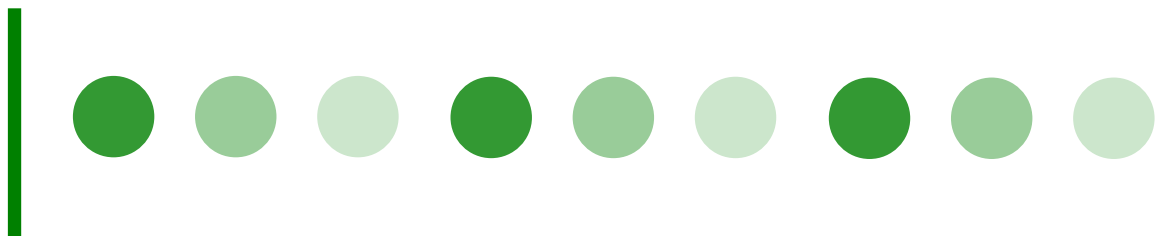


Systems and Integrating Technology T1

Biomass Energy Generation

Group Members:
2385539E
2463524H
2345063M
2509612O



Contents

Project Brief	Page 3
Analysis of the Problem	Page 3
<i>Important Aspects to be Considered</i>	Page 3
<i>Goal States</i>	Page 3
Assumptions and Constraints	Pages 3-4
Research	Page 4
<i>Biomass</i>	Page 4
<i>Agriculture Crop Waste Issue in the United Kingdom</i>	Page 4
<i>Scale of Farm</i>	Pages 4-5
<i>Feed-in-Tariff</i>	Page 5
<i>Process: Pyrolysis</i>	Page 5
<i>Product: Biochar</i>	Pages 5-6
<i>Subsystems: Boilers, Generators and Steam Turbine Engines</i>	Page 6
<i>Advantages and Disadvantages of Particular Processes</i>	Page 7
Morphological Analysis	Page 8
<i>Morphological Analysis Continued</i>	Page 9
<i>Morphological Analysis - Weighting Table Variants</i>	Page 10
‘Best Solution’	Page 11
<i>Flowchart of ‘Best Solution’</i>	Page 11
Development of ‘Best Solution’	Page 12
<i>Development of ‘Best Solution’ Continued</i>	Page 13
Evaluation of System	Page 13
Reflection	Pages 13-14
References	Pages 15-16

Project Brief

“Two important challenges related to the environment are waste treatment and clean energy generation. Many farmers end up with a huge amount of organic waste as a result of their activities. One clever way of dealing with this issue is to use the biomass to generate energy. This not only takes care of the rubbish but also generates clean energy which can be used by the farmer to power the farm and if there is a surplus, it can be sold to the energy provider. You are being hired by a farmer to design a biomass energy generation system to be installed in his farm. The system should be integrated with the current energy grid such that it can switch between selling to the grid (where there is surplus) and buying from the grid.”

Analysis of the problem

Upon analysis of our problem, we need to create a two-way system which allows for production and reception of energy as the need arises. As well as this, we have to create a system that produces clean energy from waste and allows surplus energy to be sold yet also provides sufficient energy for the farm's use. The system must also provide a way for extra energy to be sold to the grid but also allows any shortfall to be compensated from the grid back to the farm.

Important Aspects to be Considered

After analysing the brief, we had to take out the important aspects from it - the parts of the brief that stood out and needed researched into. One important aspect that stood out was that the farmers “end up with a huge amount of organic waste”. This meant that we would need to research the problem of organic waste in order to find a ‘best solution’. Another area that stood out to us was that a way in dealing with this issue was to use “biomass to generate energy”. As a team, no one had any prior knowledge of what biomass was or how it could be used so this was a massive area for research to be conducted on. Moreover, the brief highlights that if there were to be a surplus, that it could be sold to the energy supplier and that the system should be integrated with the current energy grid. This meant that we had to research into this type of system and

Goal States

There are three outlined goal states of our system. Our first goal state was to create a biomass energy system that could be used by a UK farmer to produce electrical energy using the organic waste the farmer produces as a result of their activities. Our next goal state was to create a biomass energy system that could be integrated with the current energy grid - with the farmer being able to switch between buying from the grid and selling to the grid where he has a surplus of electrical energy. Our last goal state was to create a biomass energy system that is as environmentally friendly as possible, to create a system where CO₂ emissions and carbon footprint are kept to a minimum.

Assumptions and Consumptions

There were many assumptions that had to be made in order for our system to operate. One assumption that had to be made at the start was the location of our system - the United Kingdom. We made this assumption to make the process easier for the group as we are all familiar with the UK and its conditions. Also, with it being in a specific place, this meant that we could look further into the United Kingdom's agriculture and waste-related issues.

Another one of these assumptions that was made was that the bill is paid to the electricity provider 4-weekly and it resets in time for the bill to be paid. This was because it would make things easier to go on a 4-weekly basis with the system as if we had to do it monthly, some months have a varying number of days in each, which would then provide us with issues. However, with it being a 4-weekly billing structure, this means that there is a set number of days in which the bill would reset. In addition to this, another assumption that had to be made in order for our system to run smoothly was that the government 'feed-in-tariff' (FIT) did not end, and that they were still accepting new applicants. Also, it had to be assumed that pyrolysis (our method of clean energy production) is an accepted form of energy production for the 'feed-in-tariff'. This would mean that our farmer whom we are designing the biomass energy system for is still able to sell his surplus electricity that they generate. We have made the assumption that the farmer, instead, applied to a registered electricity supplier and his application was successful. Moreover, an assumption that was made was that the main biomass income provided by the farmer is agriculture waste in the form of crops. This was made because it would limit the amount of waste that the system deals with and because crop waste in the United Kingdom is a massive issue.

Research

Biomass

There are many different types of biomass and they all have their own uses. Some examples of biomass include; wood, agricultural crops, animal residue, food waste, animal manure and human sewage. Wood as biomass can be burned to produce heat and be used to generate electricity. Also, agricultural crops can be burned as a fuel or converted to liquid biofuels. In addition, food waste can also be burned to generate electricity or converted to biogas. Many people use animal manure and human sewage as a form of biomass which can be converted to biogas and then burned as a fuel.

Agriculture Crop Waste Issue in the United Kingdom

Agriculture waste is a great issue within the UK. In 2017 it was highlighted that around 3.6 million tonnes of food surplus and waste is generated in UK farms each year, accounting for 7.2 per cent of crop production leaving the overall value of this food, costing in the region of £1.2 billion. (Benson, 2019) As well as this, in 2018 farmers reported via survey that up to 37,000 tonnes of fruit and vegetable produce is wasted every year in the UK- around 16 per cent of their overall crop is wasted. (Gabbatiss, 2018) A significant growth in over a year can be seen from the statistics given, thus emphasizing the need for a solution to find a sufficient purpose for crop waste on the farm. It is through our biomass system that we aim to take agricultural waste and put it through our system to create energy which can be later sold to the grid as stated.

Scale of Farm

An important detail we want to get right for the plant is the scale of it. We want to be realistic and don't want it to be too costly for the farmer, but we also want a plant that the farmers can profit from. A large biomass power plant is more thermally efficient compared to smaller farms; a 200 MW plant will turn 30% to 39% of thermal energy in the biomass into electricity. A 25 MW plant will turn 20% to 25% into electricity (Austin, 2009). It's losing more heat per unit of capacity; this is because the surface area per unit of biomass is bigger.

Although a larger facility will cost a lot more to build the plant would generate more power and would be more efficient which would eventually outweigh the high initial costs “This is an economic scale” according to Peter Flynn. However, for an everyday farmer a large 200MW plant is too large in area and the initial costing as well as staff needed (Austin, 2009).

Although a larger plant is much more thermally efficient it is out of question for the majority of farmers due to the initial cost, massive area of land as well as all the staff needed to man the plant. To understand how much space, we need for the farm, David Mackay adopted the figure of 0.5 W/m² power that can be generated in the UK (Clark, 2013). So, if we are wanting our plant to generate 20,000W in order to power approximately 20 homes we would need an area of 40,000m² or rounded up to 10 acres. A smaller scaled farm like this would be much more accessible to farmers in every way.

Feed-in-Tariff

The feed-in-tariff was a government scheme that allowed people to sell their own generated electricity - known as the ‘generation tariff’ to their energy supplier. It also meant that people could also receive payments from their energy supplier for any surplus electricity that they made - i.e. after they produced their own electricity and then used it - any surplus would be credited. This is known as an ‘export tariff’. The technologies covered by this feed-in-tariff scheme were solar photovoltaic (PV) panels, wind turbines, hydro turbines, anaerobic digestion and micro combined heat and power (micro-CHP). This scheme stopped accepting new applicants on March 31st, 2019. (Feed-in tariffs: get money for generating your own electricity, 2020)

Process: Pyrolysis

Pyrolysis has become a popular method over the past couple of years due to its fast reaction time of just below two seconds, which in turn minimizes any secondary reactions that may occur. The pyrolysis process occurs at high temperatures between the ranges of 400-800 degrees Celsius. Pyrolysis is the chemical decomposition in the presence of heat occurring through the absence of oxygen. (Bridgwater, 2012) Due to this process, it allows for an increasingly high yield of biomass that can be used in a variety of ways. Pyrolysis is the first stage in gasification, occurs in the absence of oxygen, and combustion, which takes place when there is a sufficient amount of oxygen present. The rate of pyrolysis increases with the range of temperature, as previously stated. Smaller-scale operation the temperature may be much lower meaning a longer turn out time. by the end of the pyrolysis process, charcoal better known as biochar - is produced which later can be put back into the biomass for better production.

Product: Biochar

In the pyrolysis process, organic materials, in our case - agricultural crops, are burned in an environment with little oxygen present. This process results in the production of biochar which is a ‘stable form of carbon that can’t easily escape into the atmosphere’ (Spears, 2018). This process is considered as a ‘clean’ process, meaning that it is considered as a cleaner form of charcoal as other forms. In addition to this, it was found that biochar can be fed back into our system - rather than being just a bi-product that does not get utilised. Instead, the biochar can be mixed with the biomass at the beginning of the process. It was found that

adding biochar to the biomass reduces the CO₂ and the ammonia emissions. (Schmidt and Wilson, 2014).

Subsystems: Boilers, Generators and Steam Turbine Engines

Within our system, the boiler is used to store the cold water from the water tank. Here, it is where the heat generated from moisture evaporation, degasification and carbonisation is then fed through to the boiler. This then heats the water that is being stored until it is converted into steam. From here, it then passes through to the steam turbine engine.

Generators work by converting mechanical energy or chemical energy into electrical energy. Within our system, the generator is used to convert the mechanical energy created by the steam turbine engine into electricity. The generator is able to transform this mechanical energy into electrical current through electromagnetic induction. Electromagnetic induction was first introduced by Michael Faraday. It was discovered that the flow of electric charges could be induced by moving an electrical conductor. As a result of this movement, it then creates a voltage difference between the electrical conductor. With this, it allows the electric charges to then flow and, in turn, generates electricity (How Does a Generator Create Electricity? How Generators Work, n.d.).

Within our system, steam turbine engines are used to generate electricity. Steam turbines work, in this system, by using the heat generated during the biochar production process in order to heat the water in the boiler until it is converted to steam. As the turbine spins, the steam passing through it expands and cools down. The steam's potential energy is then converted into kinetic energy as it is rotated by the turbine's blades. The turbine is then connected to a generator which then produces energy through a magnetic field that, in turn, produces an electric current. (How Does a Steam Turbine Work?, n.d.)

With regards to powering the boiler and the steam turbine generator, this will be done via the mains. Electricity from the mains supply will be used to power both of these. This will be the method used because it allows for a constant flow of electricity to the boiler and steam turbine engines on demand when electricity is required. It also means that, when the system is selling surplus electricity to the electricity supplier, the amount accumulated from powering the boiler and steam turbine engine can be deducted from the four-weekly bill.

Advantages and Disadvantages of Particular Process

Process	Advantages	Disadvantages
Combustion	This approach allows waste management to be more efficient and easier. (8 Pros and Cons of Incineration, 2016)	This process creates pollutants which would need to be effectively ‘cleaned up’ so as to not be released into the atmosphere and environment. The ash that is produced from combustion may be toxic so would need to be carefully disposed of. (8 Pros and Cons of Incineration, 2016)
Gasification	Energy can be stored since syngas can be stored and used on demand. (Harris, n.d.)	This process has a much higher cost. (Harris, n.d.)
Anaerobic Digestion	This process produces a liquid and a fibrous fertilizer. (What is Anaerobic Digestion?, n.d.) This process sanitises the waste which is put through - as long as the temperature remains higher than the required temperature for a pre-defined time period. It has reduced odour which is below unprocessed waste odour levels. (The Advantages and Disadvantages of Anaerobic Digestion vs Composting, 2015)	This process needs a high level of investment. If ran ineffectively, this process can create a bad odour. This process takes a while - it can take 30 days for anaerobic digestion in a biogas plant to complete a batch of biomass. (The Advantages and Disadvantages of Anaerobic Digestion vs Composting, 2015)
Pyrolysis	This process on any batch of biomass can be completed in less than one hour. This faster process results in a much lower carbon footprint and lower development costs. The mass of the remaining ash is much lower than the mass of the digestate remaining after anaerobic digestion. (AZoCleantech, 2013)	The unwanted products from the thermal decomposition must be removed from the flue gas. This process can be technically demanding to comply with the EU clean air regulation requirements. This process can be expensive. (AZoCleantech, 2013)

Diagram
representing three of
the four processes
outlined above:

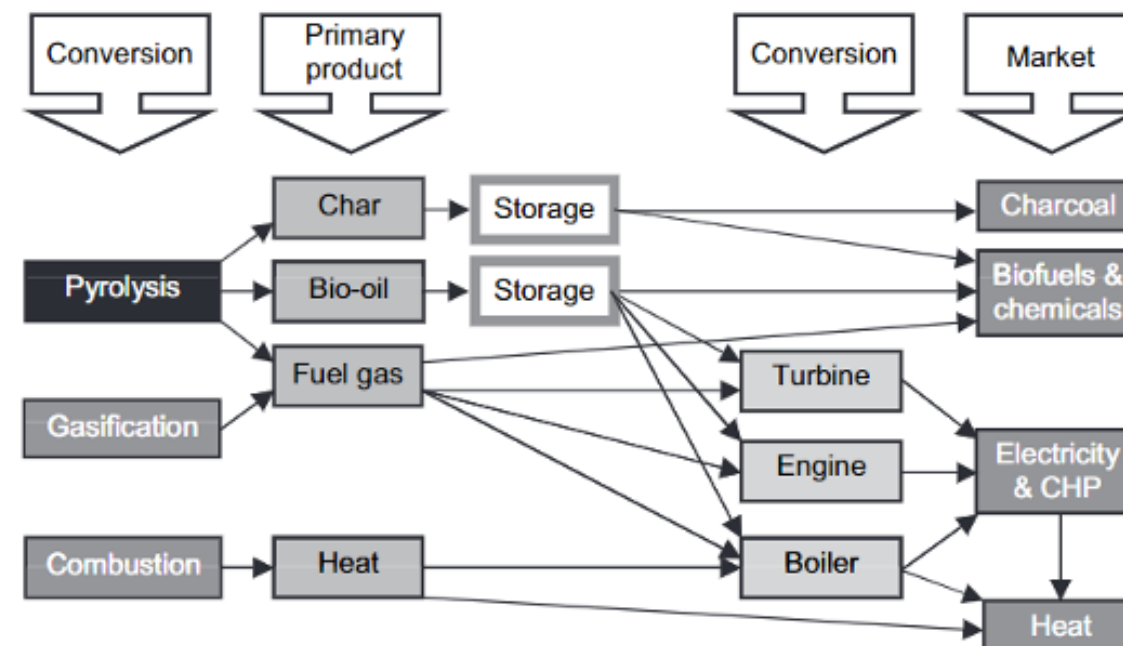
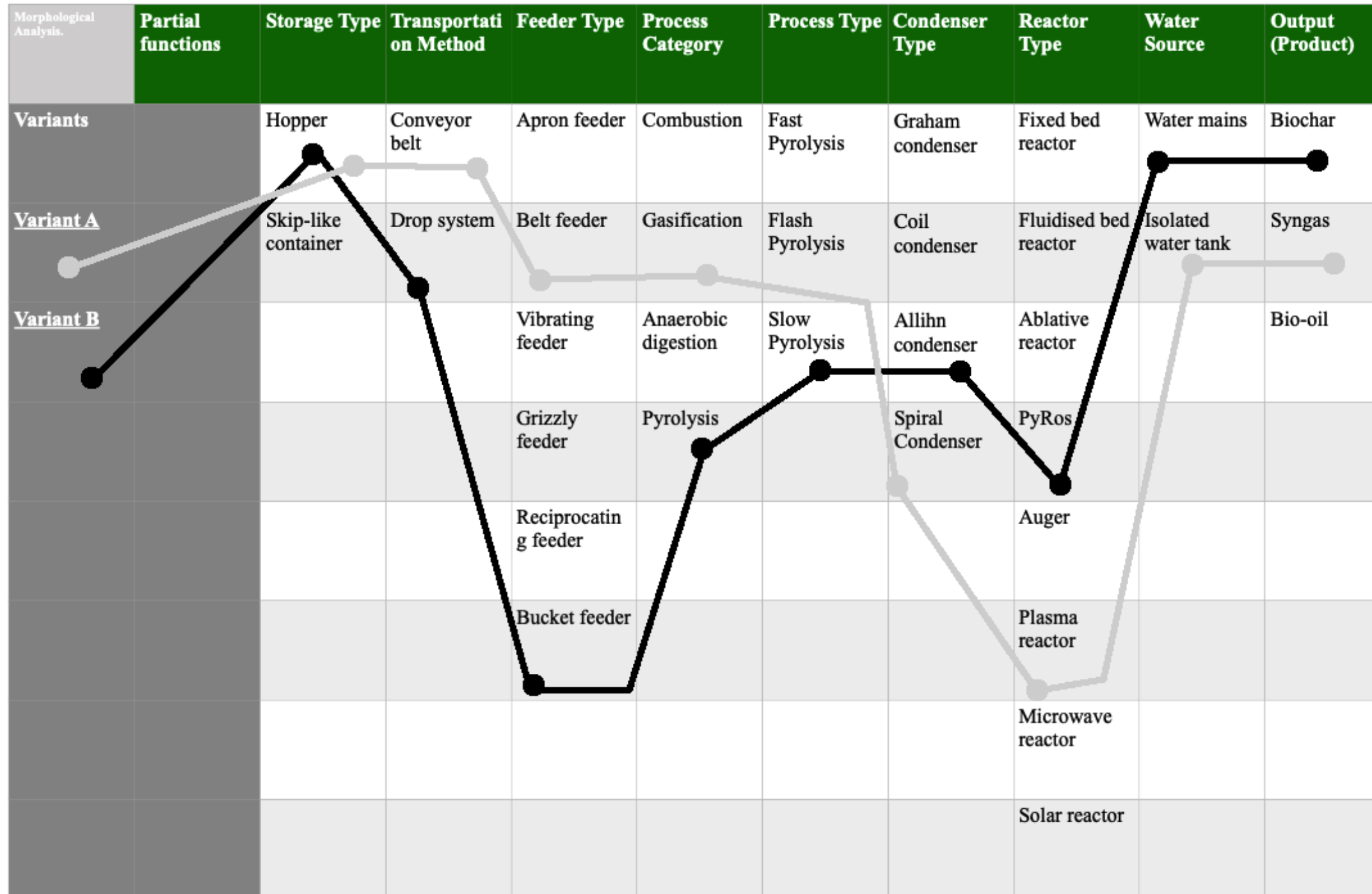


Fig. 1 – Products from thermal biomass conversion.

(Bridgwater, 2012 - Fig. 1 e Products from thermal biomass conversion pg 69)

Morphological Analysis

A method for structuring and investigating the total set of relationships contained in multi-dimensional, non-quantifiable, problem complexes. Ritchey T. (2011)



Morphological Analysis Continued

Decisions based on weighted utility values. According to VDI 2225 Guidelines the five-points system will be used:

0 = Unsatisfactory, 1 = Acceptable, 2 = Satisfactory, 3 = Good, 4 = Very good.

Partial Functions	Variant A	Cost	Quality and Quantity	Environmental Impact	Points	Variant B	Cost	Quality and Quantity	Environmental Impact	Points
Storage	Hopper	1 x 4 = 4	2 x 4 = 8	4 x 4 = 16	4 + 8 + 16 = 28	Hopper	1 x 4 = 4	2 x 4 = 8	4 x 4 = 16	4 + 8 + 16 = 28
Transportation	Conveyor belt	1 x 3 = 3	2 x 3 = 6	x	3 + 6 = 9	Drop system	1 x 3 = 3	2 x 3 = 6	x	3 + 6 = 9
Feeder	Belt feeder	1 x 3 = 3	2 x 3 = 6	x	3 + 6 = 9	Bucket feeder	1 x 4 = 4	2 x 3 = 6	x	4 + 6 = 10
Process Category	Gasification	1 x 3 = 3	2 x 3 = 6	4 x 1 = 4	3 + 6 + 4 = 13	Pyrolysis	1 x 2 = 2	2 x 4 = 8	4 x 3 = 12	2 + 8 + 12 = 22
Process Type	x	x	x	x		Slow pyrolysis	1 x 2 = 2	2 x 4 = 8	4 x 4 = 16	2 + 8 + 16 = 26
Condenser	Spiral condenser	1 x 2 = 2	2 x 2 = 4	4 x 2 = 8	2 + 4 + 8 = 14	Allihn condenser	1 x 2 = 2	2 x 4 = 8	4 x 2 = 8	2 + 8 + 8 = 18
Reactor	Plasma reactor	1 x 1 = 1	2 x 2 = 4	4 x 2 = 8	1 + 4 + 8 = 13	PyRos reactor	1 x 2 = 2	2 x 4 = 8	4 x 2 = 8	2 + 8 + 8 = 18
Water Source	Isolated water tank	1 x 3 = 3	2 x 3 = 6	4 x 3 = 12	3 + 6 + 12 = 21	Water mains	1 x 4 = 4	2 x 3 = 6	4 x 3 = 12	4 + 6 + 12 = 22
Output	Syngas	1 x 4 = 4	2 x 3 = 6	4 x 1 = 4	4 + 6 + 4 = 14	Biochar	1 x 4 = 4	2 x 4 = 8	4 x 4 = 16	4 + 8 + 16 = 28
Total Points: Percentage Strength:		23 / 32 (72%)	46 / 64 (72%)	52 / 96 (54%)	121 / 192 (63%)		27 / 36 (75%)	66 / 72 (92%)	88 / 112 (79%)	181 / 220 (82%)

The decision-making parameters heavily incorporated the farms limitations in scale, as well as the goal states, which indicate that CO₂ emissions and the carbon footprint are to be minimised. The morphological analysis awarded points where the partial functions enhanced the product quality and quantity, lessened the costs or reduced hazardous environmental impacts. These parameters were acquired after having conducted extensive research. (Chowdhury Z. 2017)

Morphological Analysis - Weighting Table Variants

Slow Pyrolysis

Slow pyrolysis can yield high quality charcoal, using low temperature and low heating rates. Although slow pyrolysis does have a major disadvantage, as the quality of bio-oil produced in this process falls low. (Bridgwater, A., 2012) We are able to ignore the disadvantage with slow pyrolysis by selecting biochar as our preferred product type instead of bio-oil. The combination of slow pyrolysis and biochar as the product (Variant B) has been experimented with and found to be of great synergistic nature: the two individual components combined effects are greater than the sum of their separate effects.

The stoichiometric equation for production of charcoal is through the use of slow pyrolysis:



The table below gives the theoretical equilibrium yield of cellulose at different temperatures using slow pyrolysis:

Pyrolysis types	Retention time	Rate of heating	Final temperature (°C)	Products
Fast	<2 s	Very high	500	Bio-oil
Flash	<1 s	High	<650	Bio-oil, chemicals and gas
Ultra-rapid	<0.5 s	Very high	1000	Chemical and gas
Vacuum	2–30 s	Medium	400	Bio-oil
Hydro-pyrolysis	<10 s	High	<500	Bio-oil
Carbonization	days	Very low	400	Charcoal
Conventional	5–30 min	Low	600	Char, bio-oil and gas

(Rahman Faijur Rafique and Rafie Bin Johan, 2017.)

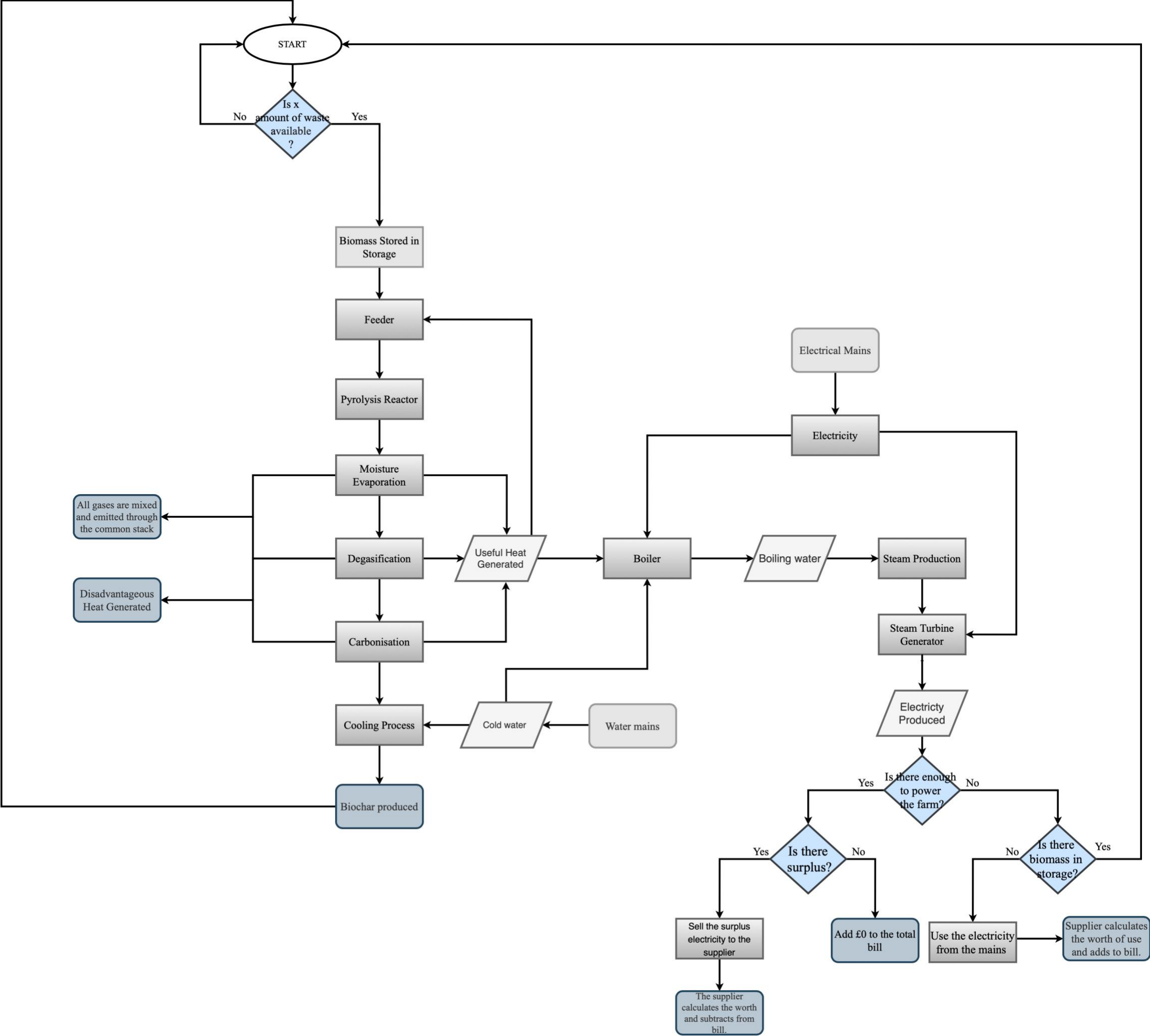
PyRos Reactor

Analysing variant B: PyRos reactor: compact and low cost, efficient heat transfer, short gas residence time. The disadvantages: complex design, solids in the bio oil, alkali dissolved in the bio oil, high temperature required. (H.S. Choi, Y.S. 2012) As our main output is biochar: the disadvantages of solids in the oil and alkali dissolved in the oil using the PyRos reactor, can be ignored without tangible consequences. Variant A's plasma reactor has high operating costs and requires extremely small particle sizes (Wageeh A. Yehye, 2017): factoring in these considerations, the plasma reactor almost becomes non accessible to our private farm. Based on the decision-making process the team has decided to select the PyRos reactor in order to fulfil the aim for a yield of high quality and affordable biochar.

Allihn condenser

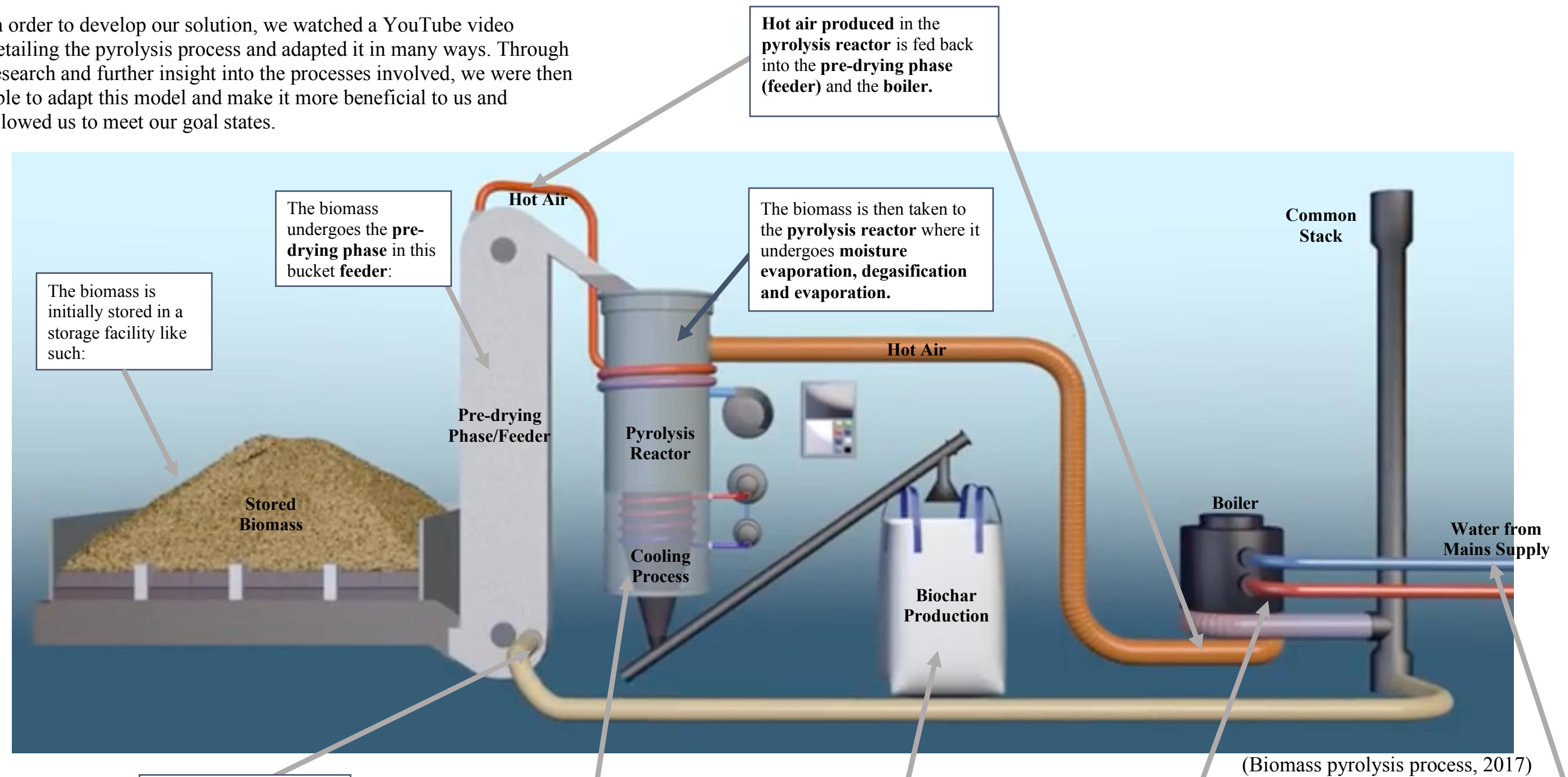
Variant B of the morphological analysis has been awarded more points in the condenser type section because the allihn condenser has potential for large scale pyrolysis systems due to a high surface area and its simple structure. Compared to variant A, where blockage may still occur due to the narrow vapour path of the spiral condenser. (Papari, Sadegh & Hawboldt, Kelly, 2018)

Flowchart of ‘Best Solution’



Development of 'Best Solution'

In order to develop our solution, we watched a YouTube video detailing the pyrolysis process and adapted it in many ways. Through research and further insight into the processes involved, we were then able to adapt this model and make it more beneficial to us and allowed us to meet our goal states.



Development of 'Best Solution' Continued

In order to develop our solution, the team had to keep refining the system and keep researching about it in an iterative manner. We started with each team member researching one way each of using biomass to generate electricity. After we got together and discussed these, a table was produced showing the advantages and disadvantages of each method. Using various analysis methods such as morphological analysis and pro and contra listings to aid the decision-making process, the team decided that we would use pyrolysis as our preferred method of preparing the biomass to then generate electrical energy. In further research of pyrolysis in biomass production, we found a detailed YouTube video (Biomass pyrolysis process, 2017) in which showed a step by step process of pyrolysis, giving our team a clearer understanding of how the method worked in each stage. By doing so, this aided us in our final decision of our system, to modify the video's process slightly to make it more beneficial to our scenario of the farm, by putting the biochar back into the biomass yield instead of storing. Therefore, allowing a better end result that is more environmentally friendly. We then had to research ways in which we could then generate electricity, paying special care to enhancing the product quality and quantity, lessening the costs and reducing hazardous environmental impacts.

Evaluation of System

Upon evaluation, it can be said that our system meets the requirements of our outlined goal states as far as possible. With regards to our first goal state "to create a biomass energy system that could be used by a UK farmer to produce electrical energy using the organic waste the farmer produces as a result of their activities", we have met this as far as possible. We have designed a system which allows a farmer to use their crop wastage to then use to produce electrical energy through a means of different processes which are outlined in the flowchart. Our second goal state was "to create a biomass energy system that could be integrated with the current energy grid - with the farmer being able to switch between buying from the grid and selling to the grid where he has a surplus of electrical energy" this also has been met as far as possible. We have designed a system which works out how much electrical energy has been produced by the biomass system and compares this to the amount needed to power the farm, and, if there is a deficit, the system is able to work out if it needs to produce more electricity or take electricity from the mains. In addition to this, the system is able to, if there is a surplus, sell this to the energy provider who, in turn, will then work out how much this equates to in sterling pounds. Moreover, our final goal state was "to create a biomass energy system that is as environmentally friendly as possible, to create a system where CO₂ emissions and carbon footprint are kept to a minimum", as a team, we have met this goal state as far as possible, too. Within our biomass energy system, we have reduced the CO₂ emissions and carbon footprint in various ways. One way in which this was done, was by adding the pyrolysis product (biochar) back into the system and mixing it in with the initial biomass. By doing so, this reduces the CO₂ and ammonia emissions. Additionally, we chose pyrolysis as our preferred method of producing electrical energy in our process. This meant that, due to it being such a fast process, it results in a lower carbon footprint.

Reflection

Throughout this project, we have been taught several types of new research and problem-solving aspects, such as morphological analysis and flow charts that we have incorporated into our report and presentation. With these new research techniques, we came across a few

challenges within our group, finding an approach which was comfortable to ourselves as well as the team. We were able to do this due to our excellent teamwork abilities, helping one another reach an understanding of what we were doing.

Due to each team members' own self-awareness, we were able to understand each persons' strengths and weaknesses. We had to consider where our strengths lay in terms of individual research and where we needed to come together as a team, or small groups of 2 - and all contribute to a specific topic. This came easily to our team; each member was confident in specifying if they needed some group assistance on their research. Not only this, there were points within the different stages where each person had to take charge as they were the only one comfortable with particular aspects; taking leadership of the team and helping everyone come to an understanding.

Working as a new group came very comfortably to our team, with each member expressing their opinions and having their voice heard in an environment where all members were willing to listen and cooperate. This was due to our great communication skills that we already had but then developed through this group project.

One main challenge we faced was COVID-19. As a result of this, we each had to use our initiative and create new means of communication as a group. With this, we had to overcome barriers of communication and worked mainly online to manage our time and turnout our report, ensuring that all aspects of the system were covered. This resulted in each team members' planning skills developing due to having to think of thorough plans so that each stage could be carried out and to a high standard. Overall, we had a positive learning experience within our team.

References

- Austin, A., 2009. *Size Matters* | *Biomassmagazine.Com*. [online] Biomassmagazine.com. Available at: <http://biomassmagazine.com/articles/2309/size-matters> [Accessed 7 April 2020].
- AZoCleantech.com. 2013. *What Is Pyrolysis?*. [online] Available at: <<https://www.azocleantech.com/article.aspx?ArticleID=336>> [Accessed 3 April 2020].
- Benson, I., 2019. *Farm Food Waste And Surplus Costing UK £1 Billion Every Year*. [online] Resource Magazine. Available at: <<https://resource.co/article/farm-food-waste-and-surplus-costing-uk-1-billion-every-year>> [Accessed 3 April 2020].
- Biogen.co.uk. n.d. *What Is Anaerobic Digestion?*. [online] Available at: <http://www.biogen.co.uk/Anaerobic-Digestion/What-is-Anaerobic-Digestion> [Accessed 3 April 2020].
- Bridgwater, A., 2012. Review of fast pyrolysis of biomass and product upgrading. *Biomass and Bioenergy*, 38, pp.68-94.
- Chowdhury Zaira Zaman, Kaushik Pal, Wageeh A. Yehye, Suresh Sagadevan, Syed Tawab Shah, Ganiyu Abimbola Adebisi, Emy Marliana, Rahman Faijur Rafique and Rafie Bin Johan (July 5th 2017). *Pyrolysis: A Sustainable Way to Generate Energy from Waste*, Pyrolysis, Mohamed Samer, IntechOpen, DOI: 10.5772/intechopen.69036. Available from: <https://www.intechopen.com/books/pyrolysis/pyrolysis-a-sustainable-way-to-generate-energy-from-waste> [Accessed 7 April 2020]
- Clark, D., 2013. [online] Cundall.com. Available at: <<https://cundall.com/Cundall/fckeditor/editor/images/UserFilesUpload/file/WCIYB/IP-25%20-%20Biomass%20and%20biofuel%20sources.pdf>> [Accessed 7 April 2020].
- Gabbatiss, J., 2018. Fruit and vegetable waste from farms ‘could feed population of Birmingham or Manchester for a year’, says environmental charity. *Independent*, [online] Available at: <<https://www.independent.co.uk/environment/fruit-vegetables-food-waste-farms-uk-birmingham-manchester-feedback-a8220171.html>> [Accessed 3 April 2020].
- Generatorsources.com. 2020. *How Does A Generator Create Electricity? Article On How Generators Work*. [online] Available at: <https://www.generatorsources.com/How_Generators_Work.aspx> [Accessed 3 April 2020].
- GOV.UK. 2020. *Feed-In Tariffs: Get Money for Generating Your Own Electricity*. [online] Available at: <<https://www.gov.uk/feed-in-tariffs>> [Accessed 3 April 2020].
- greengarageblog.org. 2016. *8 Pros And Cons Of Incineration*. [online] Available at: <<https://greengarageblog.org/8-pros-and-cons-of-incineration>> [Accessed 5 April 2020].

- Harris, W., HowStuffWorks, Science, Science, Technology and Technologies, n.d. *How Gasification Works*. [online] HowStuffWorks. Available at: <<https://science.howstuffworks.com/environmental/green-tech/energy-production/gasification.htm>> [Accessed 3 April 2020].
- H.S. Choi, Y.S. Choi, H.C. Park, Fast pyrolysis characteristics of lignocellulosic biomass with varying reaction conditions, *Renew. Energy* 42 (2012) 131–135,–
<https://doi.org/10.1016/j.renene.2011.08.049>. [Accessed 7 April 2020]
- Papari, Sadegh & Hawboldt, Kelly. (2018). A review on condensing system for biomass pyrolysis process. *Fuel Processing Technology*. 180. 1-13.
10.1016/j.fuproc.2018.08.001. Faculty of Engineering and Applied Science, Memorial University of Newfoundland.
- Petrotechinc.com. 2020. *How Does A Steam Turbine Work?*. [online] Available at: <<https://petrotechinc.com/how-does-a-steam-turbine-work/>> [Accessed 3 April 2020].
- Ritchey T. (2011) General Morphological Analysis (GMA). In: *Wicked Problems – Social Messes. Risk, Governance and Society*, vol 17. Springer, Berlin, Heidelberg.
- Spears, S., 2018. *What Is Biochar? - Regeneration International*. [online] Regeneration International. Available at: <<https://regenerationinternational.org/2018/05/16/what-is-biochar/>> [Accessed 3 April 2020].
- Schmidt, H. & Wilson, K., 2014. *The 55 Uses Of Biochar*. [online] Available at: <<https://www.biochar-journal.org/en/ct/2>> [Accessed 3 April 2020].
- The Anaerobic Digestion & Biogas Blog. 2015. *The Advantages And Disadvantages Of Anaerobic Digestion Vs Composting*. [online] Available at: <<https://blog.anaerobic-digestion.com/anaerobic-digestion-vs-composting/>> [Accessed 3 April 2020].
2017. *Biomass Pyrolysis Process*. [video] Available at: <<https://www.youtube.com/watch?v=3K1zWAYDvMA>> [Accessed 6 April 2020].