

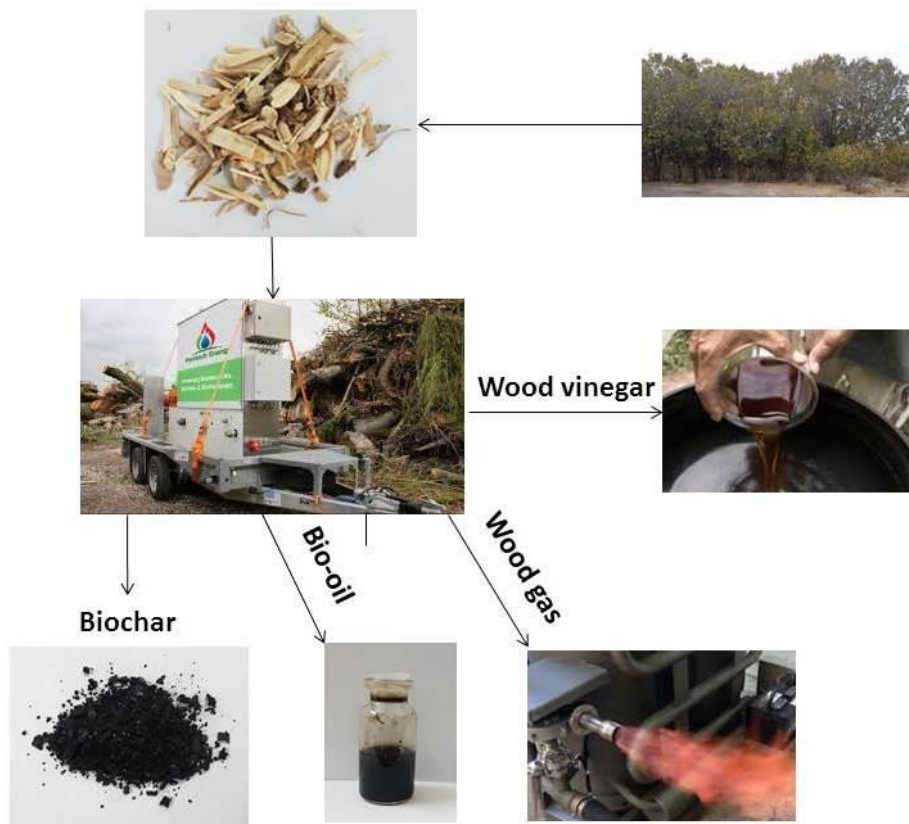


FlashPyrolyser to convert the woody biomass into fuel and vinegar

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1. Introduction

1.1. A Brief Summary of Pyrolysis Theory

At the beginning of the 20th century, crude petroleum fuels covered only 4% of the world's energy demand. However, nowadays, petroleum fuels are the most important energy source and covers about 40% of the world's energy demand. It also produces 96% of the transportation fuels. Nevertheless, petroleum fuels are non-renewable and the reserves of fossil fuel are depleting fast. In addition, the use of petroleum fuels influences environment by generating huge amounts of net carbon dioxide emission and other pollutants such as NO_x and SO_x. Therefore, there is an urgent need to find renewable and environmentally benign feedstocks for sustainable supply of fuels and energy.

Biomass is one of the potential feedstocks meet such requirement. Biomass itself is carbon-neutral and its use produces much less SO_x and NO_x due to the much lower content of nitrogen and sulphur in the biomass than in coal or petroleum oil. Biomass can be converted to liquid fuels via pyrolysis. Pyrolysis can be operated at atmospheric pressure. Hence, the conversion of biomass into a liquid fuel via pyrolysis has attracted great interest.

There are three major products from biomass pyrolysis, which includes char, bio-oil and pyrolytic gas (also called wood gas). Char is a solid product, the residual in pyrolysis of biomass, with low volatility and high carbon content. Bio-oil is the primary product of interest, which is an organic mixture of alcohols, ketones, aldehydes, phenols, ethers, esters, sugars, furans, alkenes, nitrogen and oxygen compounds. The pyrolytic gas is mainly the result of cracking and decomposition of big molecules that forms from the initial stages of pyrolysis. It consists of carbon dioxide, carbon monoxide, hydrogen, low carbon number hydrocarbons, nitrogen oxide, sulphur oxide and etc. The yield for char, bio-oil and gas can vary significantly under the different process conditions. Typically, the yields of bio-oil, bio-char and the gaseous products are 50-70, 13-25 and 12-15 wt%, respectively.

1.2. Australia as a Potential for Biomass Base fuel and products

Through to the availability of high amount of biomass, especially wood, in Australia, pyrolysis technology can be a potential technology to convert it into fuel and also other products. According to "Clean Energy Finance Corporation (CEFC)" report in 2015, pyrolysis technology is not developed well in Australia. Only below 0.9 % of the Australia Electricity use is produced by this technology. Therefore, it is required to accelerate the development of pyrolysis process in Australia for having a greener Australia and better fuel and other products' economies. CEFC estimated that 3.5-5 billion USA dollars should be invested in this field in 2020. This can produce 800 MW of electricity with avoiding nearly 9 million tonnes of CO₂ each year.

2. PyroTech Energy Pty Ltd Pyrolysis Technology

Pyrotech Energy is a licensor and provider of the pyrolysis technology in Australia. By using the flash pyrolysis technology, it can convert the woody biomass into fuels and chemicals. The technology called Mobile flash pyrolyser can convert the woody biomass into dry bio-oil, wood vinegar (also called wood acid), char and wood gas. The reactor (called PyroFlash) includes a new design and an innovative separation process, which can separate

the mixture of acids and water from the bio-oil. The general schematic of the PyroFlash process is shown in Figure 1.

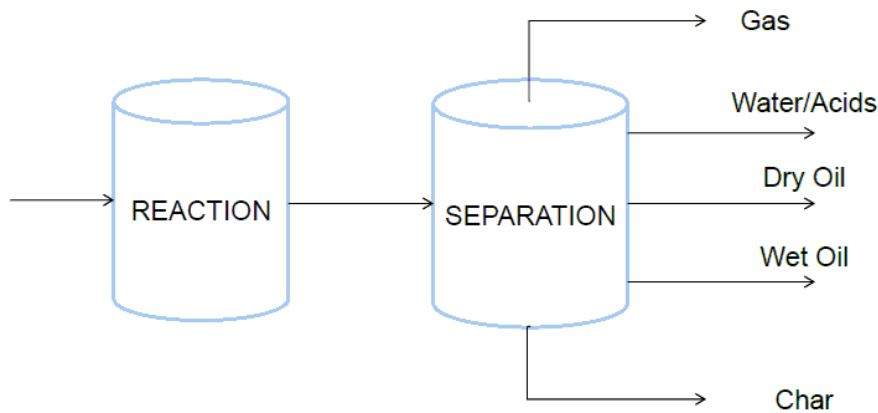


Figure 1. The schematic of PyroFlash process to convert the woody biomass into bio-oil.

The typical yields of the products from the pyrolysis of the woody feedstock by PyroFlash technology considering 10 wt% water in biomass are shown in Table 1.

Table 1. The yield of the different products from the pyrolysis of woody biomass

No.	Product	wt% of feed
1	Biochar	10
2	Bio-oil*	25
3	Wood vinegar	25
4	Wood gas	40

* It should be noted that the bio-oil includes 5 and 20 wt% wet and dry oils.

Pyrotech Energy technology is a proven and registered technology by Nettenergy Company with two available production capacities including 2 and 10 tonnes per day of woody biomass feeding. The most string fact is that both plants are mobile and can be taken to the farm land or the biomass source. In addition, Pyrotech Energy is doing all engineering service regarding the pyrolysis technology from the design up to installation processes.



Figure 2. The mobile pyrolyser with 2 and 10 tonnes per day feeding capabilities

In Table 2, the main features of the both plants are presented.

Table 2. The dimensions of the both available sizes of the PyroFlash set-up

No	Capacity (Ton/day feeding)	Size of container (L×W×H) (m)
1	2	6×2,4×2,6
2	10	12×2,4×2,6

Key features of the PyroFlash technology. The main features of the Pyrotech Energy Company pyrolysis technology are:

- Easily transported unit with access to most remote areas.
- Fully automated feeding process.
- 10 tons of woody biomass will yield 2.5 tons of bio- oil, 2.5 tons of wood vinegar, 1ton of biochar and wood gas equal to a 1.2MW a day.
- Batch processing takes 22-24 hours depending on moisture content.
- Very low emissions
- High thermal energy output (High heating value of 24 MJ/kg).
- Designed for farm and forestry machinery operations.

The detailed information regarding the products is presented in below:

- Dry Bio-oil

Bio-oil as one of the most important products of the pyroflash technology is characterised as below in Table 3.

Table 3. The detailed analysis of woody bio-oil produced through to the Pyrotech Energy pyrolyser

No.	Parameter	Amount
1	Appearance	Cloudy
2	Colour	Black
3	water content (wt%)	9.6
4	Ashes (815°C) (wt%)	0.1
5	Higher heating value (kJ/kg)	21200
6	Lower heating value (kJ/kg)	19700
7	Carbon (wt%)	53.1
8	Nitrogen (wt%)	<0.1
9	Hydrogen (wt%)	7.2
10	Sulphur (wt)	0.006

- Wood Vinegar

Wood vinegar (also called pyroligneous acid) is the most valuable product of the pyroflash technology, which can be supplied as a biocide. Recently, through to integrated pest management programs (IPM), which aims to reduce the risk of using synthetic biocides on the environment pollution and also human being health, the demand for natural pesticides is enhanced. The wood vinegar main analysis from Pyrotech Energy pyrolysis technology is presented in Table 4.

Table 4. The detailed analysis of wood vinegar produced through to the Pyrotech Energy pyrolyser

No.	Parameter	Amount
1	Appearance	Clear
2	Colour	Brown
3	Water content (wt%)	69
4	Ashes (815°C) (wt%)	0.3
5	Higher heating value (kJ/kg)	<1000
6	Lower heating value (kJ/kg)	<1000
7	Carbon (wt%)	14.6
8	Nitrogen (wt%)	<0.1
9	Hydrogen (wt%)	10
10	Sulphur (wt)	0.005

- Wood Gas

Another important product of the flash pyrolyser is the wood gas, which is mainly composed of the below components:

Table 5. The main components presented in the gas phase of wood pyrolysis products

No.	Parameter	Amount
1	Oxygen	1.34
2	Hydrogen	9.63
3	Carbon dioxide	10.26
4	Carbon monoxide	26.64
5	Methane	2.83
6	Ethane	0.15
7	Propene	0.09
8	Propane	0.03

It should be mention that it has high and low heating values of 6.49 and 6.88 MJ/m³, respectively.

- Biochar

Biochar as another product of the pyroflash technology can be supplied as a soil amendment including carbon sequestration, soil fertility improvement, pollution remediation and agricultural by-product/waste recycling. It can also be used in catalytic utilisation, energy storage and environmental protection and a sustainable platform carbon material for other high-value applications. It can also be used as a sorbent for the removal of pollutants in water. In addition, char also could be used as a sorbent for the removal of pollutants in flue gas, such as SO₂ and NO_x. In Table 6, the main results from the analysis of biochar produced from the pyrolysis of woody biomass by Pyrotech Energy pyrolyser is shown.

Table 6. The detailed analysis of biochar produced through to the Pyrotech Energy pyrolyser

No.	Parameter	Amount
1	Appearance	Solid
2	Colour	Black
3	Water content (wt%)	3.8
4	Ashes (815°C) (wt%)	3.3
5	Higher heating value on dry basis (kJ/kg)	29800
6	Lower heating value on dry basis (kJ/kg)	27700
7	Carbon (wt%)	81.6
8	Nitrogen (wt%)	0.55
9	Hydrogen (wt%)	2.4
10	Sulphur (wt)	0.028

3. Electricity Production

In the case of considering of dry bio-oil, gas and biochar as a source for electricity production, it is calculated that by using the gas generator and steam turbine (assuming 30 and 20% efficiency for gas generator and steam turbine, respectively) the below amount of electricity can be produced.

Table 7. The net electrical power production by Pyrotech Energy pyrolyser

No.	Used machine	Parameter	Using 2 ton/day plant	Using 10 ton/day plant
1	Gas generator	Net electrical power production (kWh)	13	65
2	Gas generator	Net electrical power production (MW/year)	93.6	468
3	Steam turbine	Net electrical power production (kWh)	28	139
4	Steam turbine	Net electrical power production (MW/year)	200	1000
5	Gas generator	Net electrical heat production (kWh)	42	210
6	Gas generator	Net electrical heat production (MW/year)	302.4	1512
7	Steam turbine	Net electrical heat production (kWh)	111	556
8	Steam turbine	Net electrical heat production (MW/year)	800	4000

Note. Every year is considered of 300 working days.

4. Graphical Abstract of the Pyrotech Energy Pyrolysis Technology

