CHAPTER 1
INTRODUCTION

1.1. Background

Climate change refers to changes in climate that can be identified by changes in the average temperature or the variability in nature and lasts for a long period, usually decades, according to Climate Change 2007-Synthesis Report of Intergovernmental Panel on Climate Change (IPCC) [1]. Climate change brings abnormal variations in the Earth's atmosphere and subsequent effects on other parts of the planet, as inland plants, and reduction of annual yield. The melting of the polar icebergs causes sea level rise and flooding in the lowlands [2].

Climate change is the most serious, complex, and multidimensional challenge to humanity at the beginning of the 21st century, maybe even until the 22nd century. There is no country or group of people in the world able to escape from this challenge. The challenge of climate change and global warming forces to revise human behaviors and lifestyle. Political decisions, patterns of development, choice of technology, socioeconomic conditions, and international agreements are important aspects of climate change.

There are facts that the earth's temperature is increasing, rainfall patterns change drastically, climate and weather becomes extreme, catastrophic droughts happen, huge storms and flood attack, the heat waves and forest fires spread almost endlessly. Tens of millions of vulnerable poor people in developing countries without
clean water have increasingly threatened by the failure and decline of agriculture and fishery outcomes, as well as face health problems and malnutrition, famine and plague [3].

Weather and climate on Earth actually change seasonally, annually and in decades. However, extreme weather comes more frequently than in previous years and seems to continue for the long period. The study by the scientists, who are members of the Intergovernmental Panel on Climate Change (IPCC), indicated that climate change started in the last 150 years and it was found not only in nature, but also in consequence of human activities.

Human activity is a driving force of the global warming and climate change. Human activities, especially activities related to the utilization of energy resources from fossil fuels (petroleum, natural gas and coal) should be mentioned.

1.1.1. Global Warming

Global warming is one of typical phenomena of climate change. Activities in the industry and the transport sections have emitted exhaust gases since the industrial revolution in Western Europe and the emitted gases have been accumulated in the air for a long time. The accumulation of atmospheric pollutants transformed into greenhouse gas (GHG) brings about the phenomenon of global warming. Among greenhouse gases, the most important ones are carbon dioxide (CO₂), methane (CH₄), nitrous oxide (N₂O), and chloro fluoro carbon (CFC). All these elements contribute to the process of solar radiation that is emitted/ reflected to the earth, so that the
temperature of the earth's atmosphere is warmed up and heated up, which is called global warming.

Global warming occurs gradually over hundreds of years, but its impact has been recognized in the present. Although the industrial age began almost one million years before, the concentration of CO₂ in the atmosphere was only about 170-250 ppm at that era. When the industrial revolution began in England around 1850, the concentration of CO₂ in the atmosphere began to rise to 280 ppm and Earth's average temperature increased by about 0.74°C. However, it is estimated by IPCC scientists that the accumulation of CO₂ in the atmosphere has reached 390 ppm 160 years after the industrial revolution. The burning of fossil fuels and part of forest conversion cause this phenomenon. If the patterns of production and consumption, and life styles are kept unchanged, it is estimated that in 100 years later, CO₂ concentration will continue to increase up to 580 ppm or over double of that before the industrial revolution.

The earth's average temperature will rise by 1.1°C over a period of 50-100 years, if humans do not take any action to stabilize GHG in the atmosphere. Therefore, according to the IPCC assessments, international communities fought through the United Nations Framework Convention on Climate Change (UNFCCC) and enacted Kyoto Protocol 17 years ago, which aimed to keep the earth's temperature rise of less than 2°C threshold. To keep the earth's temperature rise of less than 2°C, the concentration of CO₂ in the atmosphere should be suppressed and limited to 450 ppm at a maximum of 2020. This means that the earth is required to
stop the CO₂ emission or at least reduce CO₂ emission by 80% of the emission level in 1910.

Small island states in the Pacific Ocean belong to the Alliance of Small Island Developing States (AOSIS) set a target of the maximum temperature rise of 1.5°C and the CO₂ concentration in the atmosphere of less than 350 ppm, which must be achieved by 2015. All countries should follow the AOSIS target and reduce their carbon emission by 2015. The earth's temperature rise of more than the 2°C threshold will negatively affect small islands and low-lying. It is estimated that nearly 40% of small islands will be submerged in the ocean [4].

To reduce CO₂ emission, other energy resources replacing fossil fuels are developed in the world. One of big potential energy resources is a renewable energy resource like biomass represented by woods. However, convenience in the use of fossil fuels must be kept for renewable energy resources. Gasification of wood is one of most promising ways.

1.1.2. Energy Crisis

It is anticipated that world energy consumption increases by approximately 70% during the period 2000 to 2030 as shown in Fig 1.1 [5]. Therefore, it should be noted that an average increase per year of 2.38% is significantly larger than 1.4% increase per year in the period from 1980 to 2000. In 2030, fossil fuels (coal, oil, natural gas), and primary electricity still occupy 88% of world energy consumption.
In figure 1.2, the evolution of energy consumption per capita in 2030 is illustrated for various regions of the world. Except Community of Independent States (CIS), Central and Eastern European Countries (CEEC), energy consumption per capita in each region gradually increases to 2030. As shown at the left hand side of the figure, energy consumption of the world also gradually increases to 2030.
Since the world population is projected to also increase every year and reach more than 8.3 billion in 2030 from 6.1 billion in 2000, it can be easily understood that the world energy consumption significantly rises to 17,000 (=2.1 × 8.3 × 10^9) Mtoe (million ton of oil equivalent) in 2030.

Oil, gas and coal supplies in the world are anticipated sufficing for the next three decades. In figure 1.3, the world oil production is projected to increase up to around 6,000 Mtoe in 2030.++

![World Oil Production Chart](image)

Figure 1.3. World Oil Production [5].

Sources: World energy, technology and climate policy outlook 2030 (WETO)

Similarly, world gas and coal productions are projected to increase up to 4,800 and 4,400 Mtoe in 2030, respectively in World energy, technology and climate policy outlook (WETO) by the European Commission. The total world fossil fuel production in 2030 can suffice for world consumption of fossil fuel in 2030. According to the report of the US Energy Information Administration, the world
energy consumption is projected to increase from 504.7 quadrillion Btu (1270 Mtoe) in 2008 to 769.8 quadrillion Btu (1990 Mtoe) in 2035. It is also projected that energy consumption in developing countries in Asia will increase from 137.9 quadrillion Btu (348 Mtoe), which is around a half of the OECD, in 2008, to 298.8 quadrillion Btu (751 Mtoe) in 2035, which is corresponding to total energy consumption of OECD in 2035 [6].

As mentioned above, demand for fossil fuels will be still strong in 2030. The developing countries in Asia, especially, China and India will continue their economic development that needs large amount of energy. Indonesia, Malaysia, Thailand and Vietnam will run after two heading countries in Asia. If fossil fuel has still a dominant role in energy supply in 2030 and later as shown in Fig. 1.1, it is very difficult to moderate the climate change and prevent the global warming. We need a scenario to solve such energy crisis.

1.1.3. Indonesia Energy Conditions

Energy consumption in 2000 reached 760 million Barrel Oil Equivalent (BOE) and increased gradually to reach 829 million BOE in 2004 at an average increase rate of 2.1% per year and decreased by 0.12% of total consumption in the previous year in 2005. However, in 2006 to 2010, energy consumption again increased gradually at the average increase rate of 4.0% per year as shown in Fig. 1.4.
According to Indonesia Energy Outlook 2012, as shown in Fig. 1.5, the basic scenario based on the average GDP growth rate of 7.6% per year projects that energy demand in 2030 becomes nearly three times larger than the energy demand in 2010. According to the scenario MP3EI based on the GDP growth rate of 10.4% per year, the anticipated energy demand in 2030 rises to 4.3 times of the energy demand of this year 2013. In the short term, namely in the year 2015, energy demand is increasing at a rate of 4.5 % per year. The energy demand in the short term has no significant difference between the basic scenario and the scenario MP3EI.

As the driving force of the national economy, the energy demand of the industrial sector is expected to continually rise and dominate the total final energy demand, followed by the transportation sector's energy demand as a supporter of economic activity sectors.
1.1.4. Renewable Energy Status in Indonesia

Development of renewable energy today is still relatively low, but has an important role in contributing to the electric energy supply in Indonesia. Some renewable energy comes from solar energy, wind energy (wind), biomass, hydroelectric power (hydropower) and geothermal energy. In Fig.1.6, it is indicated that the Presidential Decree No. 5 decided a government program to increase the production of renewable energy from 7 percent to 15 percent in fraction of total energy production by 2025. The government should positively advance the installation of renewable energy power plants in order to achieve the target that the electric power by renewable energy reaches around 90 GW by 2025 [7].

Figure 1. 5.Projection of total final energy demand by energy sector [6]
Figure 1.6. Current Energy Mix versus Future Energy Goals [7].

According to the Renewable Energy Market Assessment Report: Indonesia, Indonesia has a source of renewable energy is large enough, as shown in Table 1.1. It means that there is big potential in Indonesia to develop carbon-neutral energy that can moderate climate change and prevent further global warming:

1. Hydropower:

Indonesia as an archipelagic country has great potential for developing energy from hydroelectric power (hydropower) and ocean energy technology. Indonesia State Electricity Company has estimated energy of 75,650 MW by water. Currently, Indonesia produces only 4,264 MW of hydropower. In 2007, the United Nations provides grants to the Indonesian government in the form of integrated development programs to accelerate the development of micro hydro power plant.
2. Geothermal energy:

Indonesia has large geothermal energy sources as known in the world. Currently, geothermal energy plants have been installed only 1,052 MW of total estimated energy source, 27,510 MW. By 2025, the government is planning to increase the geothermal energy up to 5% of total energy.

3. Biomass Energy:

Sources of biomass energy in Indonesia reached 49,810 MW. This is a huge potential, next to hydropower potential, but currently only 445 MW is utilized. In 2025, the government target is to produce electrical energy of 810 MW from biomass. This number is still small compared to the amount of potential availability. Sewage plants, namely logs, lumber waste, rice husk, bagasse, rubber, oil palm empty fruit bunches and all kinds of plants can be used to generate electricity.

4. Solar Energy (solar energy):

The potential of solar radiation in the whole of Indonesia is estimated at 4.8kWh/m²/day. Until now, Indonesia has installed 12.1 MW plants. High investment cost is necessary, because the main tools and solar photovoltaic modules are imported from other countries and the efficiency of photovoltaic modules is only 16% and as a result, the price of 1 kW solar electricity is still relatively high. Such constraints discourage the installation of the Solar Power Plant (SPP) in Indonesia. Therefore, to
increase the installed capacity of solar plant, the Government should issue a regulation or devise programs for solar plant development in Indonesia.

5. Wind Energy:

Indonesian potential for wind energy is still limited because of the lack of wind along the equator. The area in small islands has potential for wind power, but in those islands, the population is quite likely small. The total wind potential is estimated at 9,910 MW, but only 1.10 MW plant has been installed.

<table>
<thead>
<tr>
<th>No</th>
<th>Energy Source</th>
<th>Installed Capacity (MW)</th>
<th>Resource Potential (MW)</th>
<th>Undeveloped Potential (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Hydropower</td>
<td>4,264.00</td>
<td>75,670.00</td>
<td>94.00</td>
</tr>
<tr>
<td>2</td>
<td>Geothermal</td>
<td>1,052.00</td>
<td>27,510.00</td>
<td>96.00</td>
</tr>
<tr>
<td>3</td>
<td>Biomass</td>
<td>445.00</td>
<td>49,810.00</td>
<td>99.00</td>
</tr>
<tr>
<td>4</td>
<td>Solar</td>
<td>12.10</td>
<td>4.8 kWh/m2/day</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>Wind</td>
<td>1.10</td>
<td>9,190.00</td>
<td>99.00</td>
</tr>
<tr>
<td>6</td>
<td>Ocean</td>
<td>-</td>
<td>35.00</td>
<td>100.00</td>
</tr>
</tbody>
</table>

1.1.5. Biomass Potential in Indonesia

Biomass is one of the energy resources used for cooking in rural households. Besides, it is also used for a raw material in the energy industry and commercial sector. In the processing industry and forest plantations, biomass is used to generate not only thermal energy (steam or heat), but also electricity.
According to the Basic Scenario 2010-2030 [8], biomass supply is statistically projected to drop from 41 million BOE (5.5 Mtoe) in 2010 to 34 million BOE (4.6 Mtoe) in 2030. The decline is due to the limited supply of biomass resulting from substitution to the easier accessible energy source, such as coal.

However, the Security Scenarios 2010-2030 [8], actually expects that biomass supply slightly increases from 41 million BOE (5.5 Mtoe) in 2010 to 51.5 million BOE (7.0 Mtoe) in 2030 at an average rate of 1.2% per year. The share of biomass in the primary energy mix is only 1.3% in 2030. This value is far small as compared with the target value of 5% by the Presidential Decree as shown in Fig. 1.6. The increase in biomass consumption can be expected associated with incentives to use energy with low-emission of carbon dioxide, or carbon neutral property to moderate climate change and prevent further global warming.

As mentioned earlier, Indonesia has the huge potential of biomass energy and the government should promote technology development to produce high quality of biomass energy, cheaply, effectively and efficiently. Table 1.2. shows that each region of Indonesia has a large biomass energy sources. In general, organic wastes are not fully utilized yet, as described earlier.

Table 1.2. Energy Potential of Biomass by Region in Indonesia

<table>
<thead>
<tr>
<th>No</th>
<th>Region</th>
<th>Waste Rice (GWh)</th>
<th>Waste Corn (GWh)</th>
<th>Waste Cassava (GWh)</th>
<th>Waste Wood (GWh)</th>
<th>Waste Coconut (GWh)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Java</td>
<td>65,652</td>
<td>26,534</td>
<td>16,216</td>
<td>5,053</td>
<td>1,532</td>
</tr>
<tr>
<td>2</td>
<td>Sumatera</td>
<td>36,292</td>
<td>8,103</td>
<td>7,062</td>
<td>41,785</td>
<td>2,243</td>
</tr>
</tbody>
</table>
Table 1.2. Energy Potential of Biomass by Region in Indonesia (Continued)

<table>
<thead>
<tr>
<th>No</th>
<th>Region</th>
<th>Waste Rice</th>
<th>Waste Corn</th>
<th>Waste Cassava</th>
<th>Waste Wood</th>
<th>Waste Coconut</th>
</tr>
</thead>
<tbody>
<tr>
<td>3</td>
<td>Kalimantan</td>
<td>13,298</td>
<td>715</td>
<td>1,007</td>
<td>68,649</td>
<td>381</td>
</tr>
<tr>
<td></td>
<td>Bali, Nusa</td>
<td>7,486</td>
<td>5,039</td>
<td>2,311</td>
<td>3,309</td>
<td>399</td>
</tr>
<tr>
<td></td>
<td>Tenggara</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>Sulawesi</td>
<td>15,304</td>
<td>7,705</td>
<td>2,086</td>
<td>19,275</td>
<td>1,613</td>
</tr>
<tr>
<td>6</td>
<td>Maluku</td>
<td>323</td>
<td>474</td>
<td>434</td>
<td>7,789</td>
<td>558</td>
</tr>
<tr>
<td>7</td>
<td>Papua</td>
<td>213</td>
<td>59</td>
<td>78</td>
<td>59,721</td>
<td>32</td>
</tr>
<tr>
<td>8</td>
<td>Total potential</td>
<td>138,568</td>
<td>48,629</td>
<td>29,194</td>
<td>205,581</td>
<td>6,758</td>
</tr>
</tbody>
</table>

Based on the background of the above issues, then how can we use high potential biomass for energy, especially wood waste? There are several ways of energy conversion of wood waste. These are as follows:

1. Direct burning for heat
2. Liquids fuel production
3. Gasification of biomass

Direct burning of wood has been used as the easiest way of energy conversion since ancient era. Technology to produce liquid fuel and gas fuel from wood is positively developed in the recent few decades. The main technology is pyrolysis. In the next section, we will review the wood pyrolysis researches.
1.2. Limitation of Problem

Based on the description of the background above is obtained a description of the issues dimension are quite broad. However, the author aware of the limitations of time and ability, therefore the author considers necessary to provide clear boundaries and focus issues. The next issues are the object of study is only limited in the conversion of biomass using the pyrolysis paths.

Pyrolysis is the thermal decomposition of fuel into liquids, gases, and char (solid residue) in the absence of oxygen. Pyrolysis is a technology that has long been developed, but the process of pyrolysis phenomenon has not been widely known. Therefore, the discussion of the pyrolysis phenomenon in the reactor chamber is the main research, this study, because pyrolysis phenomena take place inside the chamber. To describe the pyrolysis phenomenon, the numerical approach with the ANSYS software is used.

1.3. Research Objective

This work aims to obtain information about the phenomena accompanying wood pyrolysis in the pre-vacuum chamber and a key to improving the pyrolysis performance. Therefore, several issues should be examined through this numerical analysis:

a. Temperature distribution and pressure inside chamber, especially temperature of wood pieces.

b. Chemical kinetic reaction inside chamber.
c. Gas Content number of wood volatile.

d. Drafting improvement of the current system based on numerical analysis.