Performance and functionality of biomass-based materials – A methodological approach to bioeconomy planning June 2021

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Work Package	WP5 – Implementation of innovative agro-industrial value-chains and biomass-based production in SME's
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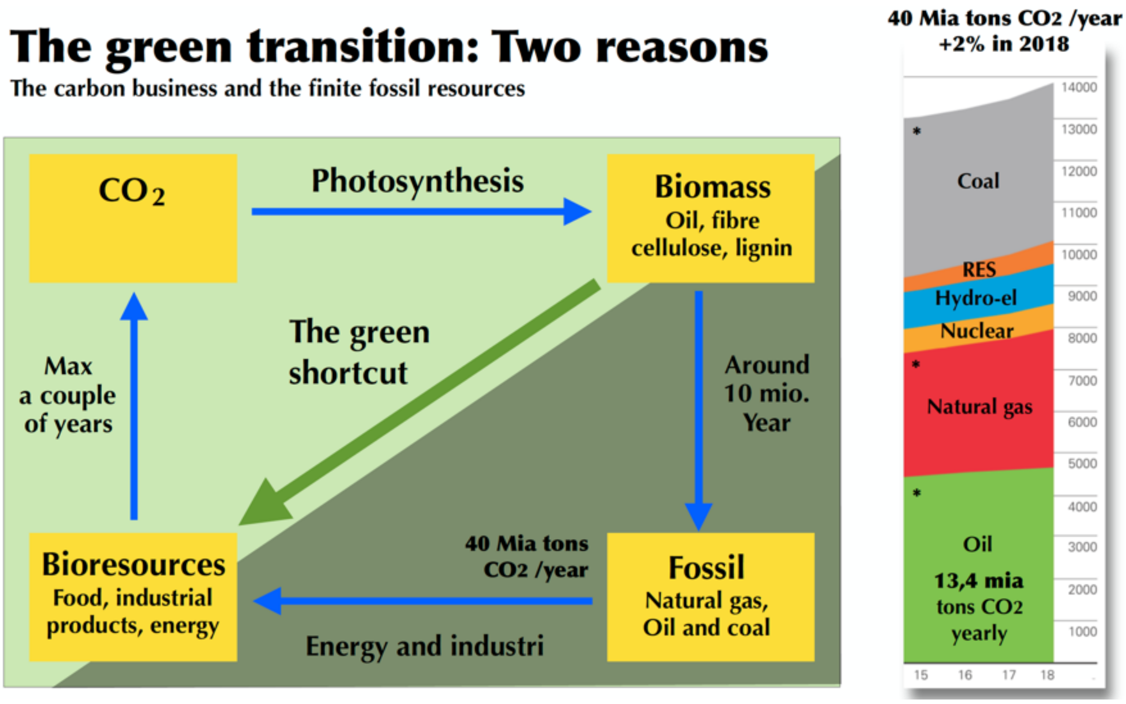
1. Introduction to the report topics.

The main purpose of this report is to elucidate the methods and consideration used in the feasibility assessment of the different cases included in the project. Supply of resources to the bioeconomy activities will typically be based on local resources - on waste and residues from the different biomass-based sectors: the agriculture sector, forestry and biomass related sector, the agro-industrial sector, and household (consumption) sector.

We are using the EU definition of biomass, namely biomass and: The bio-degradable part of products, waste and residues of biological origin from: a) Agriculture (including plant and animal substances), b) Forestry and related industries, c) Fisheries and aquaculture. d) Biodegradable fraction of industrial waste e) Biodegradable fraction of municipal waste (cf. Directive 2009/28 / EC of the European Parliament and of the Council of 23 April 2009 on the promotion of the use of energy from renewable sources).

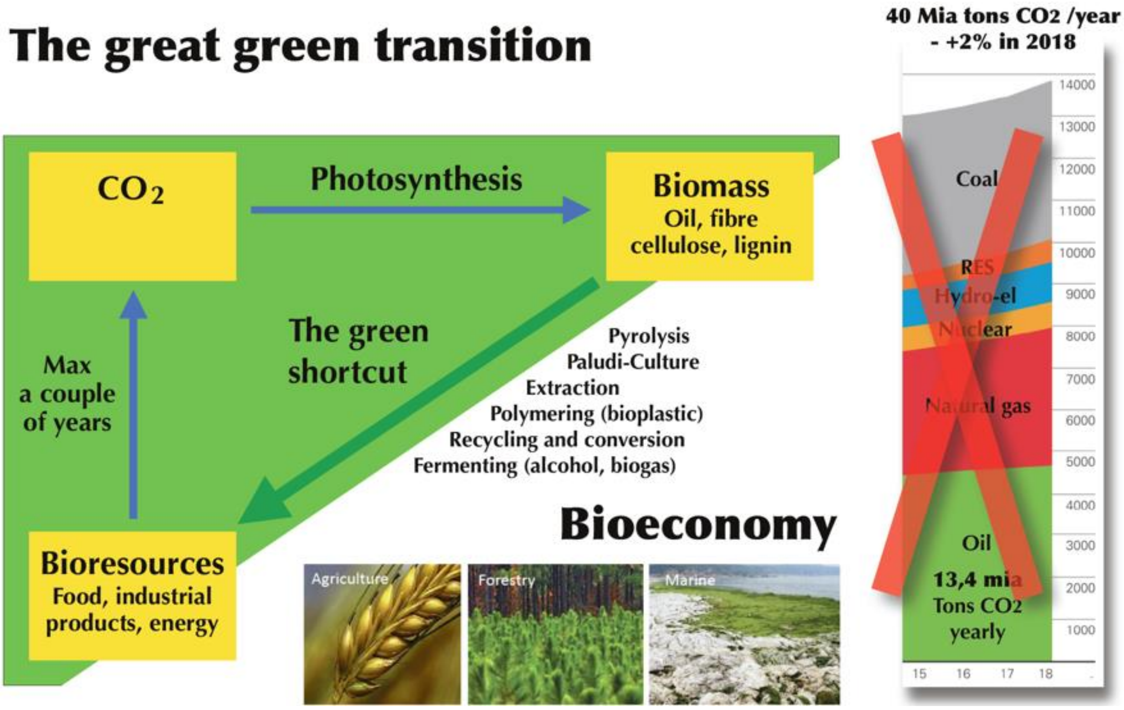
Bioeconomy - circular bioeconomy - can be understood as a green transition process, where one goes from a primary utilization of fossil biological resources to a coherent and optimal utilization of the current biological resources. It can be described in more detail by a comparison of the current main material flow (figure 1) with the material flow, which can be developed by an optimal utilization of the biological resources, as shown I figure 2 (next page).

Figure 1. The general flow model society's use of biological resources - the main supply based on fossil sources.



There are two reasons to leave this model. The *one reason* is the significant amount of greenhouse gas emissions from the use of fossil resources to alle possible purpose. The *second reason* is that fossil resources will be final. We must find a way to make a more optimal use of the bio-resources. Such a rethinking ca be illustrated by Figure 2, which shows a different and more complete use of the biological resources.

Figure 2. The green transition. A new flow model for society's use of the biological resources.



The green transition - the treading of new paths - requires new technologies and processes. They can be called bioeconomic 'engines', and are illustrated here in the figure with pyrolysis, paludi-culture, extraction, polymering (bioplastic), recycling and conversion, fermenting (alcohol, biogas, etc.).

The technologies and processes must be developed. In the following will we shown how we in the project BioBIGG have has addressed issue two to promote a circular bioeconomy - to develop the green shortcut.

2. Framework conditions for pre-feasibility studies

The purpose of this chapter is to describe the approach used by the BioBiGG consortium, when developing and evaluating project concepts for agro-industrial value-chains and biomass-based productions in SME's. A total of 18 project concepts was identified. The identification process was structured according to the guideline principles specified in WP3. These guideline principles will be described further below.

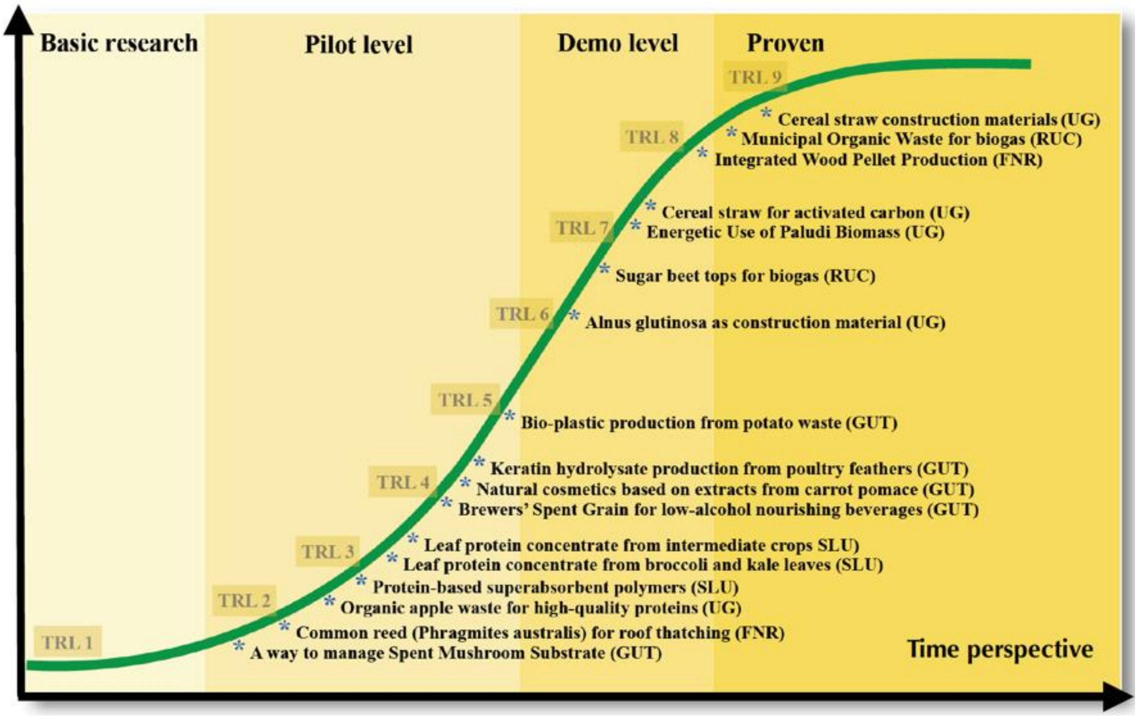
The evaluation process was based on the notion that a pre-feasibility assessment should be conducted before a project concept is further developed towards implementation. In this sense, the approach can be understood as a preliminary evaluation prior to an in-depth feasibility analysis – a process which is often time-consuming and costly for SME's.

To support a cross-border collaboration and a mutual understanding of technological development, the BioBIGG consortium agreed upon several draft disposition guidelines for evaluating the chosen project concepts. These principles consist of: Definition of relevant environment, Technology Readiness Level (TRL) and market demand/supply opportunities. These guidelines will be elaborated further in the following sections.

The pre-feasibility study should be structured by the involved stakeholders around the present development of a concept (or closely related concepts) in relation to a desired vision.

The overview below can give a picture of the various project opportunities that have been developed in the BioBIGG project, and described here according to their placement on a technological/commercial development scale, which will be elucidated in more detail below.

Figure 3. Technology and process opportunities identified in the project.



2.1. Definition of project concept and guideline principles

To make a pre-feasibility study, and later on a TRL-analysis, a project concept needs be formulated. This should be a description of the technology concepts, the applications of technology and the benefits of the technology compared to an existing one. The project concept should also address how the concept is supporting a sustainable future development.

The pre-feasibility studies treat innovations or technologies that is supporting a sustainable future development and circular bio economy. It is therefore important that all the studies are complied with the principles found in Work package 3 (»Development of common framework for a sustainable and circular bio economy). The main principles are: **Cascading** (multi-purpose use of biomass through the whole value chain)**, Use of waste, leftovers and residues** (Utilization of waste, leftovers and residues from agriculture and forestry) and **Circular economy**. (Descriptions from the project delivery: »Development of a Common Framework for a Sustainable and circular bioeconomy«).

2.2. Definition of relevant environment

The relevant environment is the context specific framework conditions for the chosen project concept. The reason why the relevant environment is important to define, is that it may help to implement the project concept. The relevant environment should therefore be focused around conditions that can assist the implementation the most.

If the technology is at an early stage, it is essential for the implementation and comercialization of the technology to unravel what kind of environment the technology needs to be implemented in.

The relevant environment is therefore a set of parameters, which could have an impact on the technology's performance. This could be related to the existing marked for the given technology or technology itself. If, as an example, the chosen technology is going to be implemented in an already commercialized production process, the relevant environment would both be related to the existing business model related to the production process and the technology used for the production process.

If the pre-feasibility is treating a case where there must be certain inputs to the concept e.g. specific biomasses or raw materials, then the relevant environment could be a location from which these are accessible, within a given range and in the right quantities. If the technology is a component that is generating power or gas, the relevant environment could be a location where it is possible to collect or store the outputs. The relevant environment is of course dependent on the individual project concepts and there might be other relevant considerations that needs to be described.

If the technology is at later stages of development and is ready for example for pilot testing, there is other framework conditions to be coped with. This could be an investigation of the current market and supply opportunities for the chosen technology. Regarding the marked demand, there should be looked into what the expected demand is for the chosen focus material that has been pretreated or as an end product. This could be supplemented by a marked strategy for the project concept.

The marked strategy is de-pended on the final product, but **if** the product as an example, is substituting an already existing product, the strategy should focus on the demand for the substituting product and how it is an improvement of the existing. If the product is new on the marked, the focus should be on analyzing the marked for the product and look into if there is a demand for the product.

There are also several things to address regarding supply opportunities, but most of them are dependent on the project concept. However, one could address the following: Are there a steady supply of the chosen material within a given range? Can it be delivered to the chosen location? If the chosen material needs to have certain quality parameters, will these needs be met with the right quality from nearby sources?

It is important to point out that framework conditions and the relevant environment could be decoupled from the project concept. There is in most cases a far-reaching regulation that the technology needs to be implemented in and an already existing marked that the innovation needs to fit into. In many cases, there will not be a new marked for the given innovation or technology, because the marked is not ready for it or because there is no demand for the innovation or technology. This is why it is important to investigate, how the technology would be implemented and what kinds of regulations or other that needs to be addressed, to ensure the implementation.

2.3. TRL as a methodology (technology readiness level)

When the project concept and the relevant environment are defined, one need to have a tool which can help to develop and structure the project concept in a strategy. This is both to understand the overall technology development but also to disseminate knowledge about the technology's development stages overall.

Technology readiness level is an excellent tool for structuring and communicating a technological development. A TRL analysis can be used to structure the development, since the analysis give a clear view on the current state of the technology, the earlier stages, the next stages of development and the commercialization or vision. The TRL-analysis can later on be used to elaborate an innovation programme and an action nlan for further developing the technology or innovation.

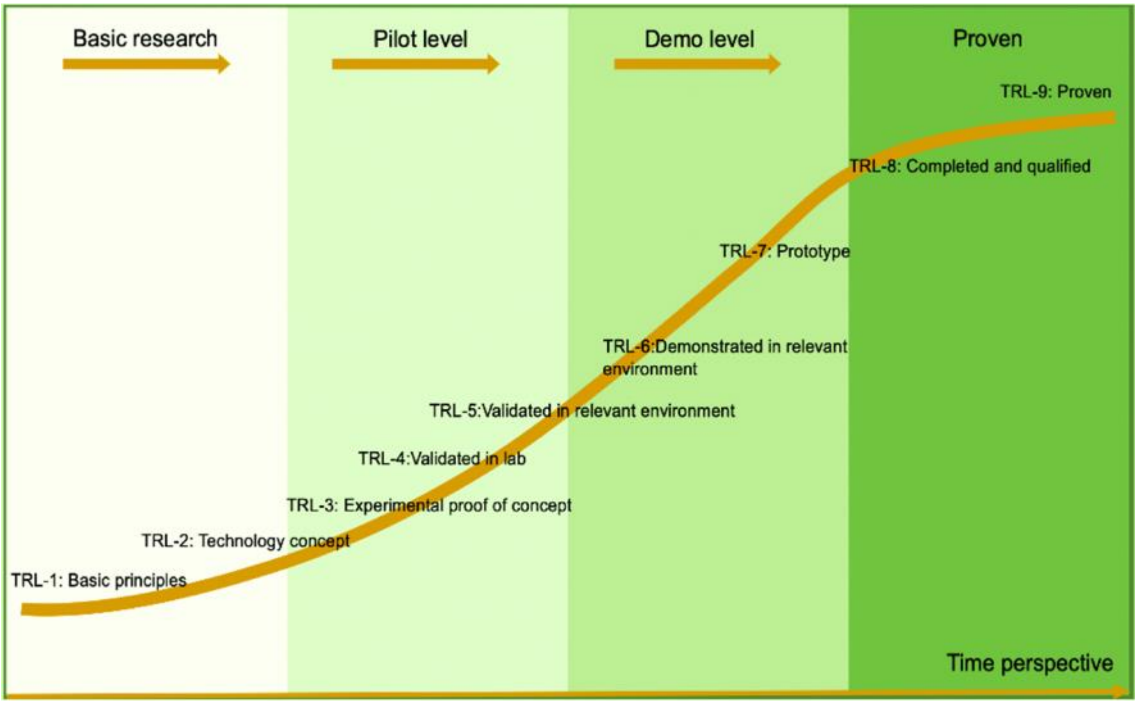
2.4. TRL as a planning tool

The original 7-step TRL-scale was created in the 1970-1980's by NASA, as a tool for communicating a technologies maturity. Since then, the TRL-scale has been developed and in the 1990's the 9-level scale was introduced, with the same purpose as the previous. As many other agencies and industries has adopted the TRL-scale since then, the focus on a technology's readiness is more aimed at a technologies readiness for commercialization and the marked, rather than communicating a certain technology's level of completion.

Therefore, the aim of TRL-scale is to communicate a technology's development from idea to commercialization. The TRL-scale also assist to develop a common understandding about the development of a technology. This is why an integration of prefeasibility studies and the TRL-scale is important for a project concept. Some agencies have been developing their own TRL-scale, with modifications, to fit their organization's needs.

However, the TRL-scale has almost the same use in all of the modifications – to reduce risk when budgeting and planning (EARTO 2015, p. 3-5). The TRL-scale has also been used in the Horizon 2020 programme (2014-2015) as a tool for funding, with the same headlines as the TRL-scale described further below. The scale can be used to communicate a technology's development, but also as a tool for planning and communication (EARTO 2015, p. 6).

Figure 4. Graphic overview of the TRL levels (Technology Readiness Level).



The TRL-scale can be roughly divided into four main technological phases, within the with the nine-part TRL scale.

2.5. Basic research in the TRL-system

Project concepts that are at 1-2 on the TRL-scale are often categorized as basic research. Project concepts in this group are mostly done by universities and research institutes, and are therefore in all cases, desk studies. When making pre-feasibilities at this TRL-level it could be of usage to clarify the following: What kind of technology is chosen for the concept and why. What is the innovation and how does it reach proof of concept?

2.6. Demo level in the TRL-system

Demo level project concepts are ranging from TRL 3-5. A demo level project is often made by private universities and are being tested in the relevant environment for the project concept. Pre-feasibility studies that treat demo level concepts could address the following: What type of production is going to be made round the technology and what capacity does the production need to have? Where is the plant going to be located (geographically) and what kind of biomass will need to be accessible for the production? What types of regulations are involved in the implementation and are they complied with? A cost analysis of the implementation, operation and revenues. Other clarifications could be supplemented, depending on the project concept.

2.7. Pilot in the TRL-system

Pilot project concepts are treating concepts at TRL-6-7. This is concepts that have been demonstrated in the relevant environment, but are in need of optimization to reach the final part of the TRL-scale. This to address at this stage could be the following:

What needs to be further investigated in terms of optimization of the concepts and how will the optimization take place? What requirements does the final product need to follow in terms of commercialization? What types of R&D is needed for the concepts to reach proven level?

2.8. Proven in the TRL-system

The last TRL-levels, 8-9 are categorized as proven. Technologies at this readiness level are in many cases at the final stage, but needs to be fine-tuned for commercialization. Most project concepts at this level have had investments from investment banks or other. The focus at this level of maturity is mostly on what kind of R&D that's needed for the technology to reach TRL-9

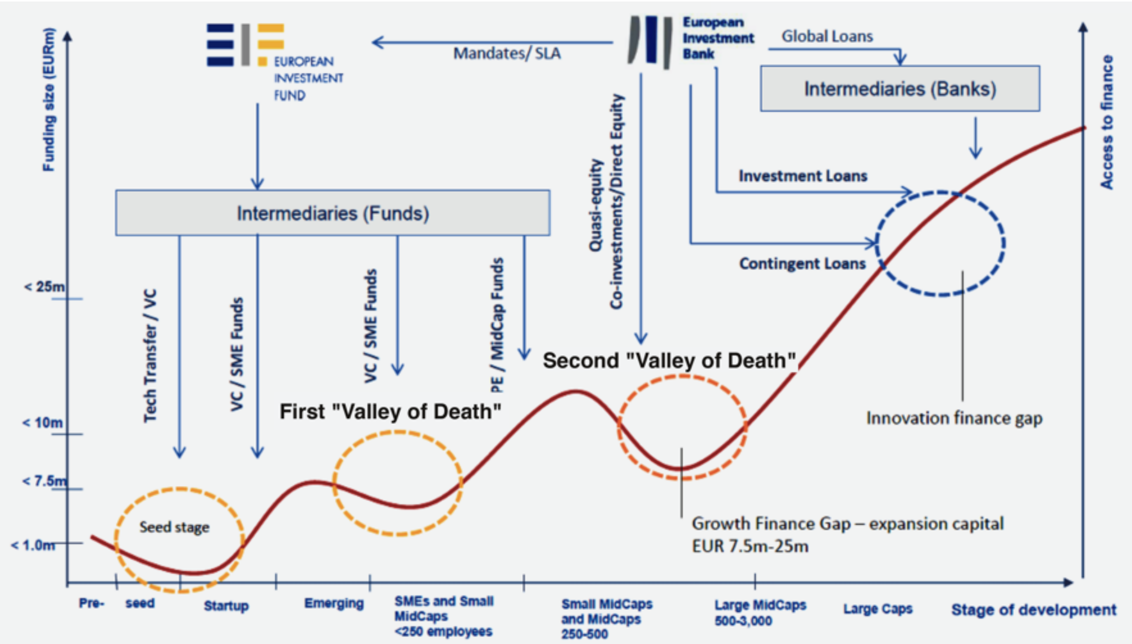
A more thoroughly definition of the various TRL-levels will be provided further below.

2.9. Valley of death or the valleys of death

The Demo-level has in many cases an illustrated gab surrounding it, mostly known as a valley of death. The valley of death is an innovation-gab from which an innovation or project falls apart. There are many reasons why a project falls apart in this part of the development, at it could be because the innovation has flaws and is set back in terms of maturity, but is also coursed by not having a business plan for the project, and therefore a lack of funding.

There can be a shortage of funding when going from pilot level to demo level, but a project also needs funding when it needs to go from demo to proven. The European In.-vestment Bank has made a graph that shows, according to them, that there in many cases are more than one valley of death, where funding is needed. This is why a business plan for a project concept is important – to mitigate risks.

Figure 5. Valleys of death. The European Investment Bank.



The reason why an innovation is ending into the valley of death is not always because of lack of funds or a technology setback. It could also be because there was a need for testing the technology many times under different conditions or similar issues, and not because the innovation in itself was going in the wrong direction.

3. Detailed introduction of TRL 1 to TRL 9

As previously mentioned, the TRL mindset is a good planning tool, which has formed the basis for a number of the case studies in BioBIGG. Therefore, the different TRL levels need to be described in more detail.

TRL 1 – Basic principles observed

The first level of the TRL-scale is the lowest level of maturity. At TRL-1 an identification of a technology or innovations basic principles is being observed and reported. Some common trends to be identified at this level could be: A description of the technology concept, barriers and applications. This could be supplemented by looking into the benefits of the chosen innovation or technology by comparing it to an already implementted/existing one (European Commission, 2017, annex 1, p. 5). At this part of the scale, the application of the technology is only theoretical and not yet refined or proven (Mankins2009, p. 1218). Studies at this TRL-level often include studies of similar technologies to examine what has been done in previous, similar studies.

TRL 2 – Technology concept formulated

At TRL-2, the basic principles from TRL-1 should be improved by a more thoroughly knowledge about the technology. What are the main components, materials for the concept? At this point, the feasibility of the concept should be estimated. This is not an in-depth feasibility, but an evaluation about the feasibility of the concept as a whole. If there is more than one technology involved in the concept, a description of how the technologies will work together, theoreticcally, could be provided.

At this level of maturity, there is no proof of concept yet but preparation for laboratory (or other kind of test-environment) test of the technology or innovation should be made. The test should focus on the specific components from the analysis and how they will work together (European Commission 2017, annex 1, p. 5). The application of the technology is still speculative at TRL-2 (Mankins 2009, p. 1218).

TRL 3 – Experimental proof of concept

At TRL-3, a proof of concept should be presented. This could include a technology prototype validated in a laboratory or an analytical proof of the technology description at TRL-2. This proof is dependent on the chosen technology, since some physical or chemical concepts could be proven on paper, and therefore the need for a physical proof (for instance in a laboratory) is less necessary (Mankins, 2009 p. 1219).

The proof of concept does not need to include the whole technology setup, but the innovative technology. Within the proof of concept, different Key Performance Indicators (technology specific indicators that is crucial for the technology to perform) for the technology needs to be described. (European Commission, 2017, annex 1, p. 5)

TRL 4 – Technology validated in lab

At TRL-4 the chosen technology needs to be validated at a laboratory (or other environment, depending on the technology) with a concept-enabling levels of performance (Mankins 2009 p. 1219). However, technologies at this TRL are expected to have a low reliability. The laboratory test should only be made at a reduced scale with the most relevant components – not the whole operating system. The laboratory test is mainly made for testing if the most important part of the technology will work together, as previously assumed. At this TRL, Key Performance Indicators of the chosen technology should be known, and at this point, be measurable (European Commission, 2017, annex 1, p. 5)

TRL 5 – Technology validated in relevant environment

To reach TRL-5, the technology needs to be proven in a relevant environment. 'Relevant environment' is dependent on the chosen technology, as mentioned earlier. The technology is proven to work in the chosen environment, with a higher level of fidelity than previous (Mankins, 2007 p. 1220). As in TRL-4, the technology needs to have a steady performance when tested and match the measurements or estimations from earlier TRL's. The chosen technology must be tested with supporting elements, so the system can be simulated in a realistic environment (Mankins, 2007 p. 1220). Too reach TRL-5, there needs to be defined, qualitative, what other parameters that needs to be copped with to scale up the production. What types of regulations and standards is relevant to fulfil regarding the technology, environmental issues, socioeconomics e.g. (European Commission, 2017, annex 1, p. 6).

TRL 6 – Technology demonstrated in relevant environment

At TRL-6 the technology is demonstrated (in pilot form) in a relevant environment. The demonstration should include a tuning of the technology to work in various operating conditions. (European Commission 20172017, annex 1, p. 5).

The demonstration of the technology could be the whole system, or be a demonstration of a similar system, but with components close to the planned system, to simulate the full setup (Mankins, 2007 p. 1220). Preparation for a business plan or a manufacturing approach is made. Conditions regarding environmental issues, regulations, standards and socio-economics needs to be investigated for the demo-plant (European Commission, 2017, annex 1, p. 6).

TRL 7 – System prototype demonstration in operational environment

When reached TRL-7, the prototype-system needs to be demonstrated in the operational envi-ronment. Not all technologies in the system needs to be demonstrated, only the crucial ones for the technology to be operating. All standards, regulations and environmental conditions are met for the demo plant (European Commission, 2017, annex 1, p. 6).

TRL 8 – System complete and qualified

The TRL-8 is reached when the chosen technology has been demonstrated in real conditions (at an actual factory, industry e.g.). The whole system is integrated, has been fully tested and is working as expected. All certifications and standards for a full plant/operation are met and production is steady enough for minor production/operations of the chosen technology. (European Commission, 2017, annex 1, p. 6).

TRL 9 – Actual system proven in operational environment

The technology or innovation is proven and can be commercialized. The whole production chain has been investigated (In and outputs) and all materials for production can be obtained and the flow is secured. The system is optimized and can handle a full-scale production. (European Commission, 2017, annex 1, p. 6)

4. Structuring a sustainable future development (primary focus of our TRL)

In the BioBIGG-project, the prefeasibility studies are mostly focused on cases in the lower levels of the TRL-scale. The next section therefore will deal with how to work with cases in the earlier stages of maturity. The section will address how to work with technologies at low stages of maturity and how to mitigate risks that potentially could occur in later stages of development.

There can be many uncertainties regarding technologies at lower TRL-levels, for instance possible unwanted residues, pollution, energy efficiency, etc. Some of these uncertainties could occur when testing technologies at higher TRL-levels, but by ensuring that the guidelines principles are complied with in the technology or innovation, some of the possible outcomes could be coped with before later stages of maturity.

It's important to address would could be 'bottlenecks' or 'hotspots' in the development as early as possible, since the price of adjusting the technology gets more expensive as the technology matures and moves up into higher TRL's. A hotspot is a pitfall where the technology could be set back in terms of maturity, if the hotspot is not addressed in the planning.

As an example: the DBI (The Danish Institute of Fire and Security Technology) started noticing that people who wanted to test their products fire engineering capabilities for a certification, had troubles with dosing the right amount of fire retardants in the products and only a few had the right dosage. The DBI therefore started working on a mini-oven for rental, as a solution for their customers to mitigate risks in the earlier stages of development. By renting the oven, one can measure products fire engineering capabilities, before doing a certification test. By measuring the fire engineering capabilities in the earlier steps of development, it is possible to have an indication of the product will pass the test in the later stages. By ensuring that the fire engineering capabilities is coped with in the early stages of development, before designing the product, e.g., the cost of changing the product is lower, than when the final product has already been made (Brandsikring.dk)

The TRL-analysis should therefore help to mitigate some of the unwanted outcomes in the technology concepts by forcing one to address some of the different hotspots through the TRL-analysis. Revealing hotspots in the different areas of a project is crucial since this is where important development is needed but are missed out in many cases, as specified above.

When making a TRL-analysis, one should address how the technology or innovation is going to be commercialized. This includes an estimate of the feasibility of the technology, even at lower TRL's, and to reach for example TRL-5, one has to qualitative describe what types of regulations is relevant to fulfil regarding environmental issues, socioeconomics e.g. This could be of usage to know early in the planning, to avoid unwanted issues regarding regulations or other, but also to prioritize them in the research and address them in the TRL-analysis.

4.1. Defining TRL for project concept

The topic is about determining the current TRL for a given project, methods for defining the current TRL and how to move from the current TRL to the target TRL.

4.1.1. Present TRL for project concept

When making a TRL analysis of a chosen technology or innovation, the starting point of the analysis should be to define the present TRL. The present TRL is the maturity level of the chosen technology or innovation at present time.

This is first and foremost to secure that the work that is being done has not yet been clarified by others. In some cases, the technology or innovation will be a modification of another technology or a modification of a system. If that is the case, it can be useful to split up the most important technology components, and check for the maturity of the components individually. Secondly, the present TRL works as the starting point of the pre-feasibility, as the pre-feasibility should address how to advance from the present TRL to the next (target) TRL-level.

4.1.2. Methods for definition of present TRL

There are many ways of defining your present TRL-level. First, it is important to know what to measure regarding TRL. What are the main technologies involved in the technology concept and what will they be used for? If, for example, your chosen project is combining different innovative technologies, there is a need for measuring the different technologies maturity individually, from a TRL-perspective, since some of the technologies may be at a higher TRL's than the others.

Therefore, the initial step is to generate knowledge about the technology concept, the important components and how they are going to be working together. The research to find the present TRL could be through peer review articles in scientific journals, reach out to companies, who specialize in the chosen technology, government agency reports, interviews with experts and researchers or other (https://www.psu.edu/).

Eventually there will be shortage of research on the subject, and when comparing the gathered knowledge with the TRL-definitions, this should end up as the present TRL. all the above criteria for different TRL-levels needs to be addressed (if relevant) and fulfilled before advancing to the next TRL-level.

4.1.3. From present TRL to target TRL's - Vision (TRL 9) (Descriptive)

Before making the pre-feasibility analysis from present TRL to the target TRL, it could be of usage to define the vision of the project (an ideal TRL-9). First and foremost, it is relevant to know what the ideal scenario would be for the chosen technology, regarding inputs, outputs, residues (and the utilization of them), economy, etc.

Secondly, it could be relevant to make small economic calculations regarding what kind of income the technology could generate, compared to already implemented technologies. By adding up inputs and outputs, there could be examples where the economy of the concept does not add up and isn't competitive with the technology it is supposed to replace. This could end up as a concept where even in an ideal vision, the concept will not be feasible, at least not in the present time. Addressing an ideal scenario for the technology could be of usage later in the process, as it may help address certain issues that is not directly linked to the technology or innovation, but is linked to the comercialization of the concept.

4.1.4. Next stage pre-feasibility (In-depth analysis)

The pre-feasibility analysis should treat how to advance from the present TRL to the target-TRL. This should include an in-depth analysis of the actions that needs to take place for the advancement. If the advancement is from TRL-3 to TRL-4, the pre-feasibility should address what needs to be done and how to meet all the above mentioned criteria for the advancement in TRL.

If some of the exit criteria from the TRL-definitions seems irrelevant or isn't applicable in the technology, there may be a need for researching other sector-specific TRL-definitions. Many government agencies and industries has made specialized TRL's that may be useful to investigate if there has been made sector-specific TRL-definitions (renewable energy TRL, agricultural TRL, for instance).

4.1.5. Primary and secondary technology concept and application

In some case there are more than one important technology within the chosen technology concept or innovation for the TRL-analysis or a technology. Some components may even be more mature than others and therefore at a higher TRL, as previously described. If the concept contains more than one important technology or component, it may be of use to make sections about the technologies individually, as far as concept and applications go. Some may need different kinds of R&D and have different barriers than others. A description of the different technologies and how they will work together should therefore be provided.

5. Innovation programmes

An innovation programme is made to attempt to shape and, hopefully, predict a future development for a chosen project concept. It is of cause not possible to predict a certain development in the future, however by making an innovation programme, one tries to establish some indicators about how it would be possible to implement a project concept within given circumstances.

An innovation programme can help to establish a plan for a chosen project concept's development, establish funding, a stakeholder network and a local, regional or national development.

5.1. Introduction to the value chain or project concept

The innovation programme should first and foremost introduce the project concept, in-novation or value chain that is, possibly, going to be implemented. Some of the content of the introduction will possibly have already been covered by the earlier made pre-fea-sibility study, but this introduction should be focused around the innovation, especially in terms of where and how the innovation is going to be implemented. Is the innovation taking place at an already existing value chain or is the innovation introducing a new value chain? Where will it be implemented in the future?

5.2. Regional innovation effort or priorities

The programme should address of there are any regional priorities in terms of how the innovation can benefit the region it's going to be implemented in. This part should address if the innovation will create new jobs, economy, energy, or other. This could help the implementation, since it can assist further funding of the project from regional funded investments.

5.3. Innovation roadmap for the concept or value chain

A way to structure an innovation programme is making a roadmap. A roadmap is made with a *backcasting approach*, where one tries to sum up what needs to be coped with in the future to implement the innovation, and afterwards work backwards in terms of linking the future development with the present. The roadmap should therefore focus around a vision for the innovation and how that vision of would be implemented.

The terms of what kind of development is needed are in all project concepts case speci-fic. The following section will focus around what should be considered when making a roadmap. The most important part of the roadmap is the describe how one is going from one step of development to the next. Most of the steps will in many cases overlap, be dependent on another parameter or similar issues. This is why it is important to try to address the order of the development, to ensure that the right progress is taking place when it should.

(1) The first step is to describe the *current situation* of where the innovation is taking place. Address the most important parameters that needs to be optimized for a later implementation.

(2) After describing the current situation, describe *the vision* for the project concept. What is the most ideal situation in the future the concept and what needs to be changed or coped with in order to implement the concept. This could include the marked for the concept, research and development, the product, technology development or other relevant topics.

(3) The next step is making *the action plan* for the roadmap. This should be a description of the plan for reaching the ideal future development from the current situation. This addresses the elements or parameters that was introduced in the current situation that was described and the vision for the concept.

(4) The last step with the roadmap is a *description of the implementation*. This could be do-ne by a visualization of how the current situation will reach the ideal situation. This is made with both a timeline (for example 5-10-15 years) and a prioritization of the most important parts, that is crucial for the implementation and planning. In some cases, this is made as 'milestones' for the implementation, since the other parts of the implementation is dependent of these milestones to be reached, before the other elements fall into place.

5.4. Stakeholder list

In many cases, there will be stakeholder involved in the implementation. If this is the case, there should be a description of who the stakeholders are and what part they will play in the implementation of the innovation programme. The stakeholders could be research institutes, SME's, decision makers or other.

5.5. Emphasis on the innovation programme

The last part of the programme is a summary of the roadmap, a description of the organization of the programme (stakeholders, etc.), how the programme could be financed and the conclusion of the programme.

6. Business case manuals

The business case manual is in many cases made in order to, hopefully, receive funding from different sources. It is made as a tool for providing necessary information about the project concept and should focused around assuring that the business is feasible and a case that is ready for investment.

The shape of the business case manual is highly dependent on the TRL of the cencepted project. If the project concept is at lower levels of maturity (TRL-1-4) the business case manual should rather focus on what kind of research and development that is needed for developing the innovation, instead of making a business case manual, where some crucial information missing regarding the economy of the business. If the TRL of the project concept is TRL-4 or higher, then a conventional business case manual is made, which will be described in the following section.

6.1. Describe project concept

The first part is a description of the project concept. This could include a description of the following, if relevant. A description of the products or value chain that is being made into a business, the relevant environment (in terms of placement and marked), possible stakeholder or companies involved in the business, sources of input materials, technology readiness level, target groups, or other relevant information revolving the business.

6.2. Business case manual

The business case manual should be focused on the marked for the product or value chain and how it could be implemented in a business. Therefore, the manual should treat topics that will be relevant for the economics and implementation of the business. One thing to describe is the partnerships for the business. What kind of partners are involved, what role will they play and what will they contribute with in terms of implementing the business? This could be supplemented with a description of what activities that are required for implementing the business in terms of funding, testing or other relevant information.

The next step is a description of the resources needed for implementation. This is both in relation to physical resources such as input material, resources, energy or other. How will they be accessible from the business and how will the output materials be disposed of or sold? Resources could also be in terms of research, development and usage of experts, in terms of implementation.

The business case manual should also treat what kind of costumers the business will attract. What types of costumers is the business aiming for, how will the costumers buy the product and how will potential costumers be reached in terms of sale? This could also include a description of the current marked for the product, if there is one, and how the product is going to fit into that marked. If the product is new to the marked, then a description on how the product is going to be introduced to the marked should be included, if possible.

6.3. Cost structure

The final part of the business case manual if the cost structure of the business. In principle this should be a in depth description of how the business is feasible or will become feasible. First and foremost, there should be a *description of the cost* of operating the plant or the production facility. This is in terms of fixed costs regarding employment, power, transportation and other operating costs. Then there should be a description of what kind of *value* the operating facility could generate. This should include the value of the final product that is being produced. This could be supplemented with a compare-son to similar products on the marked, closely related products or, if the product is new to the marked, a description of how the product is going to enter the marked.

Furthermore, an explanation of what kinds of *secondary income* the operating facility could generate or save expenses on should follow. This could be in terms of value generated by sale of by-products from the production, expenses that are being cut down by changing an existing production to the one in the business case manual, but is of cause depending of the project concept.

The last part of the cost structure is a *risk assessment* of variable cost associated with the operating facility. This is a description of possible subsidies, tax breaks, regulations or other relevant value that the operating facility could apply for. All this accumulated information should paint a picture of a feasible investment for a possible investor. The business case manual will in some cases have several pieces of uncertain information regarding the feasibility.

If the business case manual is dealing with a project concept on lower levels of maturity (TRL-4-7), some of the questions above will be hard to answer or the answer will have rough estimations, instead of calculated costs. Some of the cost structure on the fixed costs will be hard to find exact cost about, if the project concept is not yet in the demo-phase. However, there will be cases where there will be similar business constructions as the business case manual, that has already been implemented, which could help the estima-tions be closer to the real cost structure. The business case manual should end on the concluding remarks regarding feasibility of the business.

7. Concluding remarks

The circular bioeconomy can contribute to sustainable development in various ways - especially when it comes to climate and resource issues. There is a need for the development of new technology and processes that can support the circular bioeconomy. The planning and the development of the new bioeconomy technologies can advantageously be based on the TRL-system (Technology Readiness Level approach).

The TRL-concept is a good starting point for developing feasibility assessment of the exploitation of various biomass resource opportunities. It sets the framework for innovation needs and opportunities, but also the framework for innovation programs and implementation of the new »green shortcuts«.

8. References

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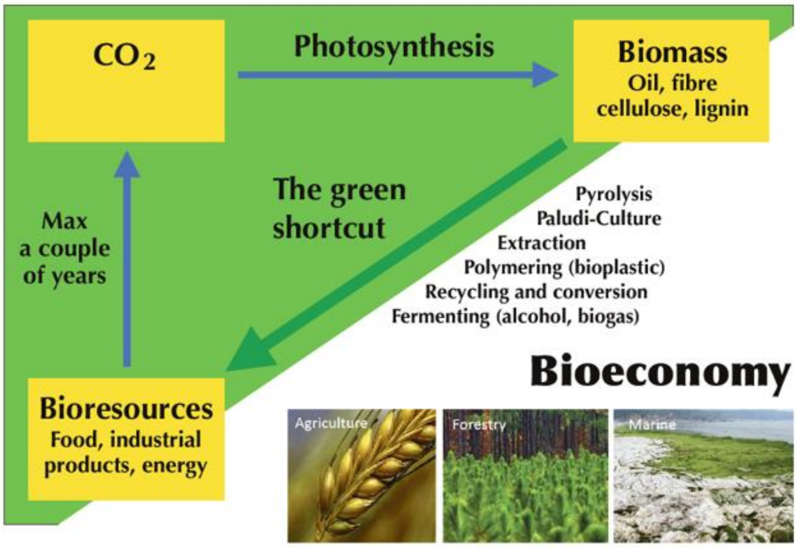
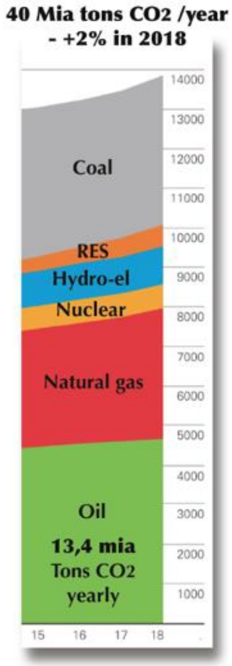
9. The appendices

To develop common methods, a number of principles and approaches were presented for the following: (1) pre-feasibility assessments studies, (2) Innovation program to support implementation of innovative value chains, (3) implementation models and (4) business case manuals.

The mentioned presentations are included as appendices to inform about the applied principles. The presentations have been prepared for a cross-border workshop in June 2019, and present the following topics:

The great green transition





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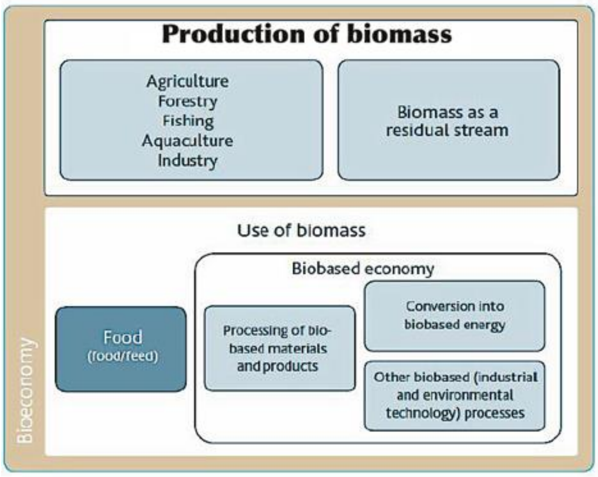
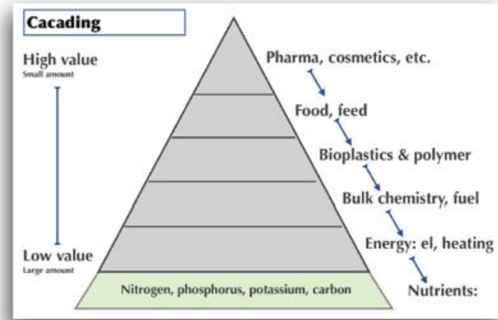
The green transition





BIOMASS

The biodegradable part of products, waste and residues of biological origin from:

- Agriculture (including plant and animal substances),
- Forestry and related industries,
- Fisheries and aquaculture
- Biodegradable fraction of industrial waste
- Biodegradable fraction of municipal waste.

Directive 2009/28/EC of the European Parliament and of the Council of 23 April 2009 on the promotion of the use of energy from renewable sources

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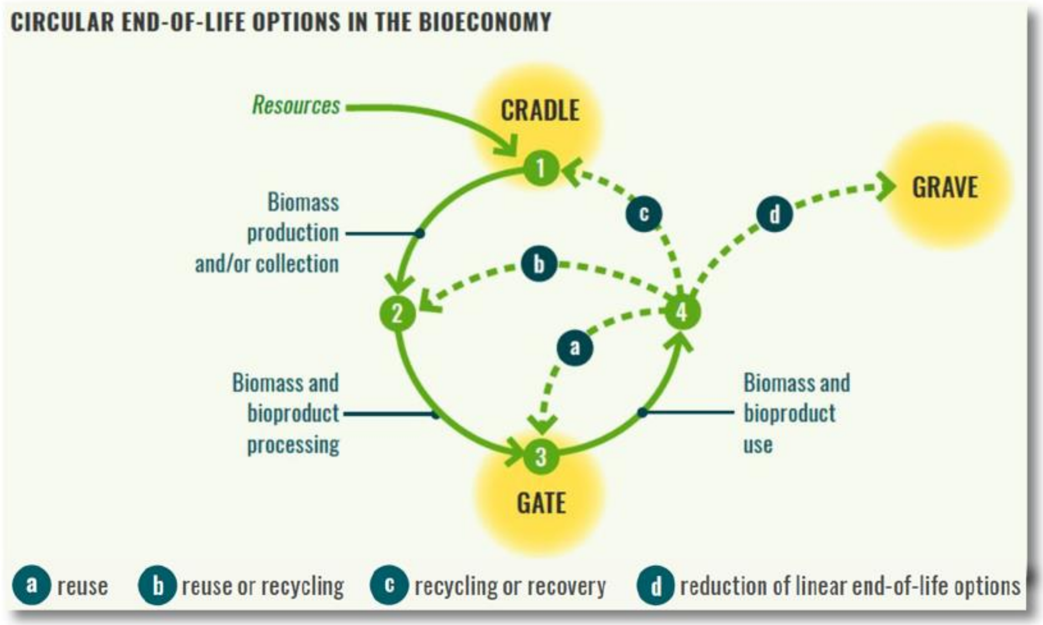
The circular value chain



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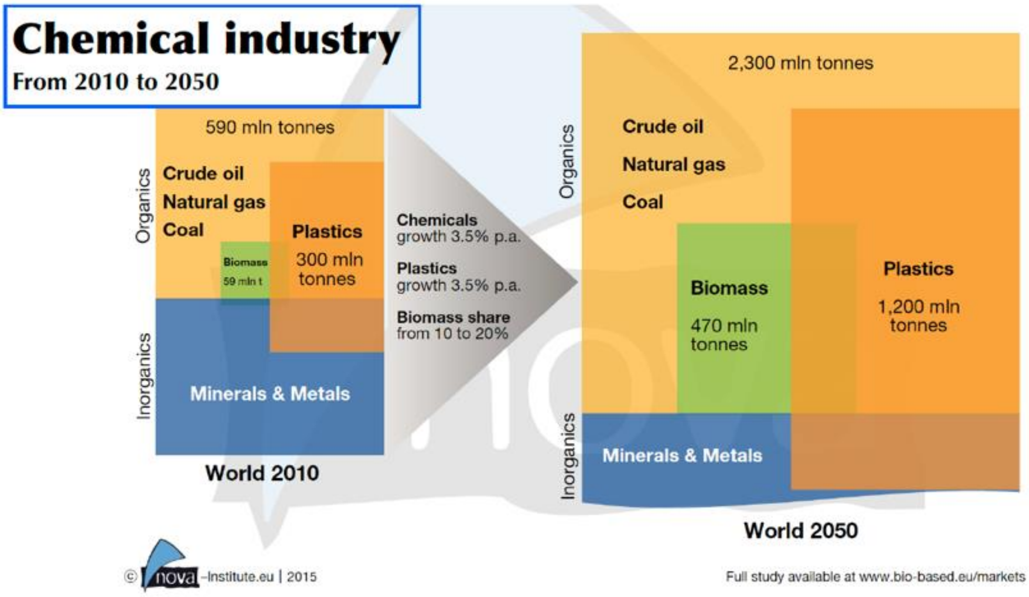
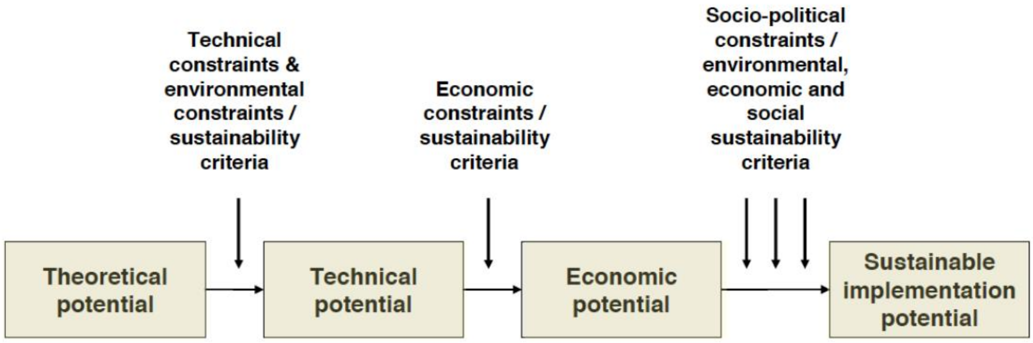
Biomass - Powerful increase - possible?



The green transition

The potentials:
- Theoretical
- Technical
- Economic
- Sustainable potentials



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Sustainable bioeconomy: Definition of biomass • SD-Criteria

BIOMASS

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- Agriculture (including plant and animal substances),
- Forestry and related industries,
- Fisheries and aquaculture
- Biodegradable fraction of industrial waste
- Biodegradable fraction of municipal waste.

Definition based on:
Directive 2009/28/EC of the European Parliament and of the Council of 23 April 2009 on the promotion of the use of energy from renewable sources

Criteria

Criteria for contribution to sustainable development

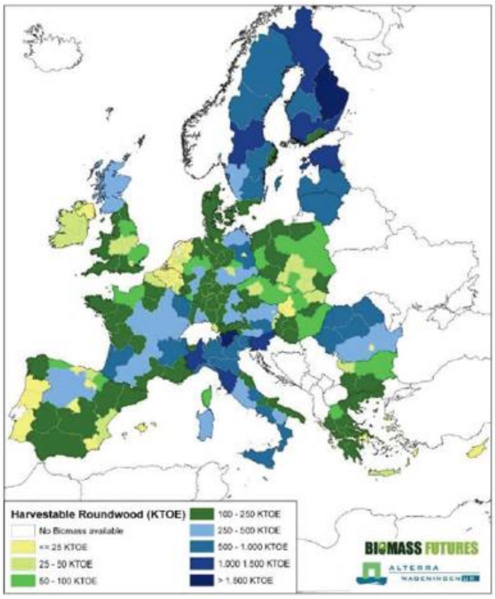
Greenhouse gas criterion
Level of use of fossil components in cultivation, transport and processing (at least 50% / 60% reduction)

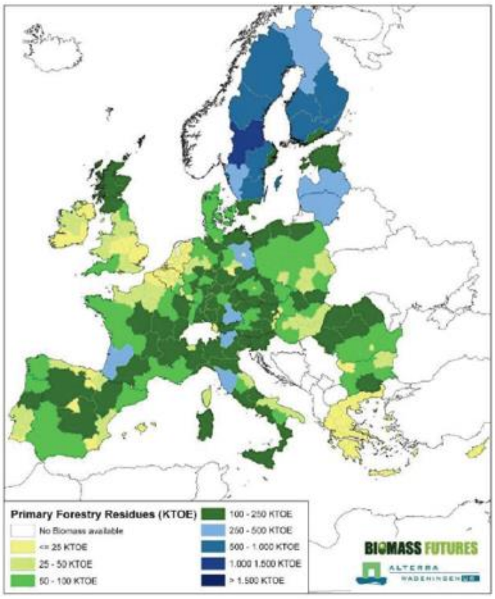
Biodiversity criterion
Not be produced from raw materials from a high biodiversity area, such as nature conservation areas.

Carbon storage criterion
The biomass must not be produced from raw materials from areas with large carbon stocks, eg. wetlands, cohesive forest areas, peat areas, m.v.

Environmental and social standards
The biomass materials must be manufactured in accordance with environmental rules and social standards for agriculture, forestry, fisheries, industry, etc.

The potentials forestry residues - 2020 and 2030





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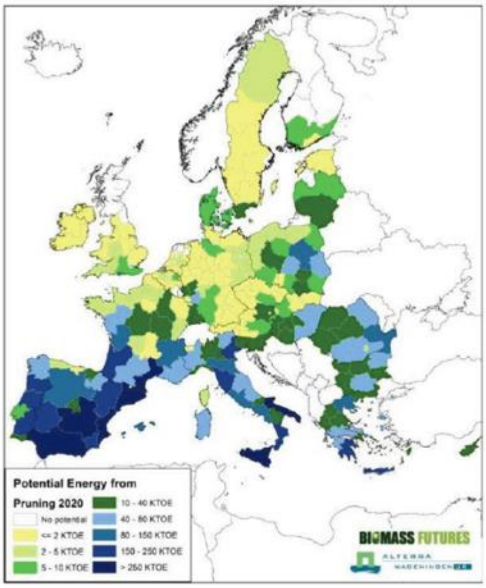
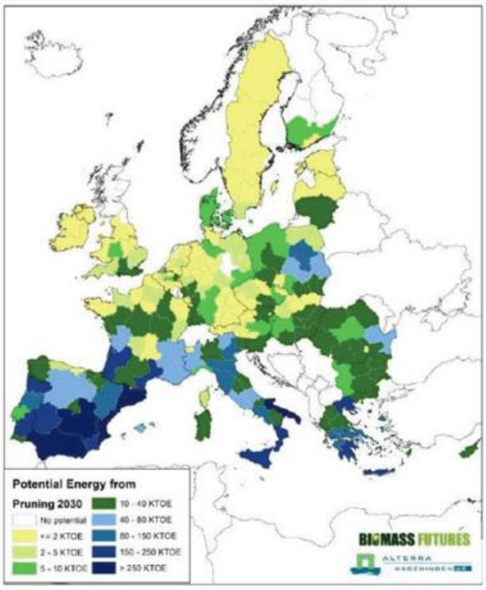
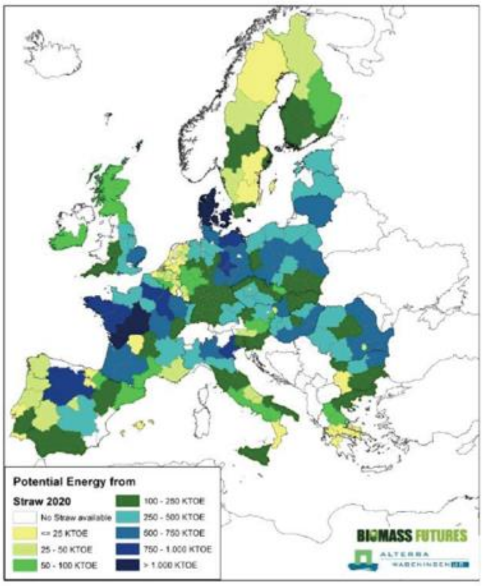
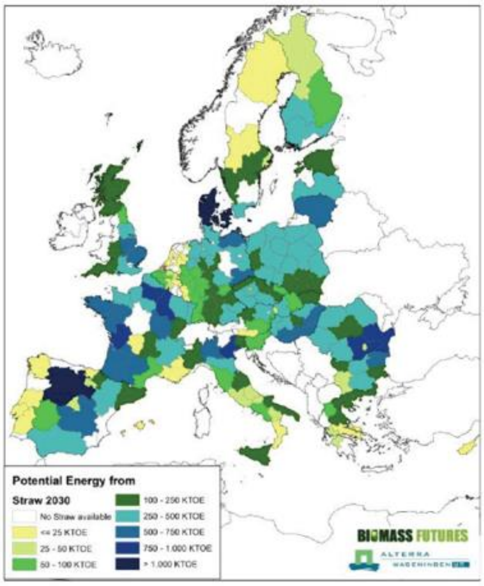
The potentials woody residues - 2020 and 2030





The straw potentials - 2020 and 2030





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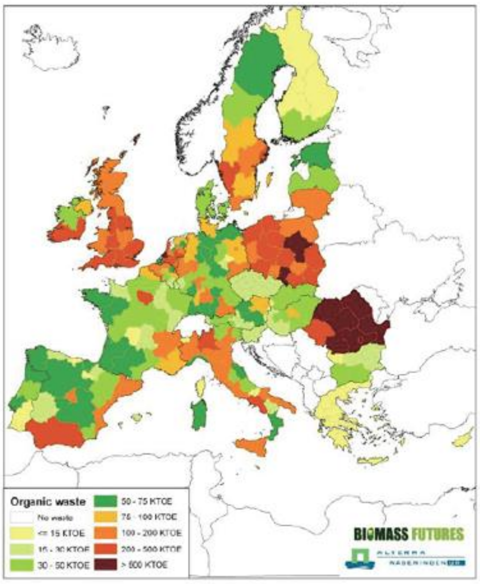
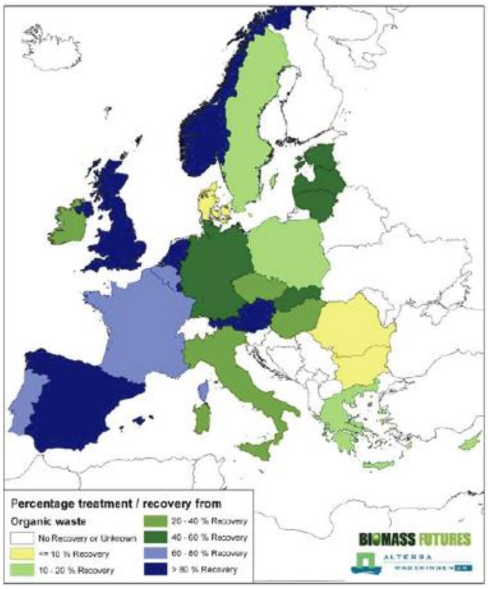
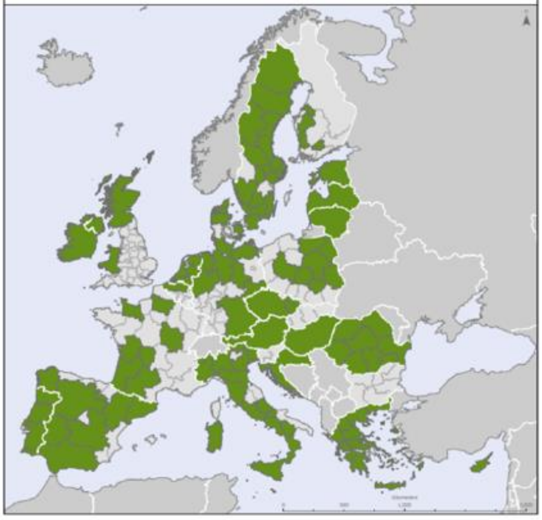
The organic waste - treatment / recovery



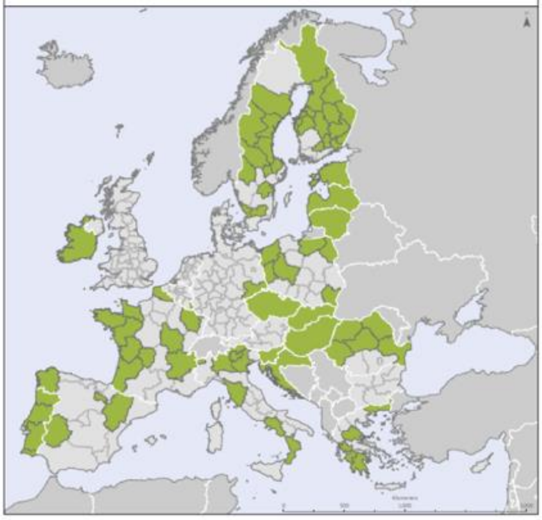


Policy support - Member States with Bioeconomy R&I priorities

EU-28 regions/Member States with Bioeconomy R&I priorities (2014-2020) related to Agriculture



EU-28 regions/Member States with Bioeconomy R&I priorities (2014-2020) related to Forest-based Bioeconomy



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Pre-feasibility
WP 5.2

Key elements in the pre-feasibility studies:
1) Market demand and supply opportunities
2) Design and choice of material or product to be produced, or process to be developed
3) Product requirements, standards and options
4) Raw materials, transportation and location
5) Technology choice, plant capacity and operating costs
6) Human resources
7) Sustainable development and local and regional development benefits
8) Comparison of the cost of the innovative biomass-based products with competing products

Key elements in the pre-feasibility studies:
1) What needs to be optimised to make implementation take place?
2) In which way can this optimisation take place?

Innovation and technology - The TRL-scale
Innovation principles

- TRL 1 – basic principles observed
- TRL 2 – technology concept formulated
- TRL 3 – experimental proof of concept
- TRL 4 – technology validated in lab
- TRL 5 – technology validated in relevant environment (industrially relevant environment in the case of key enabling technologies)
- TRL 6 – technology demonstrated in relevant environment (industrially relevant environment in the case of key enabling technologies)
- TRL 7 – system prototype demonstration in operational environment
- TRL 8 – system complete and qualified
- TRL 9 – actual system proven in operational environment (competitive manufacturing in the case of key enabling technologies; or in space)

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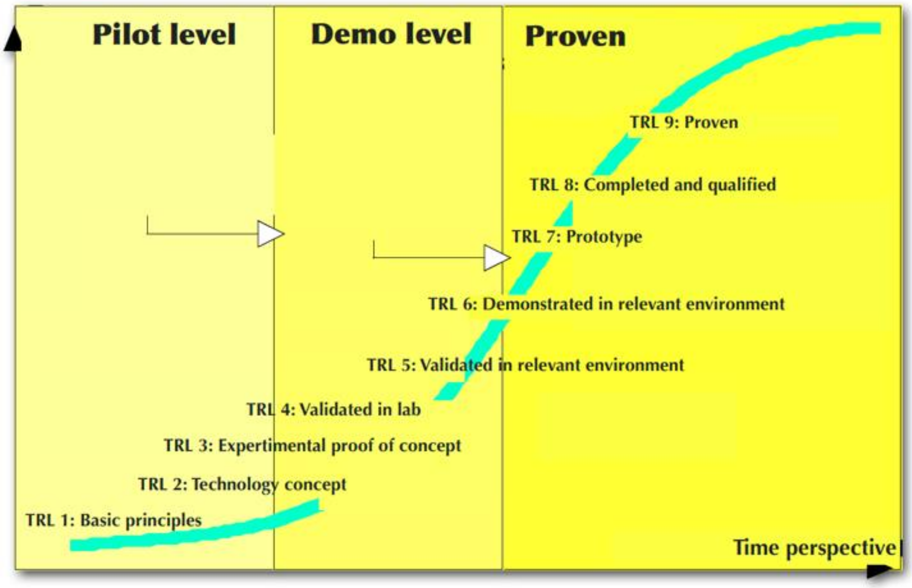
Innovation and technology - The S-kurve
Innovation principles



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Pre-feasibility
Back to the feasibility

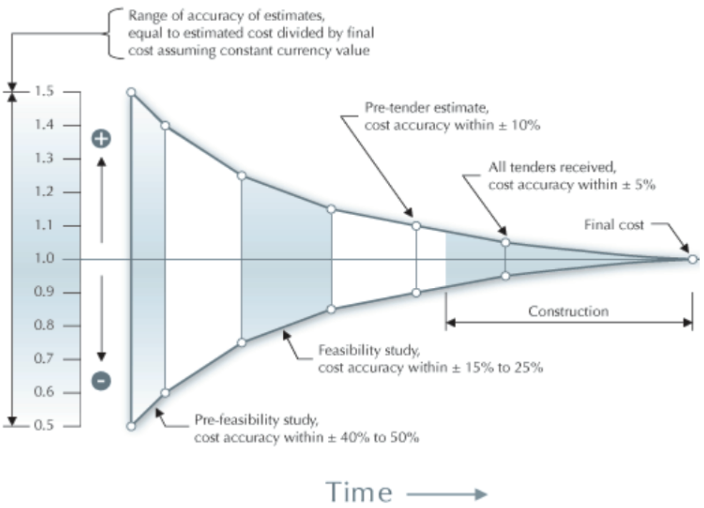
Feasibility
Four levels:

Pre-feasibility study
- cost accuracy +/÷ 40-50%

Feasibility study
- cost accuracy +/÷ 15-25%

Pre-tender / Tender
- cost accuracy +/÷ 5-10%

Final cost
- accurate



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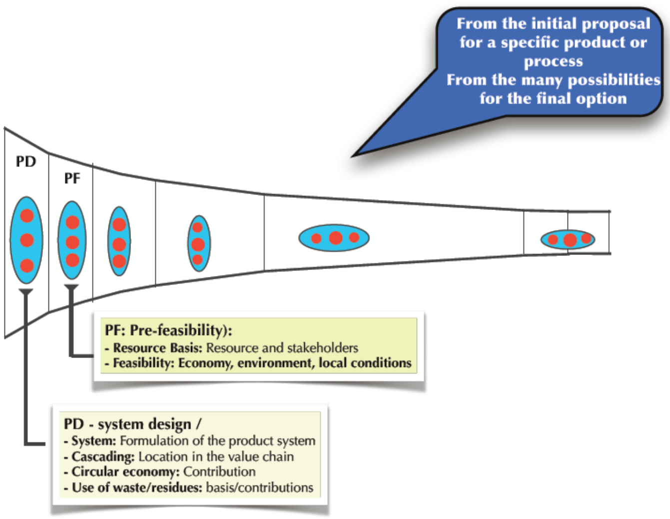
Pre-feasibility
Alternativ view: IDP (Integrated Design Process)

Pre-feasibility
Two basic elements

System-design
- The product system:
  - material
  - flow
  - product
- The principles:
  - Cascading
  - Circular economy
  - Waste/residues

Pre-feasibility
- Resource basis
- Feasibility:
  - econoomy
  - environment
  - resources effeciency
  - local conditions/benefit



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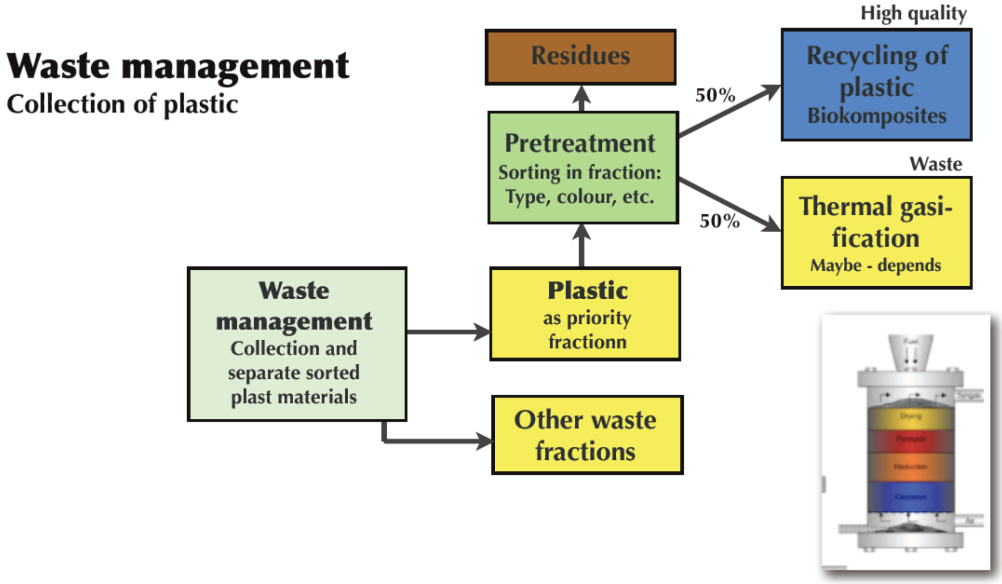
Two elements - (2) plastic

Recycling of plastic - EU Waste directive 2018 - sorting by 2025



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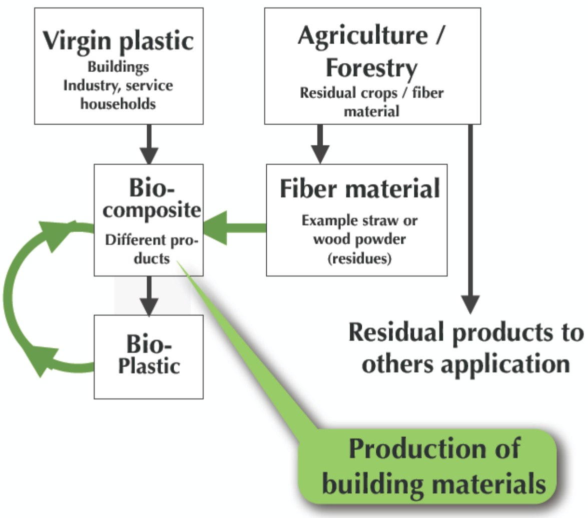
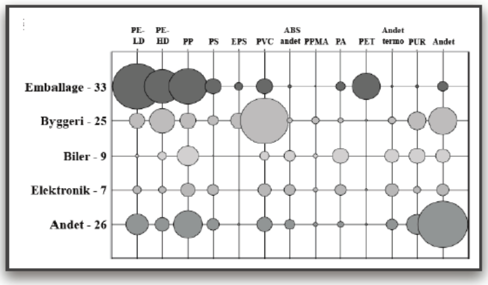
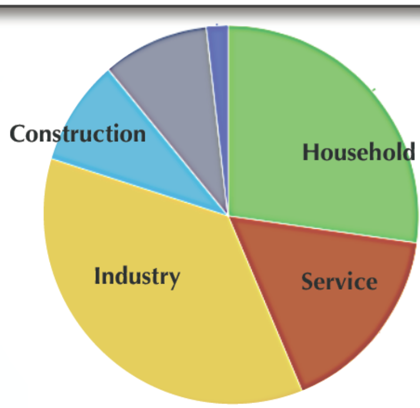
The basic concept

Double cascade







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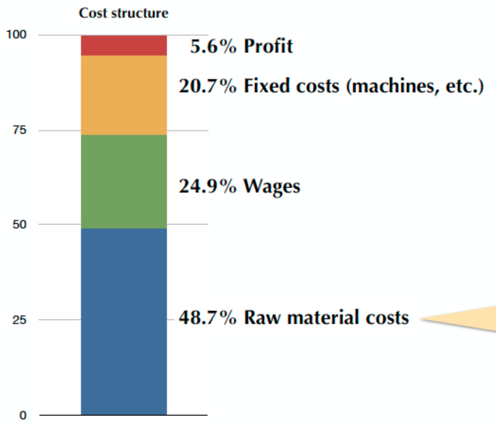
The basic elements of the pre-feasibility
Cost analysis

Cost analysis
Plastic industry Region Zealand



Biocomposites costs:

- Virgin plastic: 11-13 D.kr
- Recycled plastic: 7 D.kr

Composites:

- Recycled plastic: 7 D.kr
- Straw materials: 1 D.kr

Composite 20%
Raw material costs: 5.80 D.kr

Composite 30%
Raw material costs: 5.20 D.kr

Composite 40%
Raw material costs: 4.60 D.kr

Expected lower product prices?

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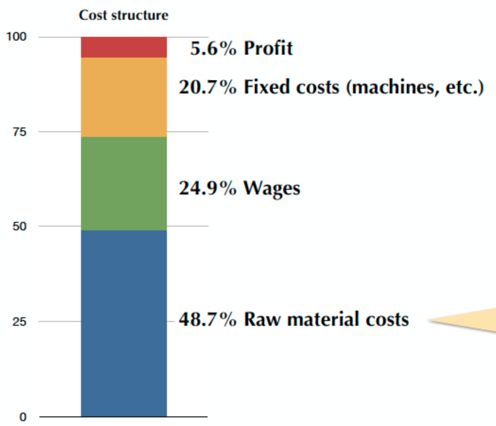
The basic elements of the pre-feasibility
Other effect - examples

Cost analysis
Plastic industry Region Zealand



Greenhouse gas effect

- Fossil plastic: 2.4-4.1 kg CO_2/kg
- Expected reduction: 3.5 kg CO_2/kg
- Fossil energy today: 1.5 kg CO_2/kg
- Net reduction: 2.0 kg CO_2/kg

Example:
Composite 30%
Production: 50.000 tons
Substitution of virgin plast: 35.000 tons
Reduction greenhouse gas: **70.000 tons**

Ressource efficiency:
Circular economy:
Recycled material: 50.000 tons
Import substitution: 35.000 tons

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Innovation programme

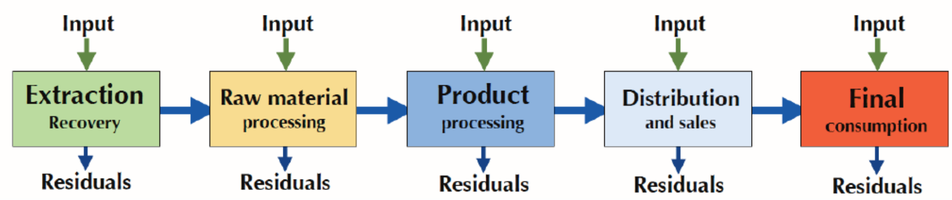
The deliverable will include two parts [here part 2]:
Innovation programmes to support implementation of the innovative value-chains

Suggested approach: Roadmapping (some time also called Technology Platform)
Roadmapping consists of at least three elements

https://www.ifm.eng.cam.ac.uk/ifmecs/business-tools/roadmapping/roadmapping-at-ifm/

Vision, goals
Strategy
action plan

[Backcasting: from goals to action plan]



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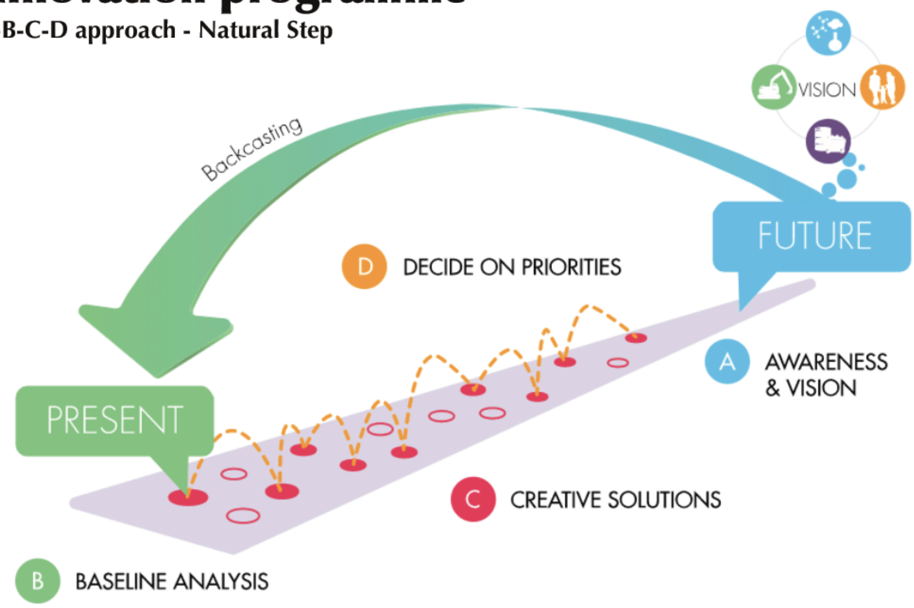
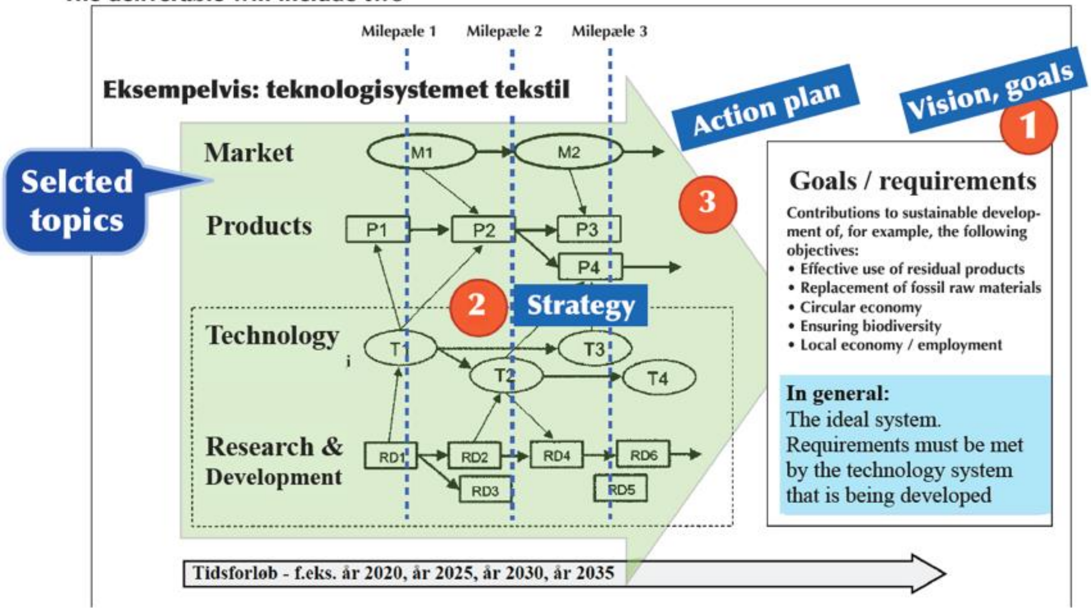
Innovation programme

A-B-C-D approach - Natural Step



Roadmapping / roadmap

The deliverable will include two



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Roadmapping - example 1

Roadmap 2015 to 2025

Textile materials from cellulose

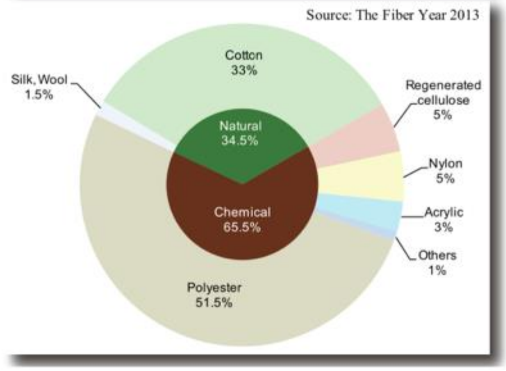
RISE - Roadmap - example 1

Development of cellulose based textile

In 2016: Establishing and development of new and existing test beds organised in a platform at the RISE institutes

In 2020: Development and pilots of textile production in close collaboration with the industry that will strengthen the knowledge transfer by increased mobility between industry and the RISE institutes

In 2025: Production of cellulose based textile materials and products thereof that strengthen Sweden's future global competitiveness.



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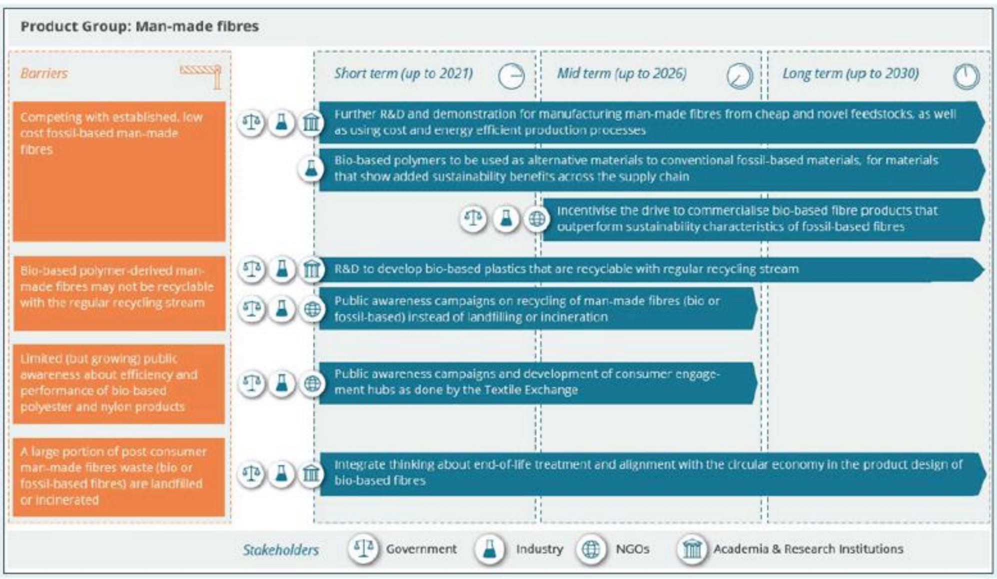
Roadmapping - example 2: Fibres

Roadmap for the Chemical Industry in Europe towards a Bioeconomy



Roadmapping - example 3: Plastic / polymers

Roadmap for the Chemical Industry in Europe towards a Bioeconomy

Product Group: Plastics/polymers

Barriers

- Cost of production in comparison to fossil-based processes is too high
- Limitations in relation to product functionality
- Some bio-based plastics cannot be recycled, e.g. Currently PLA cannot be recycled with other plastics like PET
- No clear labelling to differentiate bio-plastics, bio-based plastics and biodegradable plastics

Short term (up to 2021) | *Mid term (up to 2026)* | *Long term (up to 2030)*

- R&D, demonstration scale projects to reduce cost by increasing efficiency of bio-based chemical production
- Develop a specific Strategic Research Innovation Agenda on bio-based plastics to guide future funding decisions
- R&D to improve the performance of chemicals/materials and match product performance/ functionality with its application
- Utilise and retrofit the existing infrastructure to product bio-based polymers and bio-based polymer building blocks
- R&D to develop PLA and other bio-based plastics that are recyclable with regular recycling stream
- Provide adequate labelling to inform customers of types of bio-based plastics to raise awareness about bio-based plastic alternatives and end of life processing
- Communication along the entire value chain with accurate data for end-of-life processing to develop labelling for end-consumer

Stakeholders: Government, Industry, NGOs, Academia & Research Institutions

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Roadmapping - example 3:

Plastic /polymers

Different types - different drivers and barriers

Product Group: Plastics/polymers — *Addressable Market:* L

Subgroup	*Additional drivers*
Bio-based plastics	Enhanced performance
Elastomers	Durability
Synthetic equivalent of natural rubber	Safe alternative to natural rubber, high purity, clarity, flow, low gel content, no nitrosamines
Thermoplastics	Enhanced chemical, optical or physical properties
Thermoplastic elastomers	
Thermoset	

Barriers

- Cost of production in comparison to fossil-based processes is too high
- Limitations in relation to product functionality
- Some bio-based plastics cannot be recycled, e.g. currently PLA cannot be recycled with other plastics like PET
- No clear labeling to differentiate bio-plastics, bio-based plastics and biodegradable plastics

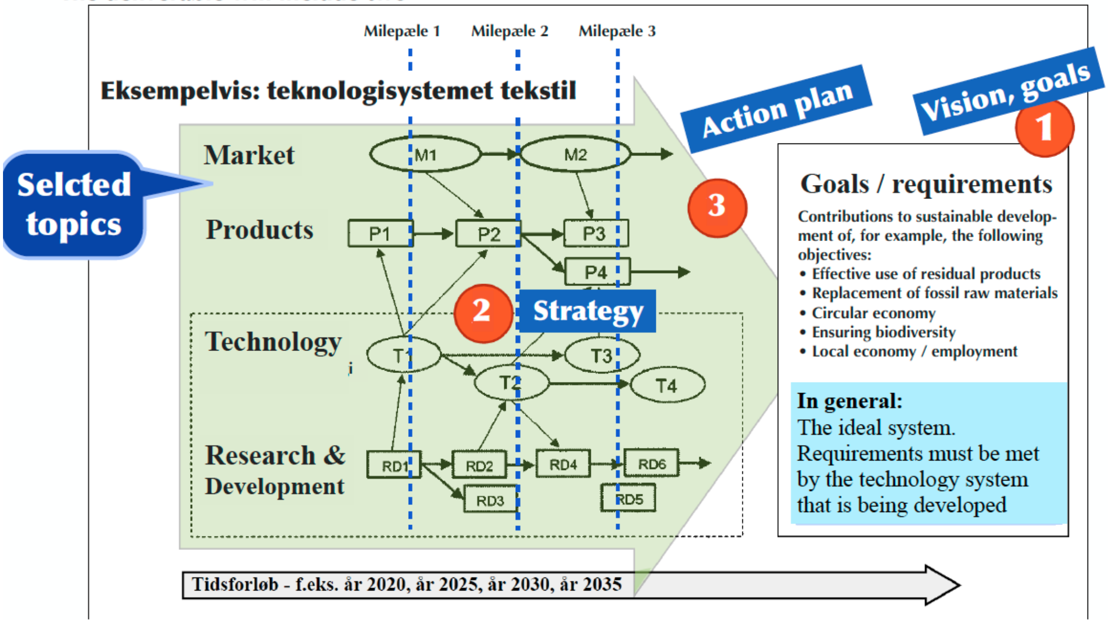
Sustainable drivers: Biodegradability, Low ecotoxicity, Lower GHG emissions, Recyclability, Low human toxicity

Addressable market: S <1,000 kt; M 1,000 – 10,000 kt; L >10,000 kt

**Addressable market is based on the current production volume of fossil-based chemicals in the product group in Europe*
Note: Biodegradability is not a commonly desired sustainability characteristic for every bio-based chemical within the same subgroup, since end-of-life disposal is dependent on the product's use.

Roadmapping / roadmap

The deliverable will include two



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Businesss case - Sugarbeet tops

Case example

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Sugarbeet tops - estimated amount and gas yield

Method 1: Direct biogas yield
Calculation of the yield

Sugar beet total tons:	880.026	13,3%	86,5%
Expected energy production			
Lower calorific value:	9,940 KWh/m^3		**352.085** MWh

Method 2: Gas yield on silage of beet tops and straw
Calculation of the yield with mix of straw and sugarbeet tops

Sugar beet total tons:	880.026	Beregnet som	80,0%
Straw	220.007	Beregnet som	20,0%

Biogas in total:	1.100.033	27,6%	88,6%
Expected energy production			
Lower calorific value:	9,940 KWh/m^3		**896.758 MWh**

Material input:

	Amount tons
Sugar beet tops	
Area with sugarbeets:	33.441
Amount per Ha:	26
Dry matter:	13,3%
Organic dry matter	86,5%
Sugar beet total tons:	880.026 tons

City consumption: 1,6 mio. MWh

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Sugarbeet tops - harvesting and recovery
Case example

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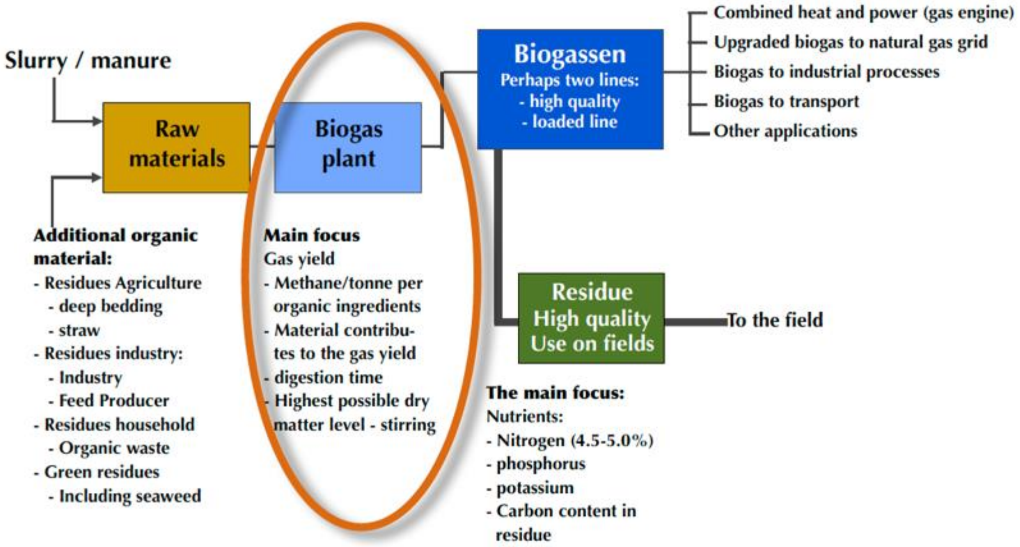
The biogas plant

- Improving of fertilizer product in new and existing biogas plant



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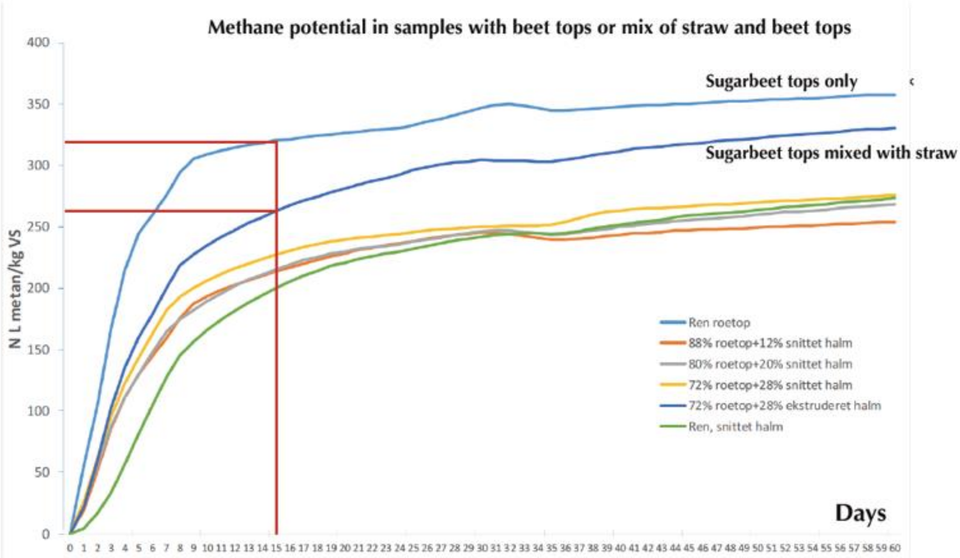
Sugarbeet tops - methane yield



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Sugar beet tops

The feasibility

Without:

Kapitalomkostninger i alt:	**5,622**	**Mio. D.kr**
Samlede udgifter på biogasanlægget:	**18,669**	**Mio. D.kr**
Result - profit:	**0,249**	**Mio. D.kr**

With sugar beet tops (mix tops & straw)

Kapitalomkostninger i alt:	**5,622**	**Mio. D.kr**
Samlede udgifter på biogasanlægget:	**18,669**	**Mio. D.kr**
Result - profit:	**2,075**	**Mio. D.kr**

Omsætning/Indtægter				
Afregningspris:	464,00	kr/MWh	21,200	Mio. D.kr
Indtægter i alt:			**21,200**	**Mio. D.kr**
Drift og vedligeholdelse				
Energiafgrøder (majs):	670	kr/tons	0,000	Mio. D.kr
Råvare halm, incl. forbehand	670	kr/tons	3,350	Mio. D.kr
Råvare - græs:	417	kr/tons	0,834	Mio. D.kr
Grødeskær - græs mv.	-10	kr/tons	-0,005	Mio. D.kr
Restprodukter/affald:	-100	kr/tons	-0,055	Mio. D.kr
Biogas - drift og vedligeholc	36,75	kr/tons RV	4,410	Mio. D.kr
Transport - tur/retur, lager:	0,90	kr/tonkm	2,592	Mio. D.kr
Tankeleje	20,00	kr/tons	1,921	Mio. D.kr
Variable udgifter i alt:			**13,047**	**Mio. D.kr**

Sum af ovenstående:

Anlægsleverancen: Beskæftigelse ved anlæg i anlægsfasen:	24,9	55,3
Driften: Beskæftiget råvare og drift & vedligehold årligt:	**9,4**	**15,7**
Den samlede beskæftigelse omregnet til årsbasis:	10,6	18,4

Lokale indtægter / afgiftsfordele ved biogasproduktionen:

Lønindtægter på biogasanlægget	1,5 mio. Kr.	Bilag 13
Lønindtægter ved tilvejebringelse af råvarer (landbrug):	1,4 mio. Kr.	Bilag 13
Lønindtægter ved transportaktiviteter:	1,2 mio. kr.	Bilag 13
Værdi af drivhusgas reduktion ved energiprod. (180 kr/tons):	3,2 mio. kr.	Bilag 15
Mindsket afgiftsbetaling på varme (energiafgift: 0,20 øre pr. kWh):	2,6 mio. kr.	Bilag 10
Samlet direkte lokal økonomi fordel:	**9,9 mio. kr.**	-

Lokal økonomi effekter - omsætningseffekt for erhverv:

Værdi af gødningsprodukter:	6,1 mio. Kr.	Bilag 14
Værdien af salgsprodukter (råvarer), tankleje mv.	5,5 mio. Kr.	Bilag 11
Samlet omsætningsværdi:	**11,6 mio. Kr.**	-

- **Samlet drivhusreduktion:**
  Samlet reduktion modreget drivhusgasudledninger fra transport og elforbrug: **24.756 tons**

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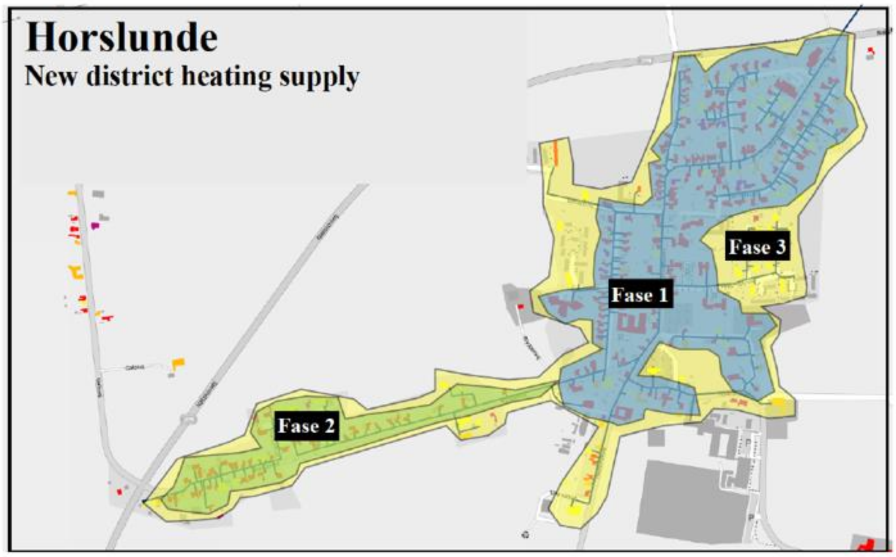
Dynamic supply

Now gas grid • Gas engine • Electricity and heat production • Minimum heat demand in the summer period



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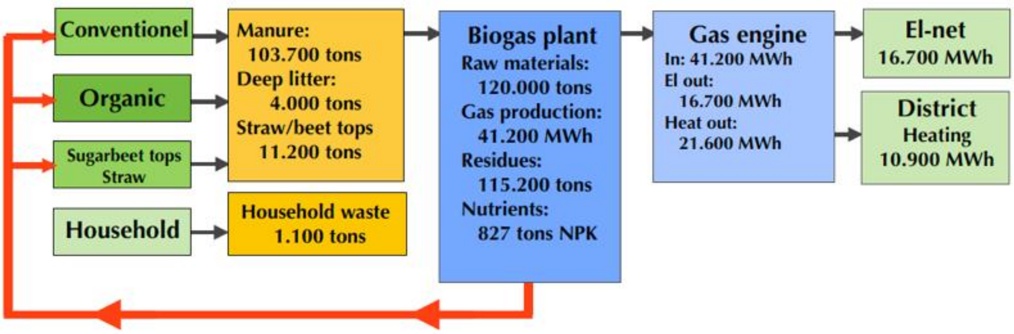
New local Biogas plant

Proposal: 120,000 tons - expected turnover: 21.2 million. Dkr annually

Local economic impact: 24.4 mio. (directly 21.2 mio.)



Recirculation of nutrients
827 tons NPK + Recirculation of Carbon

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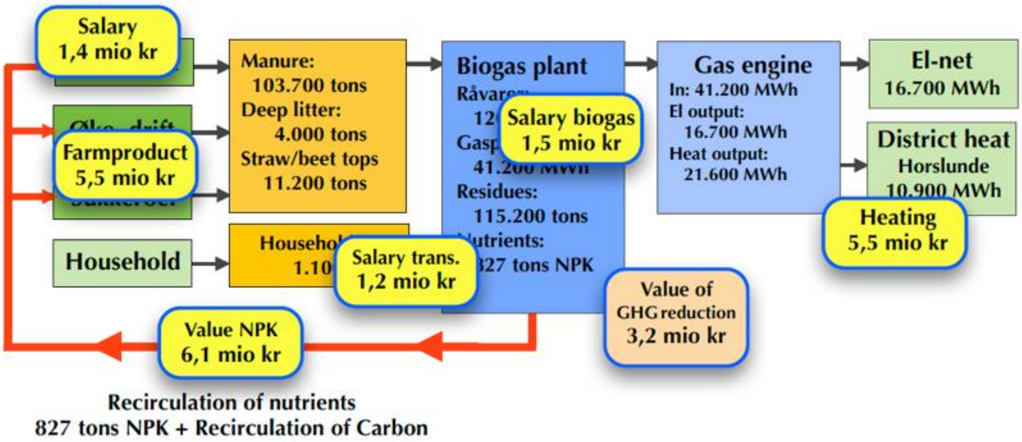

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Barriers an advantage

In the selected business case

Barriers
- Harvesting and recovery
- Storage at the biogas plant

Advantage
- Increased gas yield
- Dynamic gas production and there with increased material efficiency