CHAPTER I

INTRODUCTION

Energy is defined as a property of objects which can be transferred to other objects or converted into a different form (Kroemer & Kittel, 1980). Human has been harnessing energy for work, heating, transportation, food production, manufacturing of products, and electricity. Energy in its classical term appears in many forms in our daily life in the form of gravitational energy, kinetic or mechanical energy, electrical energy, heat radiation energy, wave energy, chemical energy, and nuclear energy. The Law of Conservation of energy states that the form of energy may change in time such as conversion of electrical energy into mechanical energy, but the total amount of energy does not change.

1.1 The world energy problem

The state of the world today is based on the capability of a human to convert energy from one form to another. The world population is rapidly growing, with a predicted global population increase from 7 billion people living today to 9 billion people in 2040. The global citizens will need energy for living, thus, the overall global energy demand will exponentially increase. The world energy problem is that of the unbalanced supply-demand situation, with the most prosperous and developed countries are the ones having good access to and use the most amount of energy. Thus, the biggest challenge for humankind in this century will be tackling the problem of energy.

The energy consumption per capita is usually linked to the living standard of a country. In 2010, in the United State (US) has registered a daily use of around 230 kWh of the energy per capita. In contrast, countries in Africa, such as Nigeria, only uses one-
tenth of this amount, around 23 kWh per day per capita. As shown in Fig 1.1, the living standard expressed in human development index can be illustrated on a global scale. As can be seen, large consumption of energy usually corresponds to the high living standards of the country.

Figure 1.1. A map depicting world energy consumption per capita based on 2003 data from International Energy Agency

In recent years, the living standard is rapidly increasing in many emerging economies such as China and India. With a combined population of almost 2.5 billion people, the population of these two countries represent almost a third of the world population. The increasing population and the expectation of high standard of living will put a large demand on the requirement of energy. The International Energy Agency (IEA) Outlook 2013 predicts that the energy consumption will increase by 56% from the year 2010 to 2040. The increase in energy demand will have a chain effect on the economy, elevating the prices of goods and services.

Refer to annual average oil prices in USD/barrel BP workbook of historical data in 2012 which is reported that the price of oil peaked in the 1970s due to the oil crisis, when oil-producing countries had imposed a halt on the trade of oil. The second peak of oil is seen in the beginning of the millennium when there is an increase in energy demand from newly emerging economies.
The second challenge facing the global community is the fact that the world energy infrastructure is heavily dependent on fossil fuel such as oil, coal and gas. Fossil fuels are essentially solar energy from million of years ago stored in the form of chemical energy. Fossil fuels are non-sustainable energy sources and are being depleted at an exponential rate. In the coming century, if the consumptions continue at the present rate, it is predicted that the global oil and gas reserve will run out. Oil companies and governments are taking greater risks in oil explorations, and several technological mishaps have occurred in the course of extracting from the depths of the current oil reserves, as can be seen from the Gulf of Mexico oil spill in 2010.

The third challenge is the production of greenhouse gasses (GHG), such as carbon dioxide, as a byproduct from the burning of oil. Scientists have postulated that the increase in carbon dioxide is responsible for the global warming and climate change, which can have drastic consequences of the habitats of people and animals (IRENA, 2013). Various technologies have been proposed to reduce the consumption of oil, such as the use of hydroelectric, wind and solar power.

1.2 Renewable energy carriers

Renewable energy carriers, such as hydro, wind and solar, are replenished by natural processes at a rate comparable or faster than its rate of consumption. For example, hydroelectricity is an energy conversion technology that is not based on heat generated by fossil or nuclear fuels. The potential energy of rain falling in mountainous areas or elevated plateaus is converted into electrical energy via a water turbine. Similarly, with tidal pools placed on the ocean beach, the potential energy stored in tides can also be converted to mechanical energy and subsequently electricity. The kinetic energy of wind can be converted into mechanical energy using windmills. Likewise, the energy contained in sunlight called solar energy, can be converted into electricity directly using devices
based on photovoltaic (PV) semiconductor materials. In solar thermal energy applications, the solar light is converted into heat (Jager et al., 2014).

1.3 Solar thermal energy

Photovoltaic technology is based on the principles of electrodynamics and solid-state physics to convert solar energy into electricity directly, whereas solar thermal energy is mainly based on the laws of thermodynamics (Jager et al., 2014).

Thermal energy storage (TES) is a technology that stocks thermal energy by heating or cooling a storage medium to be later used for heating and cooling applications and power generation. Thermal energy storage systems are particularly used in low temperature and high-temperature applications such as building and power generation. In the application, generally, half of total energy consumption that used for a living is thermal energy and the demand for which may vary in different time of days. Therefore, the utilization of thermal energy storage will possible to help to balance the energy demand and supply on a daily even seasonal basis applications. They also can improve the energy efficiency by reducing peak demand, energy consumption, CO₂ emissions and costs of energy systems. Furthermore, the conversion and storage of thermal energy as a variable renewable energy also would help to increase the share of renewables in the total energy supply. The development of thermal energy storage now is highlighted for power generation systems in applications of concentrating solar power (CSP) plants by utilized the solar heat for electricity production when sunlight is not available (IEA-ETSAP & IRENA, 2013).

Thermal energy storage (TES) commonly divided into three types in different applications, namely: 1) sensible heat storage which is absorbed and release the heat by using a liquid or solid storage medium (e.g. water, sand, molten salts, rocks); 2) latent
heat storage, absorb and store the heat by using thermal energy storage medium or known as phase change materials (PCMs); 3) thermochemical storage (TCS) that store and release the thermal by using chemical reactions as a medium (IEA-ETSAP & IRENA, 2013).

In economic feasibility aspect, the sensible heat storage medium relatively serves an inexpensive cost compared to latent heat storage and thermos-chemical storage mediums as well as it is applicable to domestic heating systems and industrial needs (IEA-ETSAP & IRENA, 2013). However, the sensible heat storage medium have a problem with a low energy density that makes them requires large volumes approximately three and five times compared to latent heat storage and thermos-chemical mediums to store a same amount of energy, respectively. Furthermore, a sensible heat storage systems come with an appropriate design to able discharge thermal energy at constant temperatures. In general, latent heat storage medium or phase change material (PCM) and thermos-chemical storage (TCS) systems are more costly than sensible heat systems and are economically feasible for systems with a large number of cycles application (IEA-ETSAP & IRENA, 2013).

A latent heat thermal energy storage (LHTES) systems can be applied either in low and high temperature as distributed and centralized systems, respectively. The LHTES distributed system mostly used in domestic heating and cooling application by capturing the solar thermal and using it for water and space heating or cooling. Furthermore, The LHTES centralized systems use to be designed for district heating or cooling, large industrial plants, combined heat and power plants, or in renewable power plants known as centralizing solar power (CSP) plants. In both cases, LHTES systems may reduce energy demand at peak times (IEA-ETSAP & IRENA, 2013). An LHTES system’s economic feature performance depends essentially on its particular application and
operational needs, including the lifetime of the systems. Developers in Germany, Slovenia, Japan, Russia and the Netherlands are working actively on new materials and techniques for all LHTES systems, including their integration into building walls (e.g. by encapsulating phase change materials into plaster or air vents) and transportation of thermal energy from one place to another (IEA-ETSAP & IRENA, 2013). These new applications are now being commercialized, even though their cost, performance, and reliability have yet to be verified.

Research and development of new storage materials for thermal energy storage (TES) integration in buildings, industrial application, and variable renewable power generation are essential to foster its commercial deployment and mass adoption. In this study, we develop the thermal storage materials in the form of a fatty acid based phase change materials (PCMs) for domestic water heating applications.

1.4 Research objectives

The overall objective of this study is to develop a phase change materials (PCMs) suitable for the thermal energy storage in solar water heating applications. The PCM developed in this work should have an appropriate phase transition temperature within the range 40-45 °C, high amount of latent heat of fusion and thermal conductivity, have a long life stability, and compatible with other construction materials. To achieve this, the following detailed objectives are addressed:

1. To prepare the eutectic phase change material (PCM) and to study the effect of surfactants on the thermal properties of eutectic PCM.

2. To investigate the thermal reliability of prepared eutectic PCMs subjected to a large number of thermal cycles.
3. To enhance the thermal conductivity of the prepared eutectic PCMs by impregnation of high conductive materials to form a eutectic composite phase change material (CPCMs).

4. To measure of the compatibility of the CPCMs with metallic container materials to evaluate weight losses and corrosion rate of the metal.

1.5 Scope of the research

Latent heat thermal energy storage (LHTES) system development should include three basic components: (a) a thermal storage material to absorb and release the heat, (b) a container for holding the storage materials and (c) a heat collector to transfer the heat from heat source to PCM. Figure in Appendix A.1 shows the scope of development of an LHTES system that can be divided into two areas, which are material investigation and heat exchanger development. For this study, the scope of work is limited to the investigation on the appropriate phase change material (PCM) suitable for use in an LHTES in domestic water heating applications.
References