided into four categories: technical, environmental, economic, and social. Although setting specific targets for each KPI was not included in Task 7.1 requirements, some of the already known project targets were also presented. The list of Key Performance Indicators presented in this deliverable will be re-evaluated, if needed, as new data becomes available during project implementation.

8 References

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