



**DESUWOW**

**DEvelopment of professional Skills for  
the use of Urban solid Wastes and  
Organic Wastes in agricultural**

**2020-1-UK01-KA202-079054**

**IO1 - Training Kit**

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## **Training Methodology**

Throughout the training programme a variety of training methods can be used. The intention is to take every opportunity to familiarise participants with different methods. Most sessions are based on contributions from participants. The training leader(s)'s main role is to elicit these contributions through tactical questioning and by leading discussions.

Naturally, an experienced training leader will not agree with the approach suggested in all the sessions - many possibilities are open to a creative participant and it is important that the training leader chooses the methods they prefer and believe to be the best. Furthermore, many issues and problems which are not mentioned in the manual will probably need attention during the training programme - it will therefore not be possible to strictly follow the session guides. The manual should be looked upon as a source of ideas and information rather than a definite lesson plan.

There are some training methods which can be implemented during the training programme:

### **Conversation - Talk**

This method can be used to allow participation and bring some deeper knowledge for the participants to better understand the context of the topic. The participants can raise their questions to the speakers, or develop a small and brief discussion during the session.

Suitable topic and across information for the talk session is important to sustain interest of the participants to learn and listen.

### **Group Discussion**

Group discussion methods can help to develop and exchange knowledge, ideas, and also perspectives between the participants to get more understanding about the topic. Also, in the smaller group, the participants can establish more effective communication and increase their confidence. After each group discussion, the participants should "report" the results of their discussion with presentation, speech, or any form of reporting.

In some points, group discussion may fail due to participation from each participant in a group as they fail to discuss the topic usefully. The training leader should take this as a point to watch and regularly ask every group about the discussion progress.

### **Case Study**

Case study method is a bit similar with the group discussion, however the case study will set specific topics which they have to analyse, solve and assess the causes to get a result that they can present to the other groups or participants. This case study can be created as a small group or individual, it is up to the number of participants.

Before creating the case study activity, the training leader should have the answers beforehand, as the result from the groups can be wrong because of the limitation of their knowledge and information about some particular topics.

Due COVID-19 restriction nowadays, some of the training programmes should be implemented online, however by the progress of the condition the training programme can be implemented offline as well.

## **Online Training Programme**

The online training programme is something that is considerably better on the safety reason side to be implemented during this COVID-19 situation. There are some guides that can be used for this method:

- The online training programme can be implemented in some online platform application like Zoom
- To make a group discussion, organisers can create break-out rooms which separate participants into small groups
- During the group discussion in the breakout room, organisers can put timer which can be a reminder to all participants to speed up the discussion
- Sometimes connection issues can delay the programme, the organisers should create spare time estimation between sessions
- Even tho during online session, ice breaking and energiser are important to be included in the schedule as it will give some refreshment to participants and can “wake” the participants up during the programme
- One or two organizing members should take responsibility as note takers. The participants’ internet connection may have some issues, the notes during the day sessions will be very useful for the participants to re-read and re-evaluate.

## **Curriculum**

### **The Target Group:**

The training programme described in this manual is intended for people who need basic training and introduction about biomass utilisation and renewable energy for their future work; that may be working in such fields.

To benefit from the training, participants should have an interest and/or may have a basic knowledge about biomass and energy, and other subjects related in which they are specialised (e.g: sustainability, project management, agriculture, forestry, communications, public policy, etc).

### **Objectives of the Training Programme:**

In general DESUWOW has its own objectives as to why the training programme is important to be implemented. The objectives are:

- Development of an innovative and modern training programme and programme
- Identify and analyse targeted needs and competences
- Carrying out a set of targeted pilot trials and transferred e-learning content
- Developing new professional skills related to biomass energy
- Promoting the EU's RES demands
- Awareness-raising and transfer of innovation for the re-use of waste in the EU

- Promoting innovation, entrepreneurship and employment in rural areas - supporting the improvement of the quality of life in rural areas and reducing migration
- Promoting environmental awareness

Apart from the objectives above, the other objective of the training programme is to give participants basic knowledge about biomass and renewable energy, and its utilisation and principles.

In particular, the course should improve participants' abilities:

- To think creatively on combating environmental issues related to renewable energy and biomass
- To organise and contribute effectively in the knowledge development and consultations related to environmental issues
- To conduct such training sessions in their small groups as a capacity building group
- To evaluate the results and effectiveness of training programme

## Objectives of the Training Manual:

The training manual aims to provide some creative approaches on delivery knowledge and increase awareness related to biomass and renewable energy to participants who are interested or professionally working in the related fields. The training manual is intended for use by the training leader(s) only (the participants in the training should not have the manual).

The manual describes how the course may be conducted, session by session. Each session begins with information about objectives, duration and material needed. Handouts for the participants are included and can be reproduced as needed.

## Objectives of the Training Curriculum:

The curriculum has been developed as a training tool for training leaders who will pass on their knowledge to the participants. It uses participatory techniques based on a variety of theoretical frameworks to ensure that the participants are confident in their abilities and able to implement the creative ideas gained from the training programme to their future work and/or innovations.

## The Training Leader:

The person(s) in charge of the training should be trained, qualified and/or experienced in environmental, sustainability, youth activities and/or energy fields. A good training leader has to be:

- **A facilitator:** A training leader should be able create and establish a collaborative relationship and learning with participants. He/she/they can create positive statements and reinforcements to participants including giving feedback or correcting participants on something.
- **Inclusive:** A training leader should be able sustain and create an inclusive environment to make all participants feel safe and comfortable during the programme no matter their races, sexual orientation, and religions. He/she/they can develop trust



and openness with the participants, so the participants feel comfortable to speak honestly, and all the different opinions are respected.

- **Including all the participants in the discussion:** Sometimes the participants having difficulties in showing their thoughts and opinions in the forum, a training leader should be sensitive with this situation and find a way to make sure all participants can be involved in the discussion. Questioning participants individually can help them to speak and include their opinion in the discussion - it is also important to ask some specific questions including their experiences on fields, opinion about the situation, etc.
- **A good listener:** A training leader should be more flexible and listen to what the participants wish during the programme, there can be more discussion if the participants needed, etc.
- **Honest:** A training leader should be honest with the participants about his/her/their limitations including knowledge, experiences, etc. Instead pretending the training leader knows every answer of the question, better to ask another participant who may know the answer.
- **Good in time management:** A training leader should be able to develop a good sense of timing, including when to change the topic, when to bring a discussion to an end, when to cut off someone who has spoken too long and when to let silence continue for a little longer.

## Learning Methods:

The training leader should be aware that the participants may learn in different ways, like:

- Visual
- Movement (Kinesthetic)
- Auditory (Hearing)

Each participant has different styles of learning including which dominant sensory receivers that work in them - explained above. A training leader can ask or make a vote which learning methods that work more efficiently and effectively with the participants.

### Visual: Learning by sight

There are two types of visual learners, it can be linguistic and spatial. With the visual-linguistic learners they prefer to learn through a written language, like reading and writing. And with the visual-spatial learners they prefer to use more graphic types of language like charts, videos or other graphical materials.

To support visual-linguistic learners, the programme should:

- Provide written presentation handouts
- Give written assignments.

To support visual-spatial learners, the programme should:

- Use graphs, illustrations, charts, etc during the presentation or explanation
- Provide written information with some graphics or illustrations
- Provide handouts for reading and taking notes - including programme's outlines, agendas etc.

### **Kinesthetic: Learning by movement**

The participants with dominant kinesthetic sensory receivers can lose their focus easily when there is too little movement during the programme. The participants with dominant kinesthetic may take notes when the training leader or others give explanation and/or presentation.

To support kinesthetic learners, the programme should:

- Provide some activities to keep the participants up and moving - like ice breakers, energizers, etc
- Provide some highlighters, coloured markers to keep them focus as they like to use colours during their learning process
- Let the participants transfer some information or knowledge to another medium, like a chart.

### **Auditory: Learning by listen**

The participants can be more auditory. A training leader should support and facilitate a programme in more verbal and speak centeredness.

To support auditory learners, the programme should:

- Provide a summary of the programme or any new topic in each session, about the expectation, agenda, and keypoints
- Provide brainstorming, group discussion, etc
- Develop a conversation between the participants and training leader
- May ask the participants to “speak” their questions instead write it on the paper

### **Structure and Contents of the Training:**

The training is divided into six topics. This should be seen as a “model outline” or suggestion, which has to be adjusted to fit the actual needs of the participants. Topics and sessions may be added or deleted as required and more or less time can be allocated for any part of the training programme, time for practical exercises can be increased, etc.

These are the training contents:

- A4/1 - Introduction - Energy Sources
- A4/2 - Biomass for energy resources
- A4/3 - Methods of biomass utilisation for energy purposes
- A4/4 - Energy production from biomass
- A4/5 - Biomass conversion process
- A4/6 - Sustainability aspects of biomass for energy production

Below are the details of the training contents including duration, keywords and objectives. It will help training leaders to understand the contents better and be able to deliver it to participants better.

<b>A4/1 - Introduction - Energy Sources</b>	
<b>Duration</b>	2 hours (including group discussion and Q&A)
<b>Keywords</b>	Energy, renewable energy, fossil energy, electricity, green energy
<b>Objectives</b>	<ul style="list-style-type: none"> <li>• Understand the definition and can give explanation about energy in general</li> <li>• Understand the differentiation between fossil energy and renewable energy</li> <li>• Know the importance of renewable energy</li> <li>• Know the energy regulation in the European Union</li> </ul>
<b>Description</b>	Energy is one of the main components which is very essential in supporting human lives. Shifting the energy from fossil resources to renewable ones is a necessity. This will give a better understanding about clean and renewable energy. As the energy resource is very important to know, is it renewable or not? Does it produce high greenhouse gases?

<b>A4/2 - Biomass for energy resources</b>	
<b>Duration</b>	2 hours (including group discussion and Q&A)
<b>Keywords</b>	Biomass, agriculture, waste, sustainability
<b>Objectives</b>	<ul style="list-style-type: none"> <li>• Understand the definition and explanation about biomass</li> <li>• Know and can explore the types of biomass</li> <li>• Understand the characters of biomass</li> <li>• Know the advantages of the utilisation of biomass to energy</li> </ul>
<b>Description</b>	Biomass is one of the sources that can be used as a renewable resource of energy. Biomass can be from forestry products and even municipal solid waste which will be more sustainable and circular if it can be utilised to something else like energy than stored in the landfill which can create more greenhouse gases to the atmosphere.

<b>A4/3 - Methods of biomass utilisation for energy purposes</b>	
<b>Duration</b>	2.5 hours (including group discussion and Q&A)
<b>Keywords</b>	Biomass utilisation, energy, sustainable development
<b>Objectives</b>	<ul style="list-style-type: none"> <li>• Understand and explore the biomass utilisation</li> <li>• Know the methods on biomass utilisation</li> <li>• Explore the advantages and disadvantages of biomass utilisation</li> </ul>
<b>Description</b>	Biomass is quite a versatile product which can be utilised for some different types of energy purposes like biogas and biofuel. The utilisation also can be used for electricity purposes or as vehicle fuels.

<b>A4/4 - Energy production from biomass</b>
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<b>Duration</b>	2 hours (including group discussion and Q&A)
<b>Keywords</b>	Energy production, renewable energy, sustainable development, bioenergy, biofuels
<b>Objectives</b>	<ul style="list-style-type: none"> <li>• Know types of energy can be produced from biomass</li> <li>• Understand the biomass production scheme for each energy utilisation in general</li> <li>• Know the challenges on energy production from biomass</li> <li>• Understand the European Union regulation related to the energy production from biomass</li> </ul>
<b>Description</b>	The energy production from biomass is a sustainable way to produce renewable energy and neutral carbon emission. The energy production can be in the form of biogas, liquid fuel and electricity. There are different types of energy production from biomass that can be implemented depending on the quality and types of biomass itself and challenges of the systems used in the process.

<b>A4/5 - Biomass conversion process</b>	
<b>Duration</b>	2.5 hours (including group discussion and Q&A)
<b>Keywords</b>	Biomass production, gasification, combustion, <b>add some more</b>
<b>Objectives</b>	<ul style="list-style-type: none"> <li>• Know the biomass production process to energy</li> <li>• Understand the biomass production scheme</li> <li>• Explore how to reduce the emission and/or waste during the production</li> <li>• Understand the particular characters from each production process</li> </ul>
<b>Description</b>	There are some biomass conversion processes to energy like combustion, gasification, etc. The conversion processes are important to understand as each process has different mechanisms and characters. As well, different kinds of biomass utilisation use different methods and systems.

<b>A4/6 - Sustainability Aspects of Biomass for Energy Production</b>	
<b>Duration</b>	2.5 hours (including group discussion and Q&A)
<b>Keywords</b>	Sustainability, energy production, environmental impact, economic impact, social impact
<b>Objectives</b>	<ul style="list-style-type: none"> <li>• Understand the sustainability outlook of the biomass utilisation to energy production</li> <li>• Understand the advantages and impacts of biomass for energy conversion</li> <li>• Explore the challenges to solve related to the sustainability</li> </ul>
<b>Description</b>	To provide information about the importance in terms of bioenergy aspects to sustainability including economic, environment and social aspects.

## Duration:

To conduct the training programme as suggested in this training manual and utilising all material provided, would take approximately 20 hours (3-5 days). When adjustments to the outline and to individual sessions may have been considered, the actual time required can be calculated.

## Ice-Breakers:

- **All my neighbours....**

Tell all participants to form a circle. One person is in the middle and has to say something about him/herself/themselves at the beginning of the sentence with "All my neighbours". For example, the person will say "All my neighbours have... a cat" – all the people in the circle who also have a cat have to switch places with one person in the middle of the circle. The last person who didn't find a place in the circle has to start again and say "All my neighbours have...". This is a dynamic game that helps the participants to know each other better.

- **Two Truths, One Lie**

Break everyone into groups of between 3 and 5 persons. Each person in the group must tell the others two truths and one lie about themselves. The other members of the group must then guess which statement was the lie. When finished, the groups can choose their best 'liar', who can then try and fool the rest of the groups. This exercise helps people to realise how difficult it is to know a person just from external appearance and from what they say.

- **Animals' Sounds**

Prepare sheets of paper and write animal names on it (chicken, cow, sheep, goat,...)  
- there should always be at least 2 or 3 papers with the same animal on it. Distribute it to the participants. Ask the participants to make the sound of their animal, everybody at the same time. The persons who make the same sounds should form a group. This is a funny exercise that takes the timidity of the participants away. It can also be used to form groups for further group activities.

- **Mind Reader**

Ask everyone in the group to:

- Pick a number between 1 and 10 and keep it secret.
- Multiply this number by 9.
- If this number has 2 digits, add them together.
- Subtract 5 from this number.
- Equate this result to a letter of the alphabet (1 = A, 2 = B, 3 = C etc).
- Think of a country beginning with that letter.
- Think of an animal beginning with the second letter of that country.

And then can ask "How many people were thinking of a grey elephant in Denmark?"

- **Blindfold**

Participants are divided into pairs, and one of the pairs has a blindfold over their eyes. The other one has to lead the blindfolded person around the room and around obstacles in the room, such as tables, chairs, flipchart. After 5 minutes, the couple change roles, and the leader becomes the blindfolded person.

This exercise helps people to trust each other, but it also helps participants to realize what it is like to be in a vulnerable situation.

# Chapter 1 - Energy and Its Resources

**Objective** : To provide some information and better understanding to the participants about the energy and its resources. This section will focus on basic explanation of energy itself - both conventional and renewable, its advantages and disadvantages, and also overview of the EU regulations related to energy.

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## Introduction

Before starting the content about energy and its resources, trainers can provide a short brainstorming to remind the participants about the energy itself.

### **|| Activity:**

List the ideas of when and where we use the energy

**Answer:** We use energy all the time, it includes our daily activities like walking, running, cycling, talking etc. And we use energy to support our daily activities as well, like fuels for our vehicles, electricity for household appliances and lights, etc.

Energy is an important part and vital to many sectors especially to the economy. Long term availability of energy resources is important to make sure the balance between economic tradeoffs and environmental aspects, and it can lead to some issues that have major implications for the future communities, economy and sustainability, such as the demands of clean energy, reduce gas emissions, control greenhouse gases, and also economy performances regarding the energy conversion and transitions. The renewable and sustainable sources needed to provide green energy which produced low carbon to zero emissions. However, capacity building and raising awareness of people about renewable energy and responsible consumption is a necessity.

There are various types of energy forms:

- Light (radiant energy)
- Heat (thermal energy)
- Mechanical
- Chemical
- Electrical
- Nuclear

Based on the sources of energy, there 2 mainly types:

- Conventional sources or referred to non-renewable sources, like coal, natural gas, petroleum, nuclear
- Renewable sources, like biomass/waste, wind, hydro, solar, geothermal

Based on the IEA report of [Key World Energy Statistics 2020](#), the world total final energy consumption (TFC) in 2018 is 40.8% from oil, 10% from coal, 10.2% from biofuels and waste, 19.3% from electricity, 16.2% from natural gas, and 3.5% from other sources. As the data shown, the majority of the final energy consumption is still derived from fossil fuels sources which are not renewable and sustainable. Globally, biomass utilisation for energy is

still pretty low, however biomass is one of the sources that is renewable for future clean energy.

Based on the energy balance data published via Eurostat by the European Union for 2019-2020 periods, gas is the majority of the energy sources going through households, meanwhile renewable energies are increasing annually. As attached in the Figure 1.1 below, oil and petroleum sources are decreasing - it is not reaching zero yet, however it is progressing each year. The figure below can be included in the presentation slide to be shown to the participants, to provide them some information about energy - fuels related to household consumption.

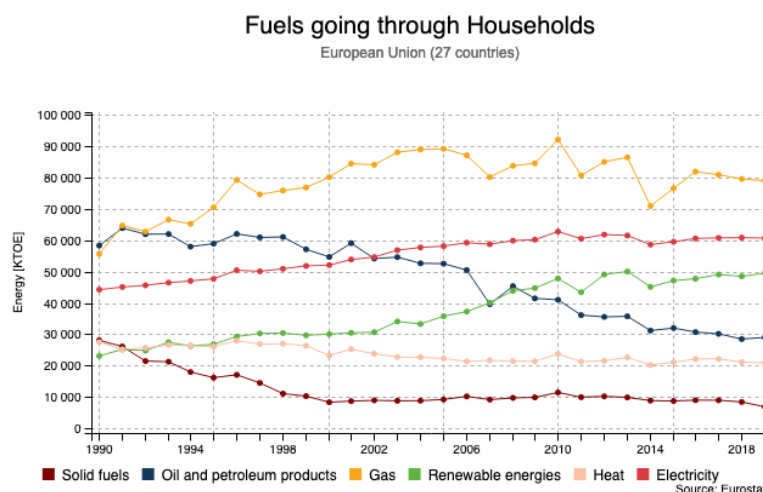


Figure 1.1. Fuels going through household (Eurostat, 2019)

## Conventional Energy Sources

Conventional energy sources are usually referred to as non-renewable and not sustainable sources as they have limited resources which may be depleted. This type of energy will create damage to the environment, human health, security risks and as well long term storage costs.

There are some sources of conventional energy:

- Mining production sources, like coal, petroleum, natural gas. This conventional energy source is usually called fossil fuels which are actually classified as nonrenewable energy because it takes many years to naturally reproduce this source. Fossil fuels are energy resources derived from altered remains of living organisms buried by sediments and exposed to elevated pressures and temperatures for millions of years ([Gerali, 2020](#)).
- [Nuclear source](#) - this energy source derived from splitting the uranium and plutonium atoms. To produce the nuclear energy, it needs mining operation which can refer to non-renewable activity, however nuclear energy production can be referred to as clean and sustainable energy, as it is a zero-emission type of energy, it produces minimal waste and consists of energy dense.



**|| Fun fact about nuclear:**

1 uranium pellet (~1 inch tall) = 17,000 cubic ft of natural gas = 120 gallons of oil = 1 ton of coal ([US Department of Energy](#)).

## Environmental Impacts of the Conventional Energy Sources

As the conventional energy sources are non-renewable and from mining activities, there are some environmental impacts - especially from fossil fuels production industries. The environmental impacts will be separated into three different aspects - air, water and soil. The industries included coal and mining industries, and petroleum refineries.

Table 1. Environmental Impacts of the Fossil Fuels Energy Sources

Industry	Air	Water	Soil
Mining Activities and Industry	<p>Dust pollution - This pollution can be happened during the production and mining processes, such as extraction, transport and storage of mining products</p> <p>There are risk of explosions and fires during the mining process which can also caused air pollution</p> <p>Emission of carbon dioxide and sulphur dioxide to the atmosphere from burning process which are considered as greenhouse gases</p> <p>Particulate matters (PM) from mines can cause global warming pollution and affect human health such as respiratory issues and premature death</p> <p>In coal mining</p>	<p>Contamination of highly acidic mine water to the surface and underground water that can give negative impacts to the water ecosystem and as well communities who using the water directly</p>	<p>As the soil is removed during coal mining activities (especially surface method), there will be soil disturbance, erosion and sedimentation to the water bodies like rivers.</p> <p>There will be land degradation during the mining activities caused by the vegetation and soil removed from their natural place</p> <p>During mining activities, there are toxic elements from coal refuse and flying that can be polluted to the soil</p>

	activities, there are some greenhouse gases such as carbon dioxide, methane, nitrogen oxide, and other types of heat-trapping gases which remain in the atmosphere for a long time and can cause global warming		
Petroleum processing/refinery	<p>The emissions of sulphur dioxide (SO<sub>2</sub>), nitrogen oxides (NO<sub>x</sub>), hydrogen sulphide (H<sub>2</sub>S), hydrocarbons (OH), carbon monoxide (CO), carbon dioxide (CO<sub>2</sub>), particulate matter, other toxic organic compounds and foul odours which came from petroleum processing and refinery activities can cause air pollution and as well will give negative impacts to the human health</p> <p>There are risks of explosions and fires from the production which can emit some harmful gases to the atmosphere.</p>	<p>Use of large quantities of water for cooling - if using fresh water resources, it can caused water scarcity in particular areas</p> <p>Emissions of hydrocarbons, caustics, oil, chromium and effluent from gas Rubbers to the water resources both surface and underground</p>	Hazardous waste sludges from effluent treatment in the refinery system such as tars, tank bottoms and spent catalysts which can pollute and harm the soil

### Advantages of Conventional Sources of Energy

Until today, conventional energy sources are still used by many consumers globally because there are some advantages regarding the well developed technology and systems. Below are some advantages of conventional energy sources:

#### 1. Technologically efficient and cost-effective

Conventional energy sources are technologically efficient as the sources used for a very long time and still the majority of the energy source in the market. As a result, they are still

used for both residential and commercial purposes globally. Conventional energy sources such as coal, natural gas, and oil are still the majority of energy sources compared to renewable energy sources such as wind or solar energy which are abundantly available and renewable. We all know how conventional sources of energy are abundant and have been around for a long time, so it comes as no surprise that they are very cost-effective. Also, conventional energy sources provide more energy because of well developed systems and technologies. It makes them still the primary source of power generation on a global scale.

## 2. The availability of the sources

The abundance of conventional energy sources are available widely. As a result, it is readily available all year. When it turns to renewable energy sources, the resources are dependent. Consider solar energy, which is reliant on the sun, and wind energy, which is reliant on the wind. When it comes to conventional energy sources, there is no such reliance. You can use them at any time of year. Furthermore, they are easy to transport, and their presence in a large number simplifies things.

## 3. Familiarity

Unlike new renewable energy source technology, the information of conventional energy production technology is well distributed and informed to communities - it is more familiar with us in daily life. Consider fuel woods, which are sourced from both natural forests and plantations. People in rural areas use them for a variety of purposes on a daily basis, like for cooking purposes. Because of its ease of access, it is a well-known source of energy. The majority of nations rely on it to meet their power needs.

## 4. Convenient

The conventional energy sources can be found all over the world, they can be easily transported across borders and quite simple to use. Some people find it difficult to operate new machines or other sources of energy, so they stick to using conventional sources of energy. In addition to their utility, these sources are relatively simple to store, making them a popular choice among the general public. People who live in areas where it is difficult to access renewable energy sources can easily use conventional energy sources, as the distribution is widely developed.

## **Disadvantages of Conventional Sources of Energy**

There are bigger consequences to using conventional energy than the benefits provided by it. We have to deal with consequences and negative effects from using conventional energy - both for the environment and human health. Here are some disadvantages of conventional energy sources:

### 1. Rely on the limited conventional energy sources

As we are still quite reliant on conventional energy resources, and as a result, transitioning to renewable energy sources is becoming more difficult. However, the conventional energy resources take centuries to form, and our consumption rate has increased as the population and needs (household and industrial) are as well increased. If there are no necessary steps now towards renewable energy, we will run out of conventional energy sources, and their slower formation rate will make matters (especially household and industrial activities) worse.

## 2. Health issues

When conventional energy sources are used, they emit gases and particulate matter (PM) which are harmful to human's health. The emission gases used to be called greenhouse gas emissions. Respiratory issues are the most commonly observed type of problem from the use of conventional energy sources. The combustion of conventional energy sources pollutes the air, water, and land. People who work in the mining industry face greater dangers, as they are exposed to the risk of work accidents.

## 3. Hazardous

There are a number of byproducts from conventional energy production that cause problems - environmental and human health. For example, when coal is burned, fly ash is produced as a byproduct. It endangers the workers at coal power plants as well as the residents who live near coal ash disposal sites and as well contribute to air pollution. Also, when fuel woods are burned uncontrollably and without efficient systems, smoke is produced that contains carbon dioxide, water, and other harmful chemicals. Carbon monoxide, nitrogen oxides, and other byproducts of conventional energy sources are hazardous to human health. The oxides released by the combustion of conventional energy sources convert rain into acidic acid, causing harm to both wildlife and humans. Other negative effects include greenhouse gas emissions, pollution, waste generation, and ozone layer depletion.

## 4. Non renewable resources

We may have come across campaigns encouraging people to switch from conventional energy to renewable energy sources. The purpose of similar initiatives is to raise public awareness about the depletion of conventional energy sources. These energy sources are gradually dwindling, and future generations will bear the consequences. As a result, it is critical to use it wisely, bearing in mind that it takes billions of years to form.

### **|| Activity:**

Create a group by 4-5 people to find out more about the mining and petroleum sectors based on countries and the impacts on the environment and social, and why shifting from the fossil fuels to renewable energy important - let them to present it to the others - this can be a presentation, drama, or any other creative forms of explanation.

## **Renewable Energy Sources**

Renewable energy is an energy which comes from sustainable resources and has the ability to be replenished naturally. The renewable energy sources can include sunlight, wind, water, tidal, waste, biomass and any other type of renewable sources. The renewable energy primarily converted to several products like heat, electricity, and type of fuels for the transportation used.

Renewable energy is one of the potential and going to be an important energy source for the future. Renewable energy produces low-carbon energy which is actually environmentally sustainable. With the rapid development there are some technologies that are used for the conversion of renewable energy like hydropower, wind turbines, photovoltaics, biomass and waste combustion. The main renewable energy sources with their usage in in different form are written below:

Table 2. Renewable energy resources and the conversion options

Energy Resource	Energy Conversion and Usage Option
Hydropowers	Power generation
Biomass	Heat and power generation, pyrolysis, gasification, digestion
Geothermal	Urban heating, power generation, hydrothermal, hot rock
Solar	Solar home system, solar dryers, solar cookers
Direct Solar	Photovoltaic, thermal power generation, water heater
Wind	Power generation, wind generator, windmill
Wave	Numerous designs
Tidal	Barrage, tidal stream

According to the State of the Energy Union Report 2021, renewable energy overtook fossil fuels as the EU's power source in 2020. Renewable energy provided 38% of the EU's electricity source, fossil fuels in 37% and nuclear in 25%. However, some of the member states of the European Union have the possibility to fail the expectation on using renewable energy at least 22% from the total electricity.

Environmental issues, climate change, and energy security are the factors that affect the demand for renewable energy globally. The awareness of fossil fuels combustion and its impacts to the environment and climate change is increasing year by year. There are some benefits of developing a renewable energy sectors:

- Create local opportunities for job creation, and income
- Utilise natural local resources like wind, sun, water, biomass and geothermal
- Decrease the percentage of the needs of fossil fuels and its imports
- As the energy utilised locally, it will create stable energy cost for the regions as it will not rely on global energy costs

### **|| Activity:**

To be a reminder of energy resources explained previously, trainers can ask the participants a question about other forms of energy and examples of it.

**Question:** Are there other forms of energy?

**Answer:** Yes, there are 7 forms of energy:

- Mechanical energy (kinetic-energy), example: wind mill, hydropower plant, cycling, etc; its counterpart is stored energy (potential energy), example: water in the canal, water wheel, hydroelectric power
- Radiant energy or sunlight or solar
- Sound energy

- Chemical energy
- Heat energy
- Electrical energy
- Nuclear energy

### Environmental Impacts of the Renewable Energy Sources

Renewable energy projects have also contributed in improving environmental impacts such as reduction of carbon dioxide gas, awakening communities about climate change. The study observed very small impacts on the people living in a particular area, tourism, cost of energy supply, and educational impacts. Significant impacts were observed in improvement of life standard, social bonds creation, and community development. They also observed that the renewable energy projects are complex to install and are local environmental and condition sensitive. Their forecasting, execution, and planning require more consideration and knowledge as compared to other projects. The two main aspects of the environment are air and water pollution, normally created by the discharged water from houses, industries, and polluted rain, and discharge of used oils and liquids containing poisonous chemicals and heavy metals like mercury, lead, etc. Along with water pollution, natural resources can be maintained and greenhouse effect and air pollution can be mitigated by the proper usage of renewable energy sources as shown in **Table 3**.

Table 3. Summary of environmental effects (Kumar, 2019)

Category of impact	Relationship to conventional sources	Comment
<b>Exposure to harmful chemicals</b>		
Emission of Hg, Cd, and other toxic elements	Reduced emissions	Emission reduced a few hundred times.
Emission of particles	Reduced emissions	Much less emission.
<b>Exposure to harmful gases</b>		
CO <sub>2</sub> emission	Reduced emissions	A big advantage.
Acid rain, SO, NOx	Reduced emissions	Reduced more than 25 times.
Other greenhouse gases	Reduced greenhouse gases	Big advantage-global warming.
<b>Other</b>		
Spouts off fossil fuels	Total or partial elimination of oil spills	Heavy fuel oil and other petroleum product spills.
Water quality	Better quality water	Reduced water pollution.
Soil erosion	Smaller loss of land	In most cases, there is no penetration deep into earth.

### **|| Fact:**

According to the State of the Energy Union Report 2021, renewable energy overtook fossil fuels as the EU's power source in 2020. Renewable energy provided 38% of the EU's electricity source, fossil fuels in 37% and nuclear in 25%. However, some of the member states of the European Union have the possibility to fail the expectation on using renewable energy at least 22% from the total electricity.

### **|| Activity:**

Create an online survey poll that can be used by the participants to answer the question below:

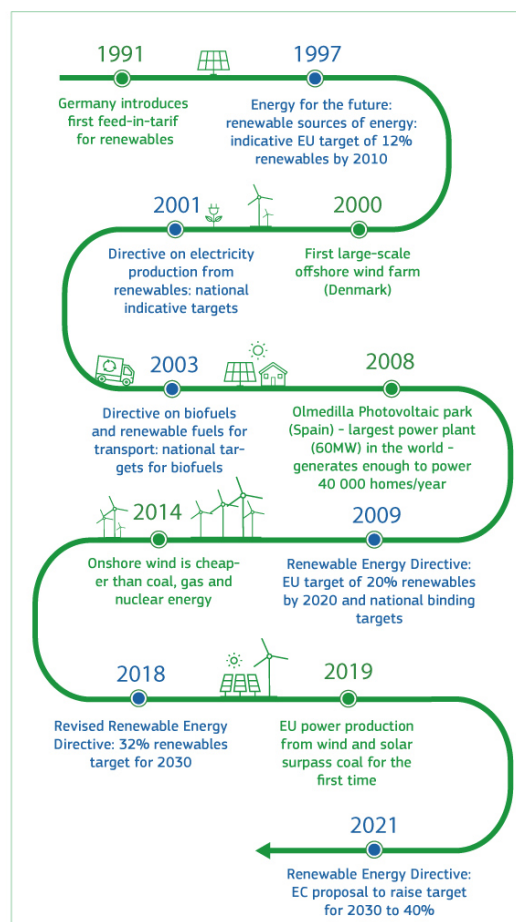
“How many percent do you think of renewable energy sources used as the EU's power source in 2020?”

**Answer:** In 2020, 38% renewable energy, 37% fossil fuels, and 25% nuclear (State of the Energy Union Report 2021).

## **Overview of the EU Regulation for Energy**

The use of renewable energy is a high priority in the EU energy policy. Renewable energy can provide an important contribution towards improving security and diversification of energy supply, environmental protection and social and economic cohesion.

Below are the timeline of the renewable energy in the European Union ([EU, 2021](#)):



In 1997 the EU agreed a strategy and target to double the share of renewable energies in gross domestic energy consumption, from 6% to 12% by 2010. In 2001, member states agreed national (non-binding) targets for electricity production from renewable sources, to expand the aggregate proportion of electricity from renewable sources in the EU from 13.9% in 1997 (3.2% excluding large hydro) to 22.1% by 2010 (12.5% excluding large hydro).

In July 2021, the European Commission proposed a revision of the Renewable Energy Directive, as part of the package to deliver on the European Green Deal. The European Green Deal (EGD) has the objective to become climate neutral in 2050 which contributes to the European economy, growth and jobs. In December 2020, the European Council requires the objective to reduce greenhouse gas emissions to 55%. The Commission proposes therefore to restore Europe's forests, soils, wetlands and peatlands. This will increase absorption of CO<sub>2</sub> and will make our environment more resilient to climate change.

This European Commission Green Deal scheme is supporting circularity and sustainability management that will:

1. Improving living conditions
2. Maintain a quality of life
3. Create quality jobs
4. Provide sustainable energy sources

### **|| Activity:**

Develop a discussion around 10-15 minutes before explaining more about the content with the participants about how to promote renewable energy effectively and be able to provide awareness to the community about renewable energy - especially electricity.

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## Chapter 2 - Biomass for Energy Resources

**Objectives:** This section will provide some explanation related to biomass and its potential to convert to one of the renewable energy resources. This section will give some information about the characteristics and types of biomass to develop better understanding to the participants.

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### Background

The Fit-for-55 package by the European Commission is a series of legislative proposals to deliver the European Union's increased climate target by reducing 55% of emissions by 2030. This package includes a higher target and new rules to support the expansion of renewables, including renewable energy resources. Also, the European Union (EU) has set ambitious climate and energy targets for 2030, including an EU-wide target for renewable energy from 32% to 40% of final energy consumption.

In 2020, the European Union renewable energy share is 21.3% ([European Environment Agency, 2021](#)). According to the European Environment Agency, that number means the EU has reached the target of 20% of renewable energy share for 2020. The constant improvement and progress on renewable energy production is a necessity as the new target of final energy consumption for renewable energy is 40% in 2030. According to the EU's Energy Factsheet, 75% of total greenhouse gases emissions in the EU comes from the energy sectors, so with the increase of renewable energy production will reduce the GHG emissions itself.

Biomass is one of the renewable energy resources that can support the EU Green Deal and Climate Target in the energy sector. According to [Scarlat et. al. \(2019\)](#), biomass for energy (bioenergy) continues to be the main source of renewable energy in the EU, with a share of almost 60% and the heating and cooling sector is the largest end-user, using about 75% of all bioenergy. Bioenergy production primary supply is from direct wood supply like forestry and wooded land. However, in 2021, the European Commission created a revision for the renewable energy directive which also includes the regulation of sustainable bioenergy production.

Sustainable bioenergy reinforced criteria in line with the EU Biodiversity Strategy for 2030 is:

- Prohibit sourcing biomass for energy production from primary forests, peatlands and wetlands
- No support for forest biomass in electricity-only installations as of 2026
- Prohibit national financial incentives for using saw or veneer logs, stumps and roots for energy generation
- Require all biomass-based heat and power installations to comply with minimum greenhouse gas saving thresholds
- Apply the EU sustainability criteria to smaller heat and power installations (equal or above 5MW)

### **|| Activity:**

Create a short discussion (10 mins) about EU Biodiversity Energy to reinforce more sustainable bioenergy production. Is it important to preserve biodiversity in the scope of energy production? Will biodiversity consideration be a “burden” for bioenergy production?”

**Answer:** Refer to EU Biodiversity Strategy which is important to preserve biodiversity and as well there are some alternative sources which can support bioenergy production apart from the direct wood supply from primary forest, wooded land and peatland - will be explained in the next chapter.

## **Introduction to Biomass**

Biomass is organic, meaning it is made of material that comes from living organisms, such as plants and animals. Biomass comes from diverse resources which includes the residues of the wood working industry, energy crops, agriculture and agri-food effluents, organic fraction of municipal solid waste, household waste and sewage sludge from wastewater treatment plants.

Biomass from **agriculture** can include crop residues, bagasse, animal waste, energy crops, etc, **forestry** can include logging residues, wood processing by-products, black liquor from the pulp and paper industry, fuelwood, etc, and **other types of biological waste** which can include food waste, food industry waste, the organic fraction of municipal solid waste, organic household waste, etc.



Biomass for energy (bioenergy) utilisation must be produced, processed and used in a sustainable and efficient way in order to optimise greenhouse gas savings and maintain ecosystem services. The biomass utilisation especially for energy purposes must be implemented without causing deforestation or degradation of habitats or loss of biodiversity. The environmental performance of a bioenergy value chain and processes greatly depends on the different steps of the pathway, from the growing and harvesting of feedstocks, to the processing, conversion and distribution of bioenergy carriers, to the final energy use. Consequently, sustainability needs to be assessed on a case-by-case basis.

## Types and Characteristics of Biomass

Feedstock is available biomass from renewable resources which are available for utilisation both direct use and processed to other forms of product to be used for energy source materials. Biomass feedstocks such as energy crops which are planted specifically for the biomass sources, agricultural activities residues, forestry residues, algae, wood processing residues, municipal waste, and wet waste which can come from wastewater treatment plants (organic sludge).

### 1. Wood and Agricultural By-Products

The supply of EU domestic biomass for energy purposes from the forestry sector amounted to over 60% in 2016, however 32.5% from the resources were constituted by direct supply of wood biomass from forests and other wooded land, and 28.2% by indirect supply of wood, agricultural crops and agricultural by-products accounted for 27%, waste (municipal, industrial, etc.) for 12% (European Commission's Knowledge Centre for Bioeconomy, 2019). Agricultural biomass is matter derived from biological organisms such as corn, straw, plants, animal waste, offal and perennial grasses. As with other types of biomass, agricultural biomass can be transformed into energy. This ensures the most optimal use of the biomass as waste and pollution is reduced. Moreover, utilising agricultural residues and by-products can reinvigorate rural economies and secure their energy independence.

The major wood and agricultural by-products biomass resources include the following:

- Firewood and wood biomass residues/wastes from forest harvesting operations (may occur as thinning in young stands or cutting in older stands for timber).
- Wood processing residues from wood and furniture industries (sawmilling, plywood, wood panel, building component, furniture, flooring etc.).
- Agricultural crops and agro-processing residues.
- Urban wood wastes (collected wood materials after construction or demolition projects, rejected wood pallets and any other construction and demolition wastes made from timber).

However, based on the **EU Biodiversity Strategy for 2030**, the sourcing of biomass for energy production directly from primary forests - like direct wood supply, also biomass from peatlands and wetlands are **prohibited**.

### 2. Waste

There is a sustainability concern on the use of biomass for energy purposes which can reduce its availability. In this context, the use of waste or residual streams of biological or organic materials could have a significant contribution on bioenergy production also, it will minimise impacts associated with landfilling. In 1885, the United States built the first waste incinerator which was used for energy recovery purposes. In 2016, the number of waste-to-energy (WtE) facilities for municipal solid waste (MSW) reached 1618 plants worldwide, including 512 plants in Europe, 822 plants in Japan, 88 in the United States and 166 in China ([Scarlat et. al., 2019](#)). Also, according to Scarlat et. al. (2019), in 2016, there were 512 plants in Europe, with 251 combined heat and power plants, 161 electricity-only and 94 heat-only plants, which provide a total incineration capacity of 93 million tonnes.

WtE conversion processes, as a source of renewable energy, are expected to play an increasingly important role in sustainable management of MSW at global level. Improved solid waste management (recycling, waste diversion from landfill and energy recovery from waste) estimated to reduce about 10–15% in the global GHG emissions.

**|| Fact:**

One ton of garbage contains about as much heat energy as 250 kg of coal. Garbage is not all biomass; perhaps half of its energy content comes from plastics, which are made from petroleum and natural gas.

### 3. Landfill Gas and Biogas

Biogas production plants for the treatment of wet-waste biomass, from wastewater treatment plants and landfill gas recovery is expanding in a number of countries. Biogas is produced in anaerobic digestion plants, from wastewater treatment and from recovery from landfill sites. In Europe, biogas is mainly produced from anaerobic fermentation in anaerobic digesters using agricultural waste, manure, and energy crops, with about 74% of the primary biogas energy output.

Biogas upgrading to higher-quality biomethane is also increasing, for use as a vehicle fuel or for injection into the natural gas grid. Biogas production has seen a significant growth in the last years in Europe, mainly driven by the favourable support schemes in place in several European Union Member States.

Looking at the sources of biogas (landfill gas, sewage sludge, anaerobic digestion or thermochemical processes). The highest amount of biogas comes from anaerobic digestion in Germany, Italy, Czech Republic and France, followed by biogas from landfill gas recovery in the UK, Italy, France and Spain. The biogas from anaerobic digesters predominates in Germany, Italy, Denmark, Czech Republic and Austria. Landfill biogas also dominates the market in Portugal, Estonia, Ireland or Greece and the UK, while biogas from wastewater treatment prevails in few countries, such as Sweden, Poland and Lithuania.

**|| Tell Story for Better Understanding: How Biogas (Methane) Produced?**

Bacteria and fungi are actually not picky eaters. They eat dead plants and animals, causing them to rot or decay. A fungus on a rotting log is converting cellulose to sugars to feed itself. Although this process is slowed in a landfill, a substance called methane gas is still produced as the waste decays. Regulations in most countries require landfills to collect methane gas for safety and environmental reasons. Methane gas is colourless and odourless, but **it is not harmless**. The gas can cause fires or explosions if it seeps into nearby homes and is ignited. Landfills can collect the methane gas, purify it, and use it as fuel. Methane can also be produced using energy from agricultural and human wastes. Biogas digesters are airtight containers or pits lined with steel or bricks. Waste put into the containers is fermented without oxygen to produce a methane-rich gas. This gas can be used to produce electricity, or for cooking and lighting.

### 4. Alcohol Fuel

#### a. Ethanol

Ethanol is an alcohol fuel (ethyl alcohol) made by fermenting the sugars and starches found

in plants and then distilling them. Any organic material containing cellulose, starch, or sugar can be made into ethanol. In recent years, interest in ethanol from renewable biomass as a motor fuel is surging globally, because of its potential to reduce both fossil fuel dependency and environmental impacts. New technologies are producing ethanol from cellulose in woody fibres from trees, grasses, and crop residues.

Main production and consumption markets are the US and Brazil, followed by the EU – in 2008, almost  $\frac{1}{4}$  (21%) of Brazil's road transport fuel demand was met with biofuels, while this share was only 4% in the US and around 3% in the EU. In 2019, nearly all of the gasoline sold in the U.S. contains around 10 percent ethanol and is known as E10.

Crop-based bio-ethanol has proven somewhat controversial due to concerns about energy balances, life cycle CO<sub>2</sub> emissions and competition with food production. To address these concerns, bio-ethanol can be derived from a large variety of residue and waste streams - either by capturing sugar or starch rich waste streams or by using waste fractions of crops (so-called lignocellulosic biomass). Utilising ligno-cellulosic biomass is still in a relatively early stage of development, but waste based ethanol can be refined from a number of industrial and municipal wastes and residues at commercial scale today.

According to [Hirschnitz-Garbers and Gosens \(2015\)](#), if we compared to wheat (crop)-based ethanol and regular gasoline, in the 'high' demand scenario of maximum feedstock supply of 65,000 million litres (ML), waste-based bio-ethanol would save 1,405 Petajoule (PJ) of energy, equivalent to saving 9.3% of all current EU transport energy use. 17 GHG emission savings would be equal to 110 million tonnes (Mt) CO<sub>2</sub>-eq when compared with gasoline, and 75.5 MT CO<sub>2</sub>-eq when compared with wheat-based ethanol. Additional benefits of waste-based fuel production are that feedstock collection and fuel conversion tend to be highly localised and, therefore, provide local employment opportunities.

## **|| What is Lignocellulosic Material?**

Lignocellulosic material (wood) is a natural resource from the stems and roots of trees and woody plants consisting of brittle and fibrous tissues. Lignocellulosic materials including wood, agricultural, or forestry wastes (Nakarmi, 2022; Dotan, 2014).

### **b. Biodiesel**

Biodiesel (FAME; Fatty Acid Methyl Ester) and renewable diesel (HVO; Hydrotreated Vegetable Oil) are renewable alternatives to fossil-derived diesel fuel. Biodiesel is a fuel made by chemically reacting alcohol with vegetable oils, animal fats, or greases, such as recycled restaurant grease. Although often made from identical feedstocks, the processes used to make FAME and HVO are different, with different end uses.

According to the [European Biodiesel Board \(2022\)](#), biodiesel use emits between 65 and 90% less CO<sub>2</sub> than fossil diesel, with every kilogram of biodiesel use reducing CO<sub>2</sub> emissions by approximately 3 kg. Engines using biodiesel also emit significantly fewer pollutants, with tailpipe particulate matter, carbon monoxide, and hydrocarbon emissions all reduced. Furthermore, biodiesel contains virtually no sulphur, so it can reduce sulphur levels in the nation's diesel fuel supply, even compared with today's low sulphur fuels and natural self-lubricating properties that reduce metal emissions associated with engine wear.



The current Renewable Energy Directive allows biodiesel crops to be grown on land that would otherwise be taken out of production, providing additional income for farmers and encouraging efficient use of existing resources. Moreover, with every kilo of crop-produced biodiesel generating two kilos of vegetable proteins, biodiesel use supports EU food- and feed-supply independence. With the EU importing close to two-thirds of vegetable proteins used in agriculture, biodiesel crop co-products provide a secure base of internal supply and help balance this import dependence.

In the EU, biodiesel represents a significant source of renewable energy. The industry dates back to 1992, when responding to positive signals from EU institutions, industrial-scale European biodiesel production first began. As the ambition of climate change targets has grown, so has the European biodiesel industry. Today, the EU is the world leader in producing and using biodiesel and renewable diesel in transport. Close to 200 plants are in operation across the EU, producing around 13 million tonnes of biodiesel annually. Most of this is consumed in France, Germany, Spain, Sweden, and Italy, which in 2018 cumulatively made up two-thirds of the EU biodiesel market; other markets are smaller but growing.

**|| Fact:**

European production of green diesel helps reduce the EU's annual diesel deficit of more than 17 million tonnes, avoiding expenditures of more than €10 billion on fossil diesel in 2018 alone. Biodiesel supports most of the more than 248.000 jobs linked to the European biofuels industry.

**|| Activity:**

Separate participants into 5 groups to discuss types of Biomass from wood and agricultural products to biodiesel. Let them find out: (2 hours)

- The definition and/or basic explanation of each group's topic
- Basic production process
- EU status on each group's topic
- Advantages of using materials from each group's topic

After that, let the participants present the results in front of other participants, and let the discussion happen in 10-15 mins for each group.

## **Biomass Utilisation as Energy Resource**

In the EU-28, the energy produced from biomass has increased 466 PJ (13%) this decade, principally driven by a rapid extension in the power and heating industries sector. In 2019, biomass constitutes a total of almost 3% of all electricity generation and 19% of derived heat production across the EU, remaining a comparatively moderate percentage of all renewable electricity but a very vital contributor to renewably sourced derived heat.

Bioenergy can play a significant role in achieving the EU targets in terms of renewable energies by 2030 and beyond. Opportunities to increase the utilisation of bioenergy are seen e.g. in the field using agricultural residues, by-products and waste. Bioenergy can also play an important role as a flexible energetic carrier to balance the power systems and thus allowing for higher shares of renewable energy sources such as wind and solar power. Also ensuring environmental aspects like securing biodiversity or maintaining ecosystem

services, bioenergy can contribute to, among other things, greenhouse gas savings, sustainability and rural development.

The EU's demand for renewable energy is set to increase considerably in the gradual phase-out of fossil fuels in the EU's energy mix and the targets set for renewable energy sources. The energy sector is by far the largest user of EU internal wood processing residues and by-products, and the heating and cooling sector the largest end-use of bioenergy in general, using about 75% of all bioenergy consumed. Bioelectricity and transport fuels account for 13% and 12% respectively (Banja et al., 2019). According to Andersen et al. (2021), by 2050, energy consumption from biomass is expected to rise at a sustained rate with estimates varying from a near doubling to a tripling. When material use is included, the consumption figure rises further with a 50% increase in material consumption alone expected as they replace other more carbon-intensive materials.

Solid biomass is most important for electricity production in Nordic countries, such as Finland and Denmark where it contributes more than 10% of the total electrical production. However, the most extensively used renewable source for electricity in Denmark is wind. In Mediterranean areas, such as Spain, biomass demand for energy is often much lower for electricity generation but remains important for heat. In Finland, primary solid biomass holds the largest share of renewable energy sources (after hydro power) with a production increase by 39% between 2000-2018.

If well managed, bioenergy pathways can deliver significant greenhouse gas savings, whilst ensuring food security and protecting ecosystems and the services they provide from deforestation, degradation of habitats and loss of biodiversity. Bioenergy production can also bring significant opportunities to deliver social, environmental and economic benefits and contribute to rural development. Possible alternative uses of biomass (e.g. for food, feed, wood products, etc.) also need to be considered to ensure the sustainability of feedstock supply from an overall bioeconomy perspective.

### **|| Activity:**

Create an activity that makes the list of the advantages of biomass utilisation.

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## Chapter 3 - Methods of Biomass Utilisation for Energy Purposes

**Objectives:** This section explains the methods of biomass utilisation for energy purposes by providing basic explanations and some advantages and disadvantages of the methods.

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### Introduction of Biomass Utilisation

Biomass energy is the most potential renewable energy resource in the world. Biomass is like a great solar chemical industry plant, it spreads in plants all over land and water throughout the world which continuously transfer solar energy into chemical energy which is stored in the inner part of plants in the form of organic matter. So, that is how a kind of abundant renewable energy - biomass energy is composed.

There are many biomass energy resources advantages such as low sulphur concentration, less ash content, sustainable and renewable resource capacity. On the other hand, it also has some unfavourable aspects such as higher water content, lower unit thermal output, large volume, decentralised resources and unsuitable for collection, storage and transportation. But these disadvantages can be overcome. As long as suitable measures are adopted, taking into account local conditions, using available science and technology, selecting a reasonable technical program, adopting advanced techniques, developing new energy conversion methods and paying attention to the energy utilisation efficiency and economy of the biological system, then biomass resources can be used efficiently.

A few centuries ago, biomass was the most important energy resource. At the present day with advanced science and technology, the energy supplied by biomass is still more than that of both hydraulic energy and nuclear energy. According to [Eurostat \(2018\)](#), Latvia (29%), Finland (24%), Sweden (20%), Lithuania (17%) and Denmark (15%) had the largest share of wood and wood products in gross inland consumption of energy.

By means of transferring, biomass can be converted to useful thermal energy, electricity and fuels for power. The main converting methods are:

1. Direct combustion
2. Gasification
3. Liquidation of biomass.

## **Biomass Pretreatment Methods**

Bioenergy products like bioethanol, and biodiesel can be produced from lignocellulosic biomass obtained from plants that are considerably large renewable bioresources. The term “lignocellulosic biomass” is defined as lignin, cellulose, and hemicellulose that constitute the plant cell wall.

The primary objective of the pretreatment process is to deconstruct the complex biomass structure comprising lignin, hemicellulose, and cellulose so that each biopolymer can be effectively utilised to produce fuels, power and as well chemical materials. Several biomass pretreatment methods are available, including physical, chemical, physico-chemical, and biological some of them are listed as follows:

1. Physical methods which consisted of extrusion, ball milling, wet-disc milling, microwave pretreatment.
2. Chemical methods which consisted of acid pretreatment, alkali pretreatment, organosolv pretreatment, ozonolysis pretreatment.
3. Physicochemical methods which consisted of steam explosion, ammonia fibre explosion, liquid hot water, carbon dioxide explosion, wet oxidation.
4. Biological methods which consisted of white-rot fungi, brown-rot fungi, soft-rot fungi.

### **Extrusion Pretreatment**

Extrusion processing is one of the promising physical pretreatment methods for deconstruction of lignocellulosic biomass. Extrusion is defined as an operation of creating objects of a fixed, cross-sectional profile by forcing them through a die of the desired cross-section. The material will experience an expansion when it exits the die.

There are some advantages and limitations of the extrusion pretreatment of the biomass, Advantages:

- Easy on process monitoring and control.
- No inhibitory compounds formation due to sugar degradation.
- Adaptability for process modification.
- Continuous and high throughput.
- No need for washing of pretreated biomass if extrusion is performed without chemical addition.
- Can be combined with other methods of pretreatment for better results.

Limitations:

- Lack of data for economic analysis.
- Energy intensive process.
- Poor flow during continuous processing leading to burning of material.

## Acid Pretreatment

Acid pretreatment is the most extensively studied and widely used for lignocellulosic biomass pretreatment process. The main objective of the acid pretreatment process is to hydrolyze the hemicellulose fraction of the lignocellulosic biomass. The effectiveness of this pretreatment method is usually enhanced with the increase in the proportion of hemicellulose and extractive fractions in the biomass.

There are some advantages and limitations of the acid pretreatment of the biomass as it follows:

Advantages:

- High reaction rate to solubilize the hemicellulose fraction of biomass thereby making the cellulose fraction accessible for cellulase enzymes.
- A method of deconstruction can be designed for biomass processing to generate separate hemicellulose hydrolyzates (after pretreatment) and cellulose hydrolyzates (after enzymatic hydrolysis).
- Cost saving for xylanase enzymes: Hemicellulose is extensively hydrolyzed during pretreatment depending upon the feedstock type and processing conditions; therefore, high-cost xylanase enzymes are not generally required for hydrolysis.

Limitations:

- Inhibitors, such as furfural and hydroxymethylfurfural (HMF), produced from sugar degradation require an additional detoxification step to make the released sugars fermentable.
- Need expensive stainless-steel vessels due to the corrosive nature of acid.
- Additional cost for alkali to neutralise acid after pretreatment.
- Environmental concern due to excessive use of chemicals.

## Alkali Pretreatment

Alkali pretreatment is another extensively studied and widely used lignocellulosic biomass pretreatment method. This process is like an acid pretreatment process, but usually carried out at a lower temperature. While acid pretreatment solubilizes hemicellulose fraction of the biomass, the goal of alkali pretreatment process is to solubilize lignin fraction of the lignocellulosic biomass. Like in acid pretreatment process, alkali pretreatment process also solubilizes most of the biomass extractives.

There are some advantages and limitations of the alkali pretreatment of the biomass

Advantages:

- Effective delignification.
- Lower sugar degradation compared to dilute acid pretreatment due to the lower processing temperature; possible to pretreat at room temperature using longer time.
- Lignin and other extractives can be separated before enzymatic hydrolysis without loss of carbohydrate; high possibility of getting reactive lignin for high value application.

Limitations:

- Excessive phenolic compounds due to lignin degradation, which are potential inhibitors for enzymatic hydrolysis of sugar polymers.
- Additional cost for hemicellulose hydrolytic enzymes in addition to cellulase enzymes.
- Additional cost for acid to neutralise alkali after pretreatment.

## Organosolv Pretreatment

Organosolv is a promising biomass pretreatment method, in which biomass is mixed with a selected organic solvent, with or without additional catalyst (acid or alkali) and heated at an appropriate temperature and time duration. Various organic solvents or solvent mixtures can be used; including low boiling point solvents, such as ethanol, methanol and acetone; high boiling point solvents, such as glycerol, ethylene glycol and tetrahydrofurfuryl alcohol; and other classes of organic solvents, such as organic acids, phenols, ketones and dimethyl sulfoxide.

There are some advantages and limitations of the organosolv pretreatment of the biomass

Advantages:

- Extracted lignin is relatively of high purity, low molecular weight and sulphur free making it possible for the high value application of lignin.
- All three biopolymers—cellulose, hemicellulose and lignin—can be separated into different streams.
- It can be combined with other pretreatment processes for effective biomass hydrolysis.

Limitations:

- High cost of solvent: Recycling process is also energy intensive. Additional solvent is required to avoid lignin precipitation due to washing with water.
- Formation of inhibitory compounds, such as furfural and HMF, due to sugar degradation when acid catalyst is used.
- Residual solvent will be inhibitory for enzymatic hydrolysis and fermentative organisms.
- Environmental and health concerns due to the use of volatile organic liquids at high temperature.

## Ionic Liquid Pretreatment

This is a relatively new approach for biomass pretreatment, in which the whole biomass is dissolved in a selected ionic liquid and the carbohydrate polymers are precipitated by adding appropriate anti-solvents; thereby, separating lignin and carbohydrates.

There are some advantages and limitations of the ionic liquid pretreatment of the biomass

Advantages:

- Ionic liquids, considered as green solvent, are stable up to 300 °C; have extremely low volatility with minimum environmental impact.
- Possible to separate each of the biopolymers—cellulose, hemicellulose and lignin.
- Ionic liquid with desirable properties can be synthesised.

Limitations:

- Cost of ionic liquids is still very high.
- Many ionic liquids are toxic to the hydrolytic enzymes and the fermenting organisms.
- Cost of solvent recovery is tedious and expensive.
- Difficult to handle the viscous biomass slurry with ionic liquid during pretreatment at temperature beyond 150 °C.

## Steam Explosion Pretreatment

Steam explosion pretreatment is a widely studied physicochemical pretreatment process. In this process, the ground and preconditioned biomass is treated with saturated steam at high temperature (160–290 °C) and high pressure (0.7 and 4.8 MPa) for a few seconds to several minutes before the pressure is explosively released. This method is more effective in hardwood and herbaceous biomass but needs addition of acid catalyst for effective pretreatment of softwood due to the presence of lower amount of acetyl groups in softwood hemicellulose.

There are some advantages and limitations of the steam explosion pretreatment of the biomass,

Advantages:

- No use of chemicals and hence no recycling and environmental costs.
- Relatively less dilution of released hemicellulose.
- High particle size biomass can be used, leading to significant energy savings. Size reduction accounts to around one third of the entire pretreatment process.

Limitations:

- Incomplete de-construction of lignin-carbohydrate complex may lead to condensation and precipitation of soluble lignin; thereby resulting in reduced biomass hydrolysis efficiency.
- High temperature (around 270 °C) is the best to enhance cellulose digestibility; however, this leads to the formation of inhibitory compounds—furfural and HMF.
- Weak acids and phenolic compounds, such as acetic, formic and levulinic acids, generated during this process are inhibitory for subsequent enzymatic hydrolysis and fermentation.

## Ammonia Fibre Explosion Pretreatment (AFEX)

The AFEX method is an alkaline physicochemical pretreatment process. Its processing method is similar to that of steam explosion but operates at lower temperature. In this process, the biomass is mixed with liquid anhydrous ammonia (0.3 to 2 kg/kg dry biomass); cooked at 60–90 °C and at pressure above 3 Mpa for 10–60 min. The optimum ratio of ammonia to biomass, and cooking temperature, pressure and time depends on the type of lignocellulosic biomass materials. The AFEX method is very effective for herbaceous crops and agricultural residues, but relatively less effective for woody biomass. AFEX is also considered as a feasible method for the pretreatment of herbaceous biomass to extract protein for animal feed along with sugar generation for biofuels production.

There are some advantages and limitations of the ammonia fibre explosion pretreatment of the biomass,

Advantages:

- No formation of inhibitory compounds like furfural and HMF from sugar degradation due to low temperature operation.
- High selectivity for delignification.
- Easy for recycling due to the volatile nature of ammonia; 99% ammonia recovery is possible.
- Residual ammonia can serve as a nitrogen source for the organisms during fermentation.

Limitations:

- Excess water requirement because the phenolic fragments of lignins must be washed to avoid inhibition during enzymatic hydrolysis and fermentation.
- Ammonia recycling is very costly for commercial scale processing.
- Inefficient for high lignin content biomass, such as softwood and newspaper waste.
- Environmental concern due to the use of volatile chemicals.

### **Liquid Hot Water (LHW) Pretreatment**

Different terminologies are used in literature to describe this process, including solvolysis, hydrothermolysis, aqueous fractionation, and aquasolv. This process is comparable with dilute acid pretreatment without using acid. In this process, biomass slurry in water is cooked at elevated temperature (160–240 °C) for various time periods, depending on biomass type, to solubilize hemicellulose fraction of biomass leading to cellulose enriched portion.

There are some advantages and limitations of the liquid hot water pretreatment of the biomass,

Advantages:

- No use of additional chemicals.
- No need to use expensive and corrosive-resistant materials for pretreatment reactors.
- Relatively large size particles can be used leading to energy saving, which is required for size reduction of biomass to fine particles.
- Possible to recover separately the cellulose and hemicellulose streams.
- Minimum formation of inhibitory compounds.

Limitations:

- The xylose stream is of very low concentration and hence needs an additional cost-intensive evaporation of water operation to get appropriate sugar concentration for fermentation.
- High cost since high pretreatment temperature is required.
- Not suitable for biomass with high-lignin content.

### **Biological Pretreatment**

Biological pretreatment involves use of microorganisms to degrade biomass lignin and make carbohydrate polymers susceptible for enzymatic hydrolysis. Among various organisms capable of producing enzymes to degrade lignin and carbohydrate polymers of biomass, white-rot, brown-rot, and soft-rot fungi are important. The white-rot fungi are the most effective for biomass pretreatment because of their enzymatic efficiency and economy. The brown-rot fungi degrade cellulose, whereas white-rot and soft-rot fungi degrade both lignin and cellulose. The ligninolytic enzyme system of white rot fungi primarily consists of lignin peroxidase (LiP), manganese peroxidase (MnP) and laccase.

Based on enzyme production patterns, the white rot fungi could be categorised into three groups:

- Lignin-manganese peroxidase group - *P. chrysosporium* and *Phlebia radiata*.
- Manganese peroxidase laccase group - *Dichomitus squalens* and *Rigidoporus lignosus*.

- Lignin peroxidase laccase group - *Phlebia ochraceofulva* and *Junghuhnia separabilima*.

There are some advantages and limitations of the biological pretreatment of the biomass,

Advantages:

- No inhibitory compounds are produced.
- The process is environmentally friendly.

Limitations:

- Very slow process; residence time is usually between 10 to 14 days.
- Large space is required to perform the process.
- Strict temperature control is required, leading to increased processing cost.
- Cellulose crystallinity could not be reduced.

## Overview of Biomass Conversion Methods

### Direct Combustion

Combustion is the most common and traditional way to produce heat from biomass. In developing countries, the thermal efficiency of direct biomass combustion is 10% - 15% generally. After transformation the thermal efficiency of stoves in rural China are about 30%, and the best can reach up to 50%. The stove is composed of a combustion chamber, fire fencing ring, smoke circulation passage, chimney, stove door, grate and air inlet. The key design points are to increase the intensity of thermal radiation and reflection in the combustion chamber and reduce the loss of complete combustion in the inner stove and the thermal loss of smoke.

Some advanced European countries adopt high-efficiency combustion equipment such as sulphurized-bed combustion equipment. In the equipment, wood is cut into small pieces which then cross the sulphurised bed in a very short time. After combustion, the incompletely burned wood pieces are returned to the sulphurised bed from the smoke exhaust system. The commercialised small- and middle-sized boilers developed by these countries take wood and residues as fuel. Their efficiencies can reach 50% - 60%. In Holland, there are about 1.75 million sets of wood stoves with specifications of 5 - 20 kW and 600, 000 wood fireplaces for domestic heating and hot water supply. Their thermal efficiencies can reach over 50%. The thermal efficiency of fixed bed model boilers burning grass and manufactured by England and Denmark are 60%.

### Gasification

#### Pyrolysis

Pyrolysing gasification of biomass is one of the optimum biomass utilisation technologies. In gasification equipment, biomass is transferred to high-grade combustible gas through thermal chemical action at high temperature. The gas can be used for drying, heating, thermal insulation and electricity generation.

Using gasification equipment, almost all biomass can be transferred to gas fuel which mainly consists of CO, CO<sub>2</sub>, H<sub>2</sub> and CH<sub>4</sub>. The other part of energy of biomass is used to carry out



gasification action. The gasification efficiency of wood is 60% - 80%. Pyrolysis enables the energy recovering rate of rice to reach over 94% and the thermal value of the combustible gas obtained is  $2.5 \times 10^4$  kJ/m<sup>3</sup>. The thermal value of combustible gas obtained from cattle manure pyrolysis is  $1.7 \times 10^4$  kJ/m<sup>3</sup>. The gasification efficiency of multiple waste is over 80%. The thermal value of combustible gas can be increased by adding hydrogen during pyrolysis processing of biomass.

Since the 1970's, some European countries began to study gasification equipment with multiple functions, suitable for different requirements and adopting high temperature pyrolysis techniques. There were two kinds of gasification equipment developed:

- **Sliding bed gasification chamber**

Biomass slides slowly from the top of the gasification chamber while gasifying. Oxidizer is flowed upwards from the bottom of the gasification chamber and crosses the biomass to gasify it. The temperature of output gas can reach 600 °C and there is no tar in the gas.

- **Sulphurised bed gasification chamber**

The ground biomass (with a size of a few mm) is fed to the gasification chamber and gasified while crossing the float material. The gas produced has a high temperature that reaches to about 800 °C. The sulphurised bed gasifier is mostly suitable for biomass.

### **Anaerobic Digestion**

With the anaerobic digestion technology, the combustible gas is obtained while organic waste is treated and the residue digested can be processed into fodder or fertiliser, which is commonly developed because of obvious economic, environmental and ecological benefits.

Some developing countries like China and India are extending and using this technology in rural areas. The family-sized digester technology of China is in the leading position in the world. Up to now, there are 4.75 million small-sized digesters which produce 1.04 billion cubic metres of biogas annually. In addition, all the middle and large scale biogas plants with an electricity capacity of 2077 kW in China can produce 29.1 million cubic metres of biogas annually.

On the aspects of treating multiple industry waste water and organic rubbish, some countries adopt highly efficient techniques, such as: anaerobic filter, UASB and sulphurised bed. France and Japan use and extend high efficiency anaerobic digestion equipment that adopt high density adhering technology to treat organic waste water to the international market. Its efficiency is ten times higher than that of traditional methods. Dry digestion technology and two-step anaerobic digestion techniques have been widely researched in recent years, and these can be used to treat solid waste.

### **|| Fact:**

According to the present technology level, 10 m<sup>3</sup> of biogas can be produced from one ton of rubbish, 35 m<sup>3</sup> of biogas from one ton of human excrement and urine and 5 - 50 m<sup>3</sup> of biogas from one ton of organic waste water with high concentration.

### **Liquefaction**

There are 2 different types of liquefaction methods for biomass conversion to biofuels:

1. Indirect Liquefaction
2. Direct Liquefaction, which consisted to 2 different types of methods:
  - a. Hydrolysis - Fermentation Liquefaction
  - b. Thermodynamic Liquefaction, which separated to 2 different types of methods:
    - i. Pyrolysis method
    - ii. Hydrothermal method

### **Indirect Liquefaction**

Indirect liquefaction is a promising technology, which is divided into two stages. The first stage is a thermochemical gasification process. In this process, the syngas is produced after the raw material reacts with air or steam. In the syngas, the primary substances are CO, CO<sub>2</sub>, H<sub>2</sub>, and H<sub>2</sub>O. The second stage is the well-established Fischer–Tropsch (F–T) process. During the F–T process, the mixture would be used to produce a range of chemicals, including methyl alcohol, dimethyl ether, and ethyl alcohol, while there is little research on the higher alcohols derived from the biomass syngas. The biggest challenges are the design of the novel catalytic reactor for the typically smaller scale of biomass conversion processes and catalysts for specific chemicals according to the molar ratio of H<sub>2</sub> to CO. We take the synthesis of ethyl alcohol as an example to introduce the indirect liquefaction process.

### **Direct Liquefaction**

#### **Hydrolysis - Fermentation Liquefaction**

In the last few decades, ethyl alcohol has attracted a great deal of attention as a potential alternative to fossil fuels. Currently, fermentation of biomass is the main industrial technology to produce ethyl alcohol, of which the primary raw materials are glucose (obtained from corn) and sucrose (obtained from sugar cane and beets). There are the same negative effects on ethyl alcohol production using starch or sugar as the raw material, which would compete with food production directly. Up to now, corn straw has been considered as a possible raw material for ethyl alcohol production.

Once the biomass is transported to the production plant, it would be stored in the warehouse to prevent fermentation and bacterial contamination. Then, the raw material would be pre-treated to make it more accessible for extraction. In the fermentation process, hydrolysate, yeasts, nutrients, and other ingredients would be added. The fermentation is usually executed at 25–30 °C and the suitable reaction time would last for 6–72 h.

#### **Thermodynamic Liquefaction**

In general, there are two types for thermodynamic liquefaction of biomass depending on the operating conditions: pyrolysis liquefaction and hydrothermal liquefaction.

#### **Pyrolysis**

In pyrolysis liquefaction, it could be divided into slow pyrolysis, fast pyrolysis, and flash pyrolysis. Slow pyrolysis is usually executed at a low reaction temperature, heating rate, and a long residence time, which produces a little bio-oil. In the flash pyrolysis process, the reaction time is only or less than several seconds with a very high heating rate and small particle size, and the primary product is syngas. Fast pyrolysis also proceeds at a high

heating rate (less than in flash pyrolysis) and short residence time of the vapor. The favourable product in the process is bio-oil. The pyrolysis bio-oils could be directly burned in boilers, or upgraded to produce valuable fuels and chemicals using the following methods: Extraction, emulsification, esterification/alcoholysis, supercritical fluids, hydrotreating, catalytic cracking, and steam reforming.

### **Hydrothermal**

Hydrothermal liquefaction of biomass is one of the effective methods to treat the biomass with high water content compared to pyrolysis liquefaction. This liquefaction of biomass is not affected by the level of water content and the types of biomass with high conversion and relatively pure products. The suitable properties for liquefaction of biomass are demonstrated, including a high density, good heat, mass transfer capability, fast decomposition, and extraction under hydrothermal conditions. This is an environmentally friendly technology, and the heteroatom in biomass could be converted into undesired by-products.

### **|| Activity:**

In this section, the trainer can create a puzzle game, which actually provides the participants into 2 different groups, and let each group put each name of method of Biomass Pretreatment methods and Biomass Conversion methods on a board provided by the organiser.

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## Chapter 4 - Energy Production from Biomass

**Objective** : To provide information and understanding about the types of energy that can be produced from biomass, the bioenergy production scheme for each utilisation in general, understand better the challenges on energy production from biomass, and the European Union regulation related to the energy production from biomass.

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### Overview of the Types of Bioenergy

#### Bioenergy

Simply, bioenergy is a type of energy which develops from living organisms like plants, animal manure, household sewages, waste etc. There are different types of bioenergy, there are direct combustion, biofuel, and biogas which can be used as electricity, heat, gas and fuel for some purposes.

#### Biofuel

**Biofuel** or also called as agrofuel is liquid fuels derived from agricultural or forestry biomass, either fresh biomass or organic waste. Although fossil fuels have their origin in ancient biomass, they are not considered agrofuels by the generally accepted definition because they contain carbon that has been out of the carbon cycle for a very long time. Agrofuels are mainly used in the transport sector, especially biodiesel (agrodiesel) and bioethanol (agroetanol).

- **Biodiesel** or also called as agrodiesel made from vegetable oils extracted from rapeseed, soy, oil palm, sunflower and algae, among others. Animal fats from the meat industry as well as used cooking oil from restaurants and the by-products of the production of Omega-3 fatty acids from fish oil can also be used as feedstock for agrodiesel. Agrodiesel can be used as a fuel for vehicles in its pure form, but is usually blended with fossil diesel. Agrodiesel is the most common liquid agrofuel in Europe, where it is used to meet the mandatory targets for renewable energy in the transport sector. It is also used in heat and power plants as a substitute for fossil oil. Rape seed, soy and oil palm are the mostwidely used crops to produce agrodiesel at an industrial scale.
- Ethanol (as well as propanol and butanol) are produced by fermenting sugar into alcohols that can be used as fuel, mainly in vehicles. **Bioethanol** or agroetanol is the most widely used. A range of crops with a high sugar and/or starch content such as sugarcane, maize, sugar beet, wheat, cassava and sweet sorghum are used as raw material for producing agroetanol, with sugar and maize being the most popular for industrial use. Agroetanol produced from easily degradable sugars and starches is referred to as **first generation**. This is usually derived from food crops and therefore competes directly with food production. In order to avoid the competition with food, many experiments have been carried out to produce enzymes able to break down the cell walls of lignin, cellulose or hemi-cellulose from e.g. trees or straw. Agroetanol based on these non-food sources is referred to as **second generation**. This is not

economically viable at present although the industry has claimed to be (nearly) ready to produce it for the last decade.

## Biogas

Biogas produced when microorganisms digest organic material in anaerobic conditions (i.e. in the absence of oxygen). Biogas is made up of approximately  $\frac{2}{3}$  methane and  $\frac{1}{3}$  carbon dioxide and possibly small amounts of other gases. Animal manure, slurry, organic waste from households and industry, and residues from agriculture are the primary sources for biogas production. In industrial agriculture, biogas is seen as a viable way to avoid nuisance odours and reduce methane emissions from slurry tanks while at the same time producing energy and providing additional income to farmers. However, for economically viable production, plant material from waste crops or crop residues must be added. When crops such as maize are added (which is frequently the case in Europe) life cycle emission accounting has shown that the production is problematic in terms of greenhouse gas emissions. Biogas can be used as a transport fuel or as a replacement for natural gas in heat and electricity production. The by-products may be used as fertiliser on agricultural soils.

### **|| Fact:**

Methane is the second most abundant anthropogenic GHG after carbon dioxide (CO<sub>2</sub>), accounting for about 20 percent of global emissions. Methane is more than 25 times as potent as carbon dioxide at trapping heat in the atmosphere ([EPA](#), 2021). About 60% of global methane emissions are due to human activities.

There are different categories of biomass used for energy generation. A large number of different technologies turn materials into solid, gas, or liquid forms of energy. Direct burning is the simplest process.

Biomass Feedstock	Examples	Primary Energy Forms
<b>Food Crops</b>		
Sugar crops	<ul style="list-style-type: none"> <li>• Sugar cane</li> <li>• Maize</li> </ul>	<ul style="list-style-type: none"> <li>• 1st generation agroetanol</li> <li>• Biogas</li> </ul>
“Oil” crops	<ul style="list-style-type: none"> <li>• Rape seed</li> <li>• Palm oil</li> <li>• Soy</li> </ul>	<ul style="list-style-type: none"> <li>• 1st generation biodiesel</li> </ul>
<b>Energy Crops</b>		
Monocultural production specifically for energy use	<ul style="list-style-type: none"> <li>• Willow</li> <li>• Eucalyptus</li> <li>• Grasses</li> </ul>	<ul style="list-style-type: none"> <li>• 2nd generation agroetanol</li> <li>• Heat</li> <li>• Electricity</li> </ul>
<b>Plant Residues</b>		
Agricultural residues	<ul style="list-style-type: none"> <li>• Straw, husks, leaves</li> </ul>	<ul style="list-style-type: none"> <li>• Heat</li> </ul>

Forestry residues	<ul style="list-style-type: none"> <li>• Branches</li> <li>• Tree tops</li> <li>• Thinning trees</li> </ul>	<ul style="list-style-type: none"> <li>• Electricity</li> <li>• 2nd generation agroetanol</li> <li>• Biogas</li> </ul>
<b>Industrial Residues</b>		
Food industry	<ul style="list-style-type: none"> <li>• Molasses, Bagasse</li> </ul>	<ul style="list-style-type: none"> <li>• 2nd generation agroetanol</li> </ul>
	<ul style="list-style-type: none"> <li>• Animal fats</li> <li>• Used cooking oil</li> </ul>	<ul style="list-style-type: none"> <li>• 2nd generation agrodiesel</li> </ul>
Wood industry	<ul style="list-style-type: none"> <li>• Wood chips and pellets (from furniture production, etc)</li> </ul>	<ul style="list-style-type: none"> <li>• Heat</li> <li>• Electricity</li> </ul>
<b>Waste</b>		
Industrial agriculture	<ul style="list-style-type: none"> <li>• Slurry</li> <li>• Animal manure</li> </ul>	<ul style="list-style-type: none"> <li>• Biogas</li> </ul>
Households	<ul style="list-style-type: none"> <li>• Sewage sludge</li> </ul>	

## Production Flow of Bioenergy

There are different methods that can be used in bioenergy production. The methods are up to the utilisation of the biomass itself, to produce biofuel has different methods on producing biogas, vice versa.

The methods also can be different based on the materials used in the production. As there are different types of pretreatment methods for different biomass types or characteristics. As explained on Modul 3 in the training manual kit, there are also different type of conversion methods on biomass utilisation to energy, there are direct combustion which used to create heat, gasification which used to create biogas, and liquefaction which used to create biofuel.

Simply, the bioenergy production flow can be explained like this:

**Biomass >>> Preparation (Pre-treatment & Conversion Process to Product (trade forms) like biofuel, and biogas) >>> Product >>> Selling and Distribution >>> Conversion (biodiesel, bioethanol, biogas) to Energy >>> Bioenergy (Heat and Power)**

## Challenges in Bioenergy Production

According to the European Biomass Industry Association, there are some challenges related to bioenergy, especially biomass supply chain related to different feedstock which can be classified into operational, economic, social and, policy and regulatory challenges.

### Operational Challenges:

- **Feedstock unavailability** - The inefficient resource management and the government non-intervention approach are the key factors hindering the expansion of the biomass industry.
- **Regional and seasonal availability of biomass and storage problems** - The seasonal variation results can impact on production and storage of biomass. Also, these issues are affecting the price. As the energy density of biomass is low, acquisition of land for harvesting and storage is difficult.
- **Pressure on the transport section** - Caused by the biomass moisture, transporting wet biomass from the plantation to the production site becomes more expensive and unfavourable with increasing distance.
- **Inefficiency of conversion facility, core technology and equipment shortage** - Technical barriers were resulting from the lack of standards on bioenergy systems and equipment, especially where the energy sources are so diverse. Appropriate pretreatment required to prevent biodegradation and loss of heating value, not only increases the production cost but also in equipment's investment.
- **Immature industry chain** - It is virtually impossible to get long term contracts for consistent feedstock supply at a reasonable price. The low ability to gain profits is also a reason that many upstream firms lack driving forces in the technology reform.

### Economic Challenges:

- **Feedstock acquisition cost** - Some of the biomass resources are scattered and in order to reduce the cost of transportation, biomass projects are eager to occupy land close to the source, leading to centralization of biomass projects.
- **Limiting financing channels and high investment and capital cost** - Because of decentralized capital, poor profitability, frequent fluctuations of international crude oil prices and high market risk, seldom investors took an initiative in the biomass power generation industry. The biomass power generation is subjected to constraints of excessive investment and high operating costs. Biomass pre-treatment technologies have extra costs, which scattered farmers and small scale fuel companies may not be able to afford.

### Social Challenges:

- **Conflicting decision** - Decision making on selection of supplier, location, routes & technologies is crucial and needs proper communication. By strengthening leadership and implementing the responsibilities, the stakeholders should be made fully aware of the economic, environmental and social wealth of resource utilization.
- **Land use issues** - Land use issues lead to the loss of ecosystems preservation and the homes of indigenous people.
- **Impact on the environment** - The biomass plantation depletes nutrients from soil, promotes aesthetic degradation and increases the loss of biodiversity. Other social impacts will result from installation of energy farms within rural areas like increased need of services, increased traffic, etc. The potential negative social impacts appear strong enough to ignore the benefit of new and permanent employment generation.



## Policy Challenges:

- **Policies** - At present, the government is subsidizing the domestic fuel price which in turn makes the electricity generating cost from conventional sources lower than the power production cost from renewable fuels.
- **System** - There are no specific rules to regulate the work of utilization of biomass resources, and there are no specific penalties for not using behavior that should be comprehensively used.
- **Regulation** - There is no special mechanism to manage the development of the biomass resources industry and no specialized department to manage the implementation of relevant national standards and policies.

## || Activity:

As mentioned above about the bioenergy production challenges, discuss with the participants about how to solve it from their experiences and specialisations. There is nothing wrong or right about the solution. This discussion is to raise analytical and creative thinking of the participants on solving problems.

## EU Policy and Regulation of Bioenergy

According to the European Commission, bioenergy is the result of the conversion of biomass resources, such as trees, plants, agricultural/forest residues and urban waste, into energy and energy-carriers including heat, electricity and transport fuels. As biomass can regrow, it is considered a renewable energy.

There are some number of directives that covered biomass and biofuels uses in the EU including the ILUC-Directive 2015/1513/EU, Renewable Energy Directive (EU) 2018/2001, Renewable Energy Directive 2009/28/EC (RED), the Fuel Quality Directive 2009/30/EC (FQD) and the earlier Biofuels Directive 2003/30/EC.

The Renewable Energy Directive 2018/2001 explains sustainability criteria in large-scale biomass for heat and power, including the biofuels and bioliquids for transport. In the directive is also adds other new criteria:

- Agriculture waste and residues, requiring evidence of the protection of soil quality and soil carbon, and for agriculture biomass, requiring evidence that the raw material is not sourced from highly biodiverse forests
- Forest biomass, requiring bioenergy generators to demonstrate that the country of origin has laws in place a) avoiding the risk of unsustainable harvesting and b) accounting of emissions from forest harvesting. If such evidence cannot be provided, bioenergy generators need to demonstrate sustainability compliance at the level of the biomass sourcing area.
- New biofuels plants need to deliver at least 65% fewer direct greenhouse gas (GHG) emissions than the fossil fuel alternative. New biomass-based heat and power plants need to deliver at least 70% (80% in 2026) fewer GHG emissions than the fossil fuel alternative
- Bioelectricity, requiring that large scale plants (above 50 MW) apply highly efficient cogeneration technology, or apply Best Available Techniques (BAT) or achieve 36% efficiency (for plants above 100 MW-), or use carbon capture and storage technology

There is another complementary regulation set out by EU Climate and Environmental Legislation to make sure all sectors contribute to the EU's 2030 emission reduction target, including the land use sector. This regulation is Regulation on Land Use, Land Use Change and Forestry (LULUCF) 2018/841.

Other than that, the European Commission launched the Green Deal which is part of the strategy to implement the United Nations 2030 Agenda and the sustainable development goals, and the other priorities announced in President von der Leyen's political guidelines. According to the communication from the European Commission, as part of the Green Deal, the Commission will refocus the European Semester process of macroeconomic coordination to integrate the United Nations' sustainable development goals, to put sustainability and the well-being of citizens at the centre of economic policy, and the sustainable development goals at the heart of the EU's policy making and action.

There are some points aimed to be achieved from the European Green Deal Plan:

- Designing a set of deeply transformative policies, which consists of:
  - Increasing the EU's climate ambition for 2030 and 2050 - planned to increase the EU's greenhouse gas emission reductions target for 2030 at least 50% and towards 55%. This point is related to the current Fit for 55 plan of the European Commission.
  - Supplying clean, affordable and secure energy
  - Mobilising industry for a clean and circular economy
  - Building and renovating in an energy and resource efficient way
  - Accelerating the shift to sustainable and smart mobility
  - Designing a fair, healthy and environmentally-friendly food system
  - Preserving and restoring ecosystems and biodiversity
  - A zero pollution ambition for a toxic-free environment
- Mainstreaming sustainability in all EU policies
  - Pursuing green finance and investment and ensuring a just transition
  - Greening national budgets and sending the right price signals
  - Mobilising research and fostering innovation - part of this plan is Horizon Europe which is a program that plays a pivotal role in leveraging national public and private investments
  - Activating education and training
  - A green oath: 'do no harm' - The objective is to ensure that all Green Deal initiatives achieve their objectives in the most effective and least burdensome way and all other EU initiatives live up to a green oath to 'do no harm'.

In 2021, the European Council also launched the "Fit for 55" package establishing a series of proposals affecting all parts of the European economy and aimed at fostering the EU's race towards 55% GHG emission reductions by 2030. On the Fit for 55 package includes the following legislative proposals and policy initiatives:

- EU Emission Trading System
- Member States' Emissions Reduction Target
- Emissions and Removals from Land Use, Land Use Change and Forestry
- Renewable Energy
- Energy Efficiency
- Alternative Fuels Infrastructure

- CO<sub>2</sub> Emission Standards for Cars and Vans
- Energy Taxation
- Carbon Border Adjustment Mechanism
- Sustainable Aviation Fuels
- Greener Fuels in Shipping
- Social Climate Fund

### **|| Activity:**

Movie time!

**Movie:** <https://burnedthemovie.com/the-film/>

After that, make a discussion with the participants. The movie can be separated to 2 parts to avoid boredom, some energizers in the middle could help.

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## Chapter 5 - Biomass Conversion Technologies

**Objective** : To provide information and understanding about the biomass conversion process in more details includes the advantages and limitations of each process.

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### Types of Biomass Conversion Process

There are some types of biomass conversion to energy, there are heat and electricity production, biofuels and biogas production. Those products are produced by different methods based on the biomass types and characteristics.

#### Heat and Electricity Production

Direct combustion is the most common method for converting biomass to useful energy. All biomass can be burned directly for heating buildings and water, for industrial process heat, and for generating electricity in steam turbines. Direct combustion is the simplest and oldest way to generate electricity from biomass. Direct combustion (or "direct-fired") systems burn biomass in boilers to produce high pressure steam. The steam turns a turbine connected to a generator-the same kind of steam-electric generator used in fossil fuel power plants. As the turbine rotates, the generator turns, and electricity is produced.

#### Biomass >>> Boiler >>> Steam >>> Turbine >>> Electricity

Some advanced European countries adopt high-efficiency combustion equipment such as sulphurized-bed combustion equipment. In the equipment, wood is cut into small pieces which then cross the sulphurised bed in a very short time. After combustion, the incompletely burned wood pieces are returned to the sulphurised bed from the smoke exhaust system. The commercialised small- and middle-sized boilers developed by these countries take wood and residues as fuel. Their efficiencies can reach 50% - 60%.

The devices used for direct combustion of solid biomass fuels range from small domestic stoves (1 to 10 kW) to the largest boilers used in power and combined heat and power (CHP) plants (>5 MW). Intermediate devices cover small boilers (10 to 50 kW) used in single family houses heating, medium-sized boilers (50 to 150 kW) used for multi-family house or building heating and large boilers (150 to over 1 MW) used for district heating. However, co-firing in fossil fired power stations enables the advantages of large size plants (>100 MWe) that are not applicable for dedicated biomass combustion due to limited local biomass availability.

According to the European Biomass Industry Association, there are most frequently used furnaces for biomass combustion:

Type	Typical Size Range	Fuels	Ash (%)	Water Content (%)
Wood stoves	2 - 10 kW	Dry wood logs	<2	5 - 20

Log wood boilers	5 - 50 kW	Log wood, sticky wood residues	<2	5 - 30
Pellet stoves and boilers	2 - 25 kW	Wood pellets	<2	8 - 10
Understoker furnaces	20 kW - 2.5 MW	Wood chips, wood residues	<2	5 - 50
Moving grate furnaces	150 kW - 15 MW	All wood fuels, most biomass	<50	5 - 60
Pre oven with grate	20 kW - 1.5 MW	Dry wood (residues)	<5	5 - 35
Understoker with rotating grate	2 - 5 MW	Wood chips, high water content	<50	40 - 65
Cigar burner	3 - 5 MW	Straw bales	<5	20
Stationary fluidised bed	5 - 15 MW	Various biomass, d < 10 mm	<50	5 - 60
Circulating fluidised bed	15 - 100 MW	Various biomass, d < 10 mm	<50	5 - 60
Dust combustor, entrained flow	5 - 10	Various biomass, d < 5 mm	<5	<20

Understoker furnaces are mostly used for wood chips and similar fuel with relatively low ash content, while grate furnaces can also be applied for high ash and water content. Stationary or bubbling fluidised bed (SFB) as well as circulating fluidised bed (CFB) boilers are applied for large-scale applications and often used for waste wood or mixtures of wood and industrial wastes e.g. from the pulp and paper industry.

## Biofuels Production

### Biodiesel

Biodiesel is an alternative diesel fuel obtained from renewable sources. The biodiesel is mono alkyl ester which is derived from animal fat or some types of oils, including cooking vegetable oils. Substances of animal and vegetable origin are classified as biomass energy sources. According to Rajaluigam (2016), The carbon will be neutral when biodiesel is used as a fuel, because during the combustion process, the amount of carbon emission is equal to an animal or plant absorbed during its whole life time. So the emission will be low in green combustion of biofuel.

According to Aktas (2020), biodiesel is produced by reacting vegetable or animal oils with an alcohol and catalyst. It is also a non-toxic, biodegradable and renewable diesel fuel. As the biodiesel are mono alkyl esters, so biodiesel does not contain oil, however can be used as a fuel, either pure or mixed with diesel oil of any proportion (Ölmez, 2005).

According to Aktas (2020), there are some oil sources that can be used in biodiesel production:

- Vegetable Oils: Sunflower, Soybean, Rapeseed, Safflower, Cotton, Palm Oils
- Recovery Oils: Vegetable Oil Industry By-Products
- Urban and Industrial Waste Origin Recovery Oils
- Animal Oils: Frost Oils, Fish Oils and Poultry Oils
- Waste Vegetable Oils: Used Cooking Oils

### **Biodiesel Production Technologies**

There are some mainstream technologies that enable the use of oil and fat feedstock types as fuel in diesel engines which are usually called biodiesel. The technologies are direct use or blending of oils, pyrolysis, micro emulsion, and transesterification. Transesterification is the method that is preferable by various researchers to use for biodiesel production due to better quality production.

#### ***Direct Use (Dilution) or Blending***

Dilution process; is a process of thinning vegetable and waste oils by mixing with a solvent or a diesel fuel in certain proportions. Direct uses of vegetable oils have generally been considered not satisfactory and impractical for both direct and indirect diesel engines. Oils used in the dilution method of biodiesel production; peanut oil, rapeseed oil, sunflower oil and waste oils. The high viscosity, acid composition, free fatty acid content, as well as gum formation due to oxidation and polymerization during storage and combustion, carbon deposits and lubricating oil thickening are obvious problems.

To avoid such problems the alternative fuel sources are directly blended with conventional fossil fuels. This kind of blending will improve the fuel quality, reduces the fossil fuel consumption, etc., so it is also preferable as a most convenient way to use an alternative fuels such as biofuels. The bio oil and diesel blends will be in different ratios like 10:1, 10:2, 10:3, etc., (Mendhe, 2015).

#### ***Pyrolysis***

The word "pyrolysis" is derived from pyro (which can be interpreted as "fire") and lysis (which is being interpreted as "separating"). Hence, pyrolysis can be simply defined as the decomposition or disintegration of organic compounds at very high temperatures, aided either by the presence of a suitable catalyst or absence of air. Pyrolysis is conducted at a temperature range of 400–600 °C. The process produces gases, bio-oil, and a char depending on the rate of pyrolysis. According to Gebremariam (2017), based on the operating conditions, the pyrolysis process can be divided into three subclasses: conventional pyrolysis, fast pyrolysis and flash pyrolysis. Fast pyrolysis is the one used for production of bio-oil.

Table. Classification of pyrolysis methods (Czernik, 2004)

Method	Temperature (°C)	Residence Time	Heating Rate (°C/s)	Major Products
Conventional/slow pyrolysis	Med-high (400-500)	Long 5-30 min	Low 10	<ul style="list-style-type: none"> <li>• Gas</li> <li>• Char</li> <li>• Bio-oil (tar)</li> </ul>
Fast pyrolysis	Med-high (400-650)	Short 0.5-2 s	High 100	<ul style="list-style-type: none"> <li>• Bio-oil (thinner)</li> <li>• Gases</li> <li>• Char</li> </ul>
Ultra-fast/flash pyrolysis	High (700-1000)	Very short < 0.5 s	Low 10	<ul style="list-style-type: none"> <li>• Gases</li> <li>• Bio-oil</li> </ul>

The organic materials that can be pyrolysed include animal fats, vegetable oils, natural triglycerides. The liquid components of the pyrolysed fats and triglycerides include biodiesel which functions in the same manner as petroleum diesel in diesel engines. Abbaszaadeh (2012) also reported that biodiesel fuel produced through a pyrolysis process or known as bio-oil is suitable for diesel engines. Singh and Singh (2010), mentioned that thermal pyrolysis of triglycerides has several advantages such as lower processing cost, simplicity, less waste, and no pollution. Another disadvantage of pyrolysis is the need for distillation equipment for separation of the various fractions. Also the product obtained is similar to gasoline containing sulphur which makes it less eco friendly (Ranganathan, 2018).

### ***Micro-emulsification***

According to IUPAC definition, micro-emulsion is dispersion made of water, oil, and surfactant(s) that is an isotropic and thermodynamically stable system with dispersed domain diameter varying approximately from 1 to 100 nm, usually 10 to 50 nm. Ma et al. (1999) explained that the formation of micro-emulsion is one of the potential solutions for solving the problem of vegetable oil viscosity.

The components of a biodiesel micro-emulsion include diesel fuel, vegetable oil, alcohol, and surfactant and cetane improver in suitable proportions. Alcohols such as methanol and ethanol are used as viscosity lowering additives, higher alcohols are used as surfactants and alkyl nitrates are used as cetane improvers. Micro-emulsions can improve spray properties by explosive vaporisation of the low boiling constituents in the micelles. Micro-emulsion results in reduction in viscosity, increase in cetane number and good spray characteristics in the biodiesel. However, as indicated by Parawira (2010), continuous use of micro-emulsified diesel in engines causes problems like injector needle sticking, carbon deposit formation and incomplete combustion.

### ***Transesterification***

Transesterification is the method which is most convenient to produce biodiesel from oil and fat feedstock types, which chemically resembles petroleum diesel. With this method, oils and fats (triglycerides) are converted to their alkyl esters with reduced viscosity to near diesel fuel levels. This product is thus a fuel with properties similar to



petroleum based diesel fuel, which enable it to be used in existing petroleum diesel engines without modifications.

Generally, transesterification is a reversible reaction, which simply proceeds essentially by mixing the reactants usually under heat and/or pressure. However, if some kind of catalyst is added to the reaction, the process will be accelerated. There are a number of ways to produce transesterification, like acid catalysed, base catalysed, lipase catalysed, supercritical, nano catalysis, and ionic liquid catalysis.

### **Acid Catalysed Transesterification**

Acid catalysed transesterification was the first method ever in history to produce biodiesel (ethyl ester) from palm oil using ethanol and sulfuric acid. The acid catalysed process is due to the reaction of a triglyceride (fat/oil) with an alcohol in the presence of an acid catalyst to form esters (biodiesel) and glycerol. This method is convenient and economically viable in producing biodiesel from oil or fat resources with high free fatty acid content. However, the acid catalysed reaction requires a longer reaction time and a higher temperature than the alkali catalysed reaction.

Acid catalysed transesterification starts by mixing the oil directly with the acidified alcohol, so that separation and transesterification occur in a single step, with the alcohol acting both as a solvent and as esterification reagent. The acid catalysed transesterification should be carried out in the absence of water, in order to avoid the competitive formation of carboxylic acids which reduce the yields of alkyl esters. Since transesterification is an equilibrium reaction, there should always be more alcohol than the oil to favour the forward reaction for complete conversion of the oil to alkyl ester. However, more alcohol beyond the optimum will also cause some extra cost on separation of more produced glycerol from the alkyl ester and that is why there should always be an optimization of the ratio for efficient production.

Sulphuric acid, sulfonic acid, and hydrochloric acid are the usual acid catalysts but the most commonly used is sulphuric acid. There are advantages and disadvantages of the acid catalyzed transesterification method.

The advantages are:

- Gives relatively high yield
- Insensitive to FFA content in feedstock, thus preferred-method if low-grade feedstock is used
- Esterification and transesterification occur simultaneously
- Less energy intensive

The disadvantages are:

- Corrosiveness of acids damage equipment
- More amount of free glycerol in the biodiesel
- Requires higher temperature operation but less than supercritical
- Relatively difficult separation of catalyst from product
- Has slower rate of production (relatively takes longer time)

### **Base Catalysed Transesterification**

The alkaline or base catalysed transesterification process is the reaction of a triglyceride (fat/oil) with an alcohol in the presence of alkaline catalysts such as alkaline metal alkoxides and hydroxides as well as sodium or potassium carbonates to form esters (biodiesel) and glycerol. Base catalysed transesterification is much faster than acid catalysed transesterification and is less corrosive to industrial equipment and therefore is the most often used commercially. However, presence of water and high amount of free fatty acid in a feedstock gives rise to saponification of oil and therefore, incomplete reaction during alkaline transesterification process with subsequent formation of emulsion and difficulty in separation of glycerol. The main disadvantage resulting due to saponification reaction is the consumption of catalyst and increased difficulty in separation process, which leads to high production cost.

Generally, base catalysts manifest much higher catalytic activity than acid catalysts in the transesterification reaction, but are selectively suitable for deriving biodiesel only from refined oils having low content of free fatty acids (FFA) usually less than 0.5%. The efficient production of biodiesel using base catalysed transesterification is not only dependent on the quality of the feedstock, it is also dependent on the crucial reaction operation variables such as alcohol to oil molar ratio, reaction temperature, rate of mixing, reaction time, type and concentration of catalyst and also on the type of alcohol used (usually methanol).

Sodium hydroxide, potassium hydroxide and sodium methoxide are catalysts usually used in base catalysed transesterification. Sodium hydroxide is mostly preferable owing to its intermediate catalytic activity and a much lower cost. There are advantages and disadvantages of the base catalysed transesterification method.

The advantages are:

- Faster reaction rate than acid catalysed transesterification
- Reaction can occur at mild reaction condition and less energy intensive
- Common catalysts such as NaOH and KOH are relatively cheap and widely available
- Less corrosive

The disadvantages are:

- Sensitive to FFA content in the oil
- Saponification of oil is the main problem due to quality of feedstock
- Recovery of glycerol is difficult
- Alkaline wastewater
- Generated requires treatment

### **Lipase Catalysed Transesterification**

The lipase catalysed transesterification process is the reaction of a triglyceride (fat/oil) with an alcohol in the presence of lipase enzyme as a catalyst to form esters (biodiesel) and glycerol. Lipase catalysed transesterification is the other way of transesterification of oils and fats for biodiesel production using enzymes in which there is no problem of saponification, purification, washing and neutralisation so that it is always a preferred

method from these perspectives. However, the problems associated with enzyme catalysts are their higher cost and longer reaction time.

Lipases for their transesterification activity on different oils can be found from different sources. Ability to utilise all mono, di, and triglycerides as well as the free fatty acids, low product inhibition, high activity and yield in non-aqueous media, low reaction time, reusability of immobilised enzyme, temperature and alcohol resistance are the most desirable characteristics of lipases for transesterification of oils for biodiesel production. Enzymes are usually immobilised for better enzyme loading, activity and stability. Selecting and designing the support matrix are important in enzyme immobilisation. With this respect, there are a number of ways to immobilise enzymes.

There are advantages and disadvantages of the lipase catalysed transesterification method.

The advantages are:

- Insensitive to FFA and water content in the oil, thus preferred when low grade feedstock is used
- It is carried out at low reaction temperature
- Purification requires simple step, by enabling easy separation from the by-product, glycerol
- Gives high purity product (esters)
- Enables to reuse immobilised enzyme

The disadvantages are:

- The cost of enzyme is usually very high
- Gives relatively low yield
- It takes high reaction time
- The problem of lipases inactivation caused by methanol and glycerol

### **Ionic Liquid Catalysed Transesterification**

Ionic liquids are organic salts composed of anions and cations that are liquid at room temperature. The cations are responsible for the physical properties of ionic liquids (such as melting point, viscosity and density), while the anion controls its chemical properties and reactivity. Their unique advantage is that while synthesised, they can be moderated to suit required reaction conditions.

Among the different possible types of ionic liquids for catalysis of transesterification reaction for biodiesel production, ionic liquids composed of the 1-n-butyl-3-methylimidazolium cation are the most widely studied and discussed compounds. Guo et al. (2014) concluded that ionic liquid catalysed transesterification proved to be efficient and time saving for the preparation of biodiesel from soybean oil.

The advantages of this method are:

- Easy to separate final products due to formation of biphasic.
- Efficient and time saving
- While preparing catalysts their properties can be designed to suit a particular need
- Catalyst can be easily separated and reused many times

- High catalytic activity, excellent stability

The disadvantages of this method are:

- High cost of ionic liquid production
- Requires relatively more alcohol for effective yield

## Bioethanol

Bioethanol is considered a potential substitute for the conventional gasoline and can be used directly in vehicles or blended with the gasoline, thereby reducing greenhouse gas emissions and consumption of gasoline. Bioethanol (E100) can be used for direct application. However there is a difficulty in starting the engine as the engine will start in low temperature or cold weather, because E100 needs higher heat for vaporisation.

Advantages of bioethanol include high-octane rating resulting in increased engine efficiency and performance, low boiling point, broad flammability, higher compression ratio and heat of vaporisation, comparable energy content, reduced burning time and lean burn engine.

There are some sources that can be used in bioethanol production:

- The first generation source comes from edible feedstock:
  - Corn
  - Sugar cane
- The second generation source comes from lignocellulose as the feedstock:
  - Switchgrass
  - Cornstalks
  - Wood
  - Herbaceous crops
  - Waste paper and paper products
  - Agricultural and forestry residues
  - Pulp and paper mill waste
  - Municipal solid waste
  - Food industry waste
- The third generation source comes from algae as the feedstock, there are types of algae with high productivity:
  - *Nannochloropsis Oculata*
  - *Tetraselmis suecica*
  - *Scenedesmus dimorphus*
  - *Porphyridium cruentum* (seawater)
  - *Porphyridium cruentum* (fresh water)
  - *Padina Tetrastromatica*

Bioethanol can be used in some applications such as:

- Fuel for transportation
- Fuel for power generation from thermal combustion
- Feedstock in the chemicals industry
- Fuel in the cogeneration systems

## **Bioethanol Production Process**

Bioethanol production included pretreatment, hydrolysis and fermentation. There are some types of pretreatment processes which are usually used in bioethanol production such as traditional pretreatment and advanced pretreatment methods for lignocellulose. In the hydrolysis process the lignocellulosic biomass can be catalysed either with enzymes or acid. In the fermentation technologies there are some types of it, such as batch fermentation process, continuous fermentation process, fed-batch fermentation process, separate hydrolysis and fermentation (SHF), simultaneous saccharification and fermentation (SSF), simultaneous saccharification and co-fermentation (SSCF), and consolidated bioprocessing (CBP).

**Lignocellulosic biomass >>> Pretreatment >>> Hydrolysis >>> Fermentation >>> Distillation >>> Bioethanol/Ethanol**

### ***Pretreatment Process***

The pretreatment process of the lignocellulosic biomass will help to separate cellulose which is usually located in a matrix of polymers that consist of hemicellulose and lignin. This cellulose separation helps the process of hydrolysis - as it becomes more accessible and easier to produce sugar monomers in hydrolysis. If there is no pretreatment, the hydrolysis process will be not effective as the enzyme will just bind on the surface of the lignin.

There are some advantages on pretreatment process include:

- Helping to prevent degradation of sugars (pentoses)
- Ensuring viability of the bioethanol production, like reactor size, heat and power requirements
- Minimise the formation of inhibitors which can reduce the yield of the hydrolysis and fermentation from sugar to ethanol

### **Traditional Pretreatment**

There are 4 different pretreatment methods such as:

- Physical pretreatment - In the physical pretreatment, the lignocellulosic biomass breaks down to the small size, this pretreatment involves milling, grinding, extrusion and irradiation. This method will increase the surface area and pore size of the biomass which can increase the efficiency of the enzymatic hydrolysis. Physical pretreatment can be combined with the chemical pretreatment to increase the efficiency of deconstruction of the lignocellulose (Edeh, 2020).
- Chemical pretreatment - The chemical pretreatment includes acid, alkali (base), and oxidative methods. However, the chemical pretreatment is highly sensitive and selective with the feedstock's types. Chemical pretreatment is very effective but it needs particular working conditions and environment, and as well by product from this method needs particular disposal.
- Physicochemical pretreatment - In the physicochemical treatment is actually combining both physical and chemical pretreatments.
- Biological pretreatment - In the biological pretreatment involves microorganisms like white-rot, brown-rot, soft-rot fungi and bacteria to breakdown the lignocellulosic biomass for further hydrolysis.

## Advanced Pretreatment

This treatment is usually called lignocellulose fractionation pretreatment (Edeh, 2020). This treatment aimed to reduce the cost of the pretreatment process in the bioethanol production. This process is achieved by using cellulose solvents which are able to enhance the separation of the cellulose, hemicellulose, and lignin in the lignocellulose biomass.

There are 2 different advanced treatment methods:

- Acid-mediated fractionation - this method uses cellulose solvent like phosphoric acid, acetone or ethanol, and operates at 1 atm and 50 °C to separate lignocellulosic biomass. This method is effectively used to pretreat some lignocellulose such as bamboo, corn stover, sugarcane, switchgrass and elephant grass (Sathisuksanoh, 2011).
- Ionic-liquid based fractionation (ILF) - Ionic liquids are simply salt solutions which consist of a significant quantity of organic cations and a small quantity of inorganic anions in the form of liquid in room temperature. This method is used to fractionate lignocellulose to obtain specific, purified and polymeric raw materials which are intact and are easily separated and used as value-added co-products (Edeh, 2020).

### **|| Fact:**

However, steam explosion pretreatment method is frequently used for the lignocellulosic biomass. Steam explosion pretreatment is physicochemical pretreatment which has advantages such as low capital investment, high energy efficiency, less environmental impact, and complete sugar recovery.

## Hydrolysis

Hydrolysis is an important process in bioethanol production. Hydrolysis used to be done after pretreatment of the lignocellulosic biomass which had already broken down to polymeric carbohydrates (cellulose and hemicellulose). This stage will break down the polymers carbohydrate to sugar monomers. Hydrolysis process can be used with acid or enzyme catalysis.

The acid-catalysed hydrolysis is the method which is commonly used in bioethanol production. The acids which are frequently used in this hydrolysis are  $\text{H}_2\text{SO}_4$  and  $\text{HCl}$  with high concentration and low temperature. The result of this method is 90% sugar recovery in a short period of time. However, this method has some advantages such as high cost, difficulty in acid recovery, control and disposal.

The enzyme-catalysed hydrolysis is another method in the hydrolysis process for bioethanol production. This process uses enzymes such as *Clostridium*, *cellulomonas*, *Erwinia*, *Thermonospora*, *Bacteroides*, *Bacillus*, *Ruminococcus*, *Acetovibrio*, and *Streptomyces*. Others include fungi such as *Trichoderma*, *Penicillium*, *Fusarium*, *Phanerochaete*, *Humicola*, and *Schizophyllum* sp. (Edeh, 2020). And the most commonly used microbial enzyme is *Trichoderma* sp. (Imran, 2016). This method has advantages such as high sugar recovery. However, there are some factors which affect the result, such as pH, enzyme loading and time, temperature and substrate concentration. The disadvantage of this method is high production cost, as the enzymes are expensive.

### ***Fermentation Process***

Fermentation is a biological process which converts monomeric sugar products from hydrolysis into ethanol, acids and also gases. This method is using yeast, fungi and bacteria. In this process, the most commonly used microorganism is yeast especially *Saccharomyces cerevisiae* as this microorganism has high yield of ethanol and high tolerance limits (Surendhiran, 2019).

There are some technologies on fermentation process to produce bioethanol such as batch, fed-batch, continuous and solid-state fermentation, simultaneous saccharification and fermentation (SSF), simultaneous saccharification and co-fermentation (SSCF), non-isothermal simultaneous saccharification and fermentation, simultaneous saccharification, filtration and fermentation, and consolidated bioprocessing (CBP).

#### **Batch Fermentation Process**

This is the most basic fermentation process in the bioethanol production, as it's easy to control and has multi-vessel. The process involves adding the substrates, microorganism, culture medium and nutrients at the beginning of the operation in a closed system under favourable conditions at a predetermined time. The products are only withdrawn at the end of the fermentation time. However, the disadvantages of this process are low yield, long fermentation time and high labour, so this process is unattractive for commercial production.

#### **Continuous Fermentation Process**

This process involves adding substrates, culture medium and nutrients into a fermentor which contains active microorganisms and continuously withdrawing the products. The advantages of continuous fermentation process are high productivity, small fermenter volumes, and low investment and operational cost (Jain, 2014). Long cultivation time is the disadvantage of this process as it is a potential decline in yeast capability to support ethanol. The advantages are low capital investment, high productivity and small fermenter volumes.

#### **Fed-batch Fermentation Process**

According to Edeh (2020), Chandel (2007), and Xiao (2019), the fed-batch fermentation process is the combination of batch and continuous fermentation processes involving charging the substrate into the fermenter without removing the medium. Compared with other fermentation processes, the fed-batch process has higher productivity, more dissolved oxygen in the medium, shorter fermentation time and lower toxic effect of the medium. The disadvantage is that ethanol productivity is limited by cell mass concentration and feed rate.

#### **Separate Hydrolysis and Fermentation (SHF)**

According to Edeh (2020), Azhar (2017), and Tavva (2016), the enzymatic hydrolysis is separated from fermentation allowing enzymes to operate at high temperature and the fermentation microorganisms to function at moderate temperature for optimum performance. Since the hydrolytic enzymes and the fermentation organisms operate at their optimum conditions, it is expected that the productivity of ethanol will be high. The disadvantages of SHF are high capital cost especially as two reactors are required, requirement of high reaction time, and possibility of limiting the cellular activities by sugars released during the hydrolysis step.

### **Simultaneous Saccharification and Fermentation (SSF)**

The simultaneous saccharification and fermentation (SSF) where the saccharification of cellulose and the fermentation of monomeric sugars are carried out in the same reactor simultaneously (Rastogi, 2018). According to Edeh (2020), the disadvantage of SSF is the variation in the optimum temperature required for efficient performance of the cellulase and microorganisms during hydrolysis and fermentation, respectively.

### **Simultaneous Saccharification and Co-fermentation (SSCF)**

This involves carrying out the hydrolysis and saccharification in the same unit with co-fermentation of pentose sugars. Usually, genetically modified *Saccharomyces cerevisiae* strains that can ferment xylose are used since normal *Saccharomyces cerevisiae* cannot ferment pentose sugar (Bondesson, 2016). Like SSF, SSCF has the advantages of lower cost, higher ethanol yield and shorter processing time (Chandel, 2007).

### **Consolidated Bioprocessing (CBP)**

According to Hasunuma (2012), this process requires the enzyme production, hydrolysis and fermentation to be carried out in a single unit. The microorganism mostly used in this process is *Clostridium thermocellum* as it has the capacity to synthesize cellulase which degrades lignocellulose to monomeric sugars and produces ethanol. Although, CBP is still at its nascent stage, the following advantages have been identified: less energy intensive, cheaper cost of enzyme, low cost of investment, less possibility of contamination (Edeh, 2020).

### **|| Activity:**

Develop discussion with the participants, there is no right or wrong about this discussion. As the biofuels production needs the higher cost in production and complex operations generally, what do they think about this?

Keywords: More research development, more participation in development, government regulation, subsidiary for the development.

### **Biogas Production**

According to the European Environment Agency, biogas is a type of gas, rich in methane, which is produced by the fermentation of animal dung, human sewage or crop residues in an air-tight container. Simply, biogas is a fuel in the form of gas which is produced by anaerobic process from biomass. Anaerobic process in biogas production is the process of methanogenesis (methane production) without the presence of oxygen.

Methane is a greenhouse gas and also a hydrocarbon which is a primary component of natural gas. However, methane can be produced in anaerobic process from biomass sources like wastes and sewage - so, it's not only come from natural gas (fossil fuel).

On average, biogas contains:

- 55-80% methane ( $\text{CH}_4$ )
- 20-40% carbon dioxide ( $\text{CO}_2$ ).
- Trace gases, including toxic hydrogen sulphide and nitrous oxide.

In methane production, there are 4 essential steps such as hydrolysis, acidification, acetogenesis, and methanogenesis. These steps consist in the anaerobic digestion process.



In the anaerobic digestion process, there are 2 different methods, including single-stage operation and two-stage operation. However, single-stage is less efficient, but it is simple. Many researchers recommended the two-stage operation, as it is more efficient in terms of retention time of biogas production.

According to the European Commission (2017), in Europe energy crops (mainly maize) provide about half of the biogas production (318 PJ, 7.6 Mtoe), followed by landfill (114 PJ, 2.7 Mtoe), organic waste (including municipal waste) (86 PJ, 2.0 Mtoe), sewage sludge (57 PJ, 1.3 Mtoe) and manure (46 PJ, 1.1 Mtoe).

### **|| Fact:**

Germany is by far the largest producer of biogas (311 PJ, or 7.4 Mtoe) in the EU which is 50% of the EU28 total, followed by Italy and the United Kingdom (UK). Biogas from landfill had a share of 18%, sewage sludge 9%, whereas 72% of the biogas was produced in other digesters, mainly farm-based plants and some industrial organic waste digesters. (EC, 2017)

Below is the simple biogas production flow scheme:

**Feedstock >>> Pretreatment >>> Anaerobic digestion process >>> Raw Biogas >>> Purification >>> Storage >>> Distribution**

### ***Pretreatment Process***

Similar to the bioethanol production process, pretreatment is needed in the biogas production. In biogas production, pretreatment aims to open up the structure of substrate which can increase the biogas yield. Pretreatment will improve the efficiency and quality of the anaerobic digestion result. There are 5 different pretreatment methods, such as physical, chemical, thermal, biological, and combination.

### **Physical Pretreatment Methods**

In the physical pretreatment, the structure of biomass will be broken down by using physical force. This pretreatment is used to make the biomass easily processed in the anaerobic digester as the biomass is susceptible to microbial and enzymatic processes. There are different types of physical pretreatment methods such as:

- Milling
- Cavitation
- Microwave irradiation
- Extrusion

### **Thermal Pretreatment Method**

According to Edeh (2020), thermal pretreatment improves hydrolysis, with increased methane yield during subsequent anaerobic digestion. A wide range of temperatures has been studied, ranging from 60 to 270°C, but temperatures above 200°C have been found responsible for the production of recalcitrant soluble organics or toxic/inhibitory intermediates during the pretreatment process (Wilson, 2009).

### **Chemical Pretreatment Methods**

There are some types of chemical pretreatment methods that can be used in the biogas production process, such as:

- Acid Pretreatment

- Alkali Pretreatment
- Oxidative Pretreatment
- Ozonation Pretreatment

### **Biological Pretreatment Method**

The biological mediated pretreatment process is based on the function of multiple forms of heterotrophic microbes (Edeh, 2020). Fungal pretreatment improves degradation of lignin and hemicellulose and hence results in increased digestibility of cellulose, which is preferably essential for anaerobic digestion process. Several fungal classes, including brown-, white- and soft-rot fungi, have been used for pretreatment of lignocellulosic biomass for biogas production, with white-rot fungi being the most effective.

### **Combined Pretreatment Methods**

There are different types of combined pretreatment methods such as:

- Steam explosion
- Physicochemical
- Ammonia fibre expansion

### ***Anaerobic Digestion Technologies***

Multiple-stage anaerobic digestion system is more efficient in terms of product quality and performance. The standard multi-stage anaerobic digestion system is a two-stage acid/gas (AG)-phased system, in which the acid-forming steps (hydrolysis and volatile acid fermentation) are physically separated from the gas-forming step (methane formation) by being conducted in separate digestion tanks. In order to design any anaerobic digester, we need to solve three principal requirements such as: to produce a high volume of high-quality biogas; able to continuously handle a high organic loading rate; and to have a short hydraulic retention time in order to have smaller reactor volume.

The first stage, known as the primary or acid phase digester, consists of the hydrolysis and the first acid-production step, in which acidogenic bacteria convert organic matter into soluble compounds and volatile fatty acids. The second stage, known as the secondary or the methane stage digester, consists of further conversion of organic matter to acetic acid through acetogenesis, as well as the methane formation step, in which methanogenic bacteria convert soluble matter into biogas.

According to EPA (2006), there are advantages of multi-stage anaerobic digestion versus single-stage anaerobic digestion processes include:

- Multi-stage systems require less digester volume to handle the same amount of input volume because they have lower retention times and allow higher loading rates than single-stage systems.
- Multi-stage systems have achieved VS reduction, which provides better odor control.
- A multi-stage system can be configured to reduce foaming problems.
- Multi-stage systems reduce the short circuiting of solids by separating the stages and optimising the retention time in each stage.

Disadvantages:

- The piping requirements for a multi-stage system, operation, and maintenance are more complex than those for a single-stage system.

There are various types of digesters, which are mostly used in the industry involving multistage systems:

- Continuous flow stirred-tank reactors (CSTRs)
- Anaerobic plug-flow reactors (APFRs)
- Anaerobic contact reactor (ACR)
- Biofilms
- Batch reactors
- Anaerobic baffled reactor (ABR)
- Hybrid bioreactor
- Upflow anaerobic sludge blanket (UASB)

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## Chapter 6 - Sustainability Aspects of Biomass for Energy Production

**Objective :** To provide information about the importance in terms of bioenergy aspects to sustainability including economic, environment and social aspects.

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### Background

Biomass is an attractive energy source which is continuously available on Earth. Bioenergy can become a clean, reliable and sustainable energy source. Also, bioenergy plays a key role towards delivering the EU climate and energy objectives. As a part of the European Green Deal, the European Commission raises the prospects of increased reliance on biomass sources for energy – and hence biomass use. There are some impacts related to bioenergy production. Bioenergy can help to reduce greenhouse gas emissions (GHG). Also, it will provide economic benefits to society, like creating new jobs and as well as

affordable energy sources. However, sustainability is not only about the environmental aspect, it is also about social and economic aspects.

Currently, no framework explains explicitly on what constitutes sustainability, which makes the interpretation of sustainability highly subjective to the variety of different actors in the biomass supply chain. The lack of a governing framework for biomass use remains an issue, particularly in giving clear market signals to suppliers and users of biomass, as is the lack of common terminology that relates to sustainability (Biomass in the EU Green Deal, 2021).

## **Environmental Aspect**

According to Institute for European Environmental Policy (2021), environmental sustainability is therefore understood the context of two fundamental principles:

- The first is to recognise and reward biomass left in its living form (for ecosystem resilience and natural carbon sinks) as providing an important contribution to the EU's green deal objectives;
- The second is where biomass is harvested and used, to ensure the protection of the ecosystems from which that biomass arises and without which there would be no enduring supply.

Based on several existing assessments of understanding and estimating the sustainable biomass supply (e.g., Kluts et al., 2018; Faaij, 2018; Material Economics, 2021), the following conditions need to be considered when mobilising biomass resources in a sustainable manner:

- Land availability and competing land uses, as well as land management, such as intensity of production. This includes indirect land use changes through displacement. Areas dedicated to food, feed and fibre production should be excluded.
- Impact on carbon cycles, by removing biomass that would otherwise continue to accumulate carbon in situ.
- Impact on other environmental objectives (other than climate mitigation) through biomass cultivation and extraction, such as water requirements for growth, or loss of soil nutrients and structure where excess residues are removed.

The production of agricultural biomass can result in negative impacts on soils (e.g. loss of nutrients and soil organic matter, erosion, peatland drainage), water availability (in particular in water scarce areas) and biodiversity. The European Commission's study in 2013 concluded that “considerable potential risks to sustainability from biofuel cultivation exist, particularly risks to soils and to water quality and water availability”. The use of agricultural residues (for example: straw) can also cause negative impacts on soils such as fertility and structure, and on biodiversity if extracted in excessive amounts. On the other hand, the use of waste to produce biogas can significantly reduce methane and other emissions. That is the reason why control and regulation is important to produce bioenergy.

In the EU, the rules of cross-compliance under the Common Agricultural Policy ensure the implementation of existing environmental requirements and the requirement of maintaining land in good agricultural and environmental condition.

According to the European Commission (2016), in the baseline scenario, Member States of the EU would still be able to introduce sustainability criteria for solid and gaseous biomass at national level. Other EU and national policies related to environmental protection would stay in place, as well as the EU Timber Regulation to reduce the risk of using illegally harvested forest biomass for energy in the EU. At the same time, legality checks do not automatically ensure safeguards on biodiversity or land use.

However, to ensure sustainability in the bioenergy production reinforced criteria in line with the EU Biodiversity Strategy for 2030 is:

- Prohibit sourcing biomass for energy production from primary forests, peatlands and wetlands
- No support for forest biomass in electricity-only installations as of 2026
- Prohibit national financial incentives for using saw or veneer logs, stumps and roots for energy generation
- Require all biomass-based heat and power installations to comply with minimum greenhouse gas saving thresholds
- Apply the EU sustainability criteria to smaller heat and power installations (equal or above 5MW)

According to Wang (2018), Life Cycle Assessment (LCA) is extensively adopted as the approach to analyze environmental impact that bioenergy may bring. LCA is defined as “cradle-to-grave” method normally with several indicators such as Global Warming Potential (GWP), Acidification Potential (AP) and Eutrophication Potential (EP), which represent different aspects of environmental sustainability assessment and can provide a full-scale simulation analysis on environmental and ecological impacts if data collected is of high quality.

## **Economic Aspect**

Methods of economic assessment in bioenergy production are typically techno-economic analysis, net energy balance, market analysis and cost-benefit analysis (Wang, 2018). The core of techno-economic analysis is the calculation of the internal rate of return (IRR), net present value (NPV), and discounted payback period, which is adopted by many scholars as a preference because of its relatively low threshold and universality. Hayashi et al. (2014) choose net energy balance as one of the indicators in their Global Bioenergy Partnership (GBEP) analysis, which contributes significantly to the holistic assessment of bioenergy.

In the economic assessment, energy efficiency is important to be considered, as the energy efficiency means high economic feasibility. According to Wang (2018), by using the methods of economic assessment and considering the research results of energy efficiency, many studies draw their conclusions which show a convergent tendency that bioenergy is economical.

According to the European Commission (2016), there are some impacts of the economic aspect in the bioenergy production:

- Contribution to gross added value - This positive impact on gross added value is a combination of:

- a positive "deployment effect": the increase in other renewable energy sources leads to more investments and therefore a larger positive impact in the economy as a whole
- a positive "income effect": the additional jobs created by this shift leads to additional income for households, which is spent in consumption
- a negative "indirect effect": other renewable energy sources require a higher level of public support, either directly through subsidies, or through feed-in tariffs. This can impact consumers, if the feed -in tariffs is directly passed on to them through an increase in energy prices, or if the subsidies are financed through an increase in taxation: in both cases, household consumption would go down. Increased support for other renewables can also be made available by giving less public support to other sectors, which will also have a negative economic impact.
- Impact on small and medium-sized enterprises (SMEs) - SMEs and micro-firms are widely represented in bioenergy production and use chain through, in particular, small forest owners and small bioenergy installations. In the baseline, SMEs in the forestry sector might be affected by national schemes. It is unlikely however that those SMEs would have to comply with several national schemes given their likely range of operations.
- Impact on rural development - Positive impacts on rural development can occur in cases where additional bioenergy demand incentivises more intensive harvesting of EU forests and use of EU agricultural feedstocks (rather than e.g. increasing imports or diverting industrial residues from other uses). This will be mostly driven by the market and/or by relevant subsidy schemes in each region. It can also be influenced at EU level by e.g. support to wood mobilisation under the Rural Development Programmes.
- Impact on the internal market and intra-EU trade
- Impact on external trade - decrease in imports from third countries for all options
- Innovation and research - While bioenergy has an important innovation angle (for example with regards to advanced biofuels for transport), the policy options are unlikely to make a fundamental difference to innovation and research since the sustainability requirements would only have an impact on well-established technologies (i.e. the use of solid and gaseous biomass for heat and power).

## Social Aspect

The implementation of biomass supply chains for the production of bioenergy and/or biofuels is often thwarted by public and local stakeholder opposition, despite potential technical-economic and normative feasibility (Sacchelli, 2016). Bioenergy projects affect the communities in which they are implemented in various ways. This can go from improved water quality to the creation of new jobs in economically depressed regions. McKenzie (2004) defined social sustainability as a life-enhancing condition within communities, and a process within communities that can achieve that condition. Social aspects of sustainable bioenergy, according to Dale (2013) involve preserving livelihoods and affordable access to nutritious food, guaranteeing the reliability of energy supply, and ensuring the safety of people, facilities, and regions.



Social aspects of bioenergy systems, according to Segon and Domac (n.d.) can be divided into two categories:

- Relates with standard of living - Standard of living in this case was related to household income, education, surrounding environment, and health care while social cohesion and stability was defined in terms of peace and communal relationship, employment, rural population stability, infrastructure and support for related industries.
- Contribute to increased social cohesion and stability.

There are some impacts on social aspect (ERIA, 2008; EC, 2016):

- Employment generation - Employment in the bioenergy economy is most significant in the solid biomass sector, where 306,800 Europeans had a job in 2014. In addition, 110,350 people were employed in the biofuels sector, 66,200 in the biogas sector and 8,410 in the renewable urban waste sector. Employment impacts will also arise as a result of the small shift from bioenergy to other renewable energy in the policy options, due to a higher labour -intensity of other renewable energy sources.
- Health benefits - improved biomass techniques for cooking and home heating will improve quality of life for women and infants. Reduced incidences of diseases will also result in economic benefits due to less hospitalisation and work-days lost and less expenditure on medical care.
- Women empowerment - Development of bioenergy has the potential for engaging women in raising nurseries and collection of seeds, which could lead to their enhanced participation in the village economy.
- Possible improvement in the human development index (HDI) - As indicated earlier, development of bioenergy programmes are expected to increase employment, which will improve income of individuals. People may use extra income to spend on their basic needs such as education, health care and nutritious food.

### **|| Activity:**

Make a discussion with the participants about the impacts of bioenergy in social, environmental and economic aspects. Separated the participants in the 3 groups, and let them present the results with the other participants - it can be presented with presentation, theatre, or anything else.

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