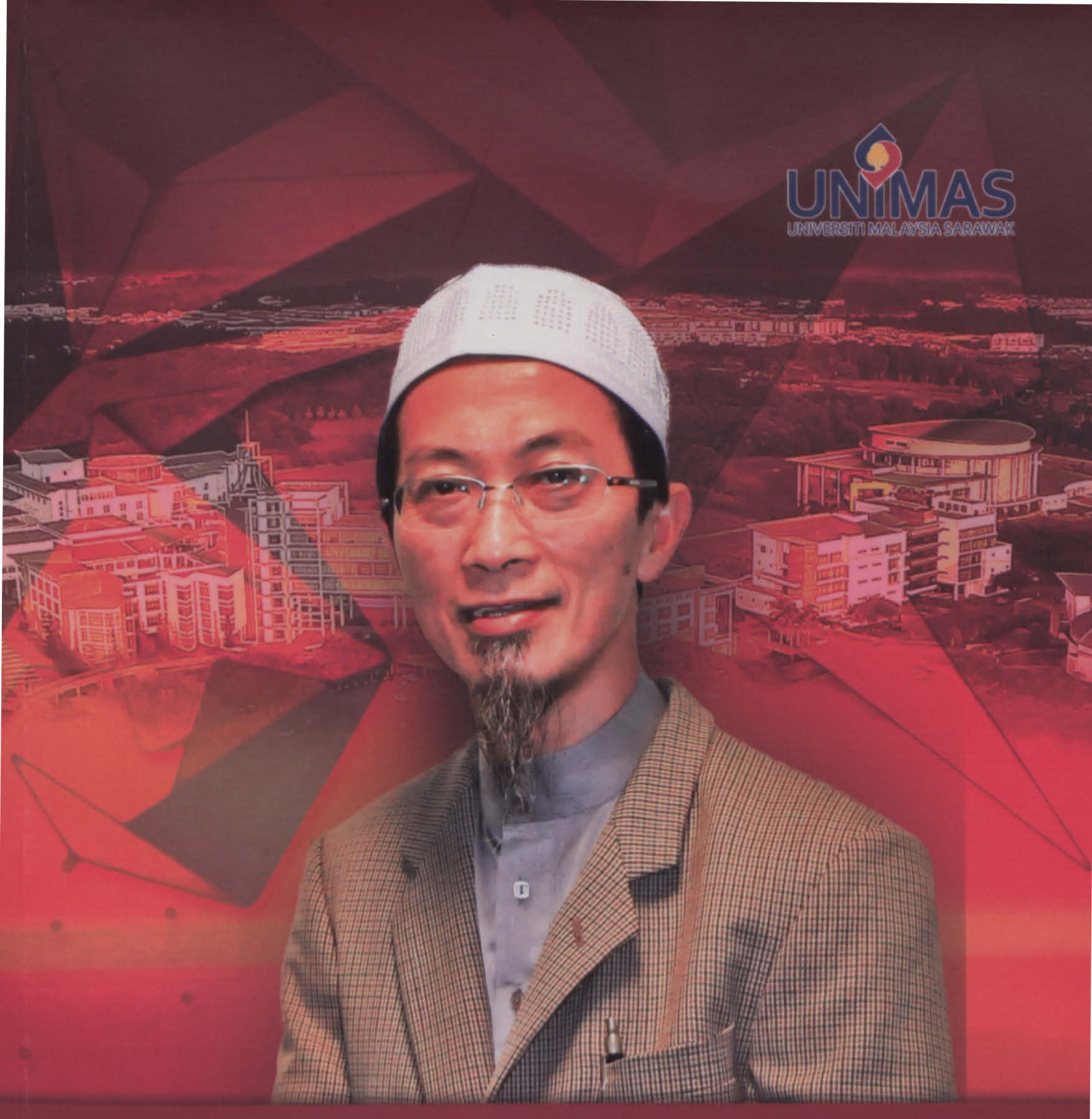

Inaugural Lecture

Applied Energy and Environment: Past, Present and the Near Future

DR MOHAMMAD OMAR ABDULLAH

Applied Energy and Environment: Past, Present and the Near Future

Applied Energy and Environment: Past, Present and the Near Future

Mohammad Omar Abdullah

Universiti Malaysia Sarawak
Kota Samarahan, Sarawak

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Introduction

PROFESSOR DR MOHAMMAD OMAR ABDULLAH

Mohammad Omar Abdullah is a Professor in Applied Energy at the Faculty of Engineering, Universiti Malaysia Sarawak, UNIMAS from 2014 until present.

The beginning of his academic accomplishments can be traced back to his admittance into UTM Kuala Lumpur to pursue a five-year Petroleum and Natural Gas Engineering course in the Department of Petroleum Engineering, *Fakulti Kejuruteraan Kimia dan Sumber Asli* (FKKKSA) from 1984 till 1989. He graduated with a degree in B.Eng. (Hons) (Petroleum and Natural Gas Engineering) in 1989. He pursued his Master studies under the supervision of Dr. Abu Azam (now Dato' Professor Dr Abu Azam) and Encik Azmi Khamis (now Professor Dr Azmi Khamis). He earned his degree in MSc (by research) (Petroleum & Natural Gas Engineering) from UTM in 1992, with a thesis entitled *Study of using palm methyl ester as continuous phase in oil based mud drilling* (in Malay). Employed as a Research Assistant while he was conducting research in UTM has build his repute as an established researcher. In 1994, UNIMAS welcomed Mohammad Omar Abdullah as an academic staff and he was among the pioneers who have helped to set up both the Mechanical and Chemical Engineering Programmes, including designing the curriculum for Energy. He graduated with a PhD degree in the field of Environment Engineering (Energy) in 2002 at University of Hertfordshire (UH), United Kingdom under the supervision of Professor Emeritus F.S Bhinder while both Dr. Sarim Al-Zubaidi and Dr Naseer as his co-supervisors. All his studies are essentially geared towards Energy, or more precisely in the field of Energy from fossil fuels (petroleum and natural gas engineering) and alternative energy, as well as environment pollution and controls.

Mohammad Omar Abdullah was the founding Head of Energy Research Group (ERG) at the Faculty of Engineering, UNIMAS in 2005. His team was assigned with the responsibility of setting up a new department, which is the Department of Chemical Engineering and Energy Sustainability (ChemES) and he was named the first Head of Department effective July 2006.

His niche as an academician and researcher is indicated by his enormous contribution in the industrial-related research activities.

He was able to secure more than 10 research grants (local and international) and consultancy projects. To date, he has published more than 14 articles in high impact ISI-indexed journals (with cumulative impact factor of journals published > 51.93) as well as other around 50 research articles in the international and national journals and proceedings. These include high-impact reputable energy engineering journals such as Applied Energy, *Renewable and Sustainable Energy Review*, *Journal of Power Sources*, *Energy* *and Fuel, Energy, ASHRAE HVAC&R Research,* and *International Journal of Thermal Science.* He also published professional technical journals such as *Applied Engineering in Agriculture* (published by American Society of Agricultural and Biological Engineers (ASABE)), *Corrosion* (published by National Association of Corrosion Engineers (NACE), USA), Society of Petroleum Engineers (SPE) Technical Paper (USA), and *IEM Journal* (published by the Institution of Engineers, Malaysia). Some of his works have been widely acknowledged where the editors (local and abroad) invited him to become a board member of editors and journal reviewers to conduct evaluations on technical papers related to his field. He is also the editor-in-chief for a special edition on Energy in the International Journal of Research & Review in Applied Science.

Apart from journals, Mohammad Omar Abdullah has published more than two books. One of the books is entitled "Applied Energy: An Introduction", published by an international publisher based in California, USA, i.e. CRC Press in 2013. The book has been extensively cited.

Through the running of research projects under his supervision, 13 postgraduate students by research are currently being trained: two doctorate (PhD) and seven Master (by Research) students have graduated; a candidate has submitted his thesis and is now nearing completion. Currently, three students are pursuing their PhD studies in the field of Energy: biodiesel synthesis from CaO derived from ostrich egg shell coupled with emulsion study, hybrid microbial fuel cell – activated carbon adsorption study, and comprehensive energy, Sarawak Corridor of Renewable Energy (SCORE) framework study, respectively.

Mohammad Omar Abdullah had filed three (3) patents, a patent on the construction of an exhaust-driven "bio-compressor" for air-conditioning of vehicles; the second invention is the construction of a space- and energy-saving portable slicing machine; and the third invention is a hybrid adsorption-thermoelectric cooling system powered by solar energy. The patent on the "bio-compressor" had been fully granted with MY status i.e. after initial PI status.

During the annual appraisal exercise, his overall performance has been always assessed as excellence and was awarded the Excellence Service Award twice. He also acquired various research awards such as highest impact paper awards and best book awards. He was one of the eBario groups that won the Gold Medal of the Commonwealth Association of Public Administration and Management (CAPAM) International Innovations Awards in Sydney, Australia in October 2006.

Mohammad Omar Abdullah is also active in many educational activities. He served as one of the members of Board of Studies and the Industrial Advisory Panel, Faculty of Petroleum and Renewable Energy Engineering (FPREE), Universiti Teknologi Malaysia (UTM) (2008-2012). He was also a member of the Malaysian Public Universities (IPTA) Engineering Apparatus Auditing Group in Year 2009.

Nationally, he was a member of the Panel Audit for the IPTA Post-graduate Audit Programme. He went to UTM Skudai on 25- 26 September 2013, UTM and contributed in an audit exercise there, in particular for the FPREE faculty. He serves on the board of advisors for a number of national/international conferences.

He is a member of the American Chemical Society (ACS), American Society of Heat, Refrigerating and Air-conditioning Engineers (ASHRAE), and Member of CEng (IMechE) of UK. On top of these prestigious memberships, he had been awarded and appointed as a Senior Member of the Academy of Malaysian SMEs (S.M.A.M.S) in March 2009 during the IKS2009 Presentation and Exhibition in PWTC, Kuala Lumpur (he was one of two invited speakers).

Born in 1964 to the late YB Mak Yau Lim and Mary Wong Ah Siew in the District of Sundar, Lawas, Sarawak; Mohammad Omar Abdullah had his early education in a Chinese school - Soon Hwa School (老越顺华华文小学) in the same district. He continued his secondary education at Sekolah Menengah Kerajaan Lawas (SMK Lawas), Lawas from Form 1 till Form 3. His academic excellence prompted an entrance into Kolej Tun Haji Bujang, Miri where he completed the rest of his secondary education from 1983 to 1984[1]. As the second youngest, he grew up alongside three sisters and four elder brothers.

Apart from academic related activities, Mohammad Omar Abdullah is a devoted Muslim. He plays a significant role in contributing to religious and dakwah activities. He believes in rectifying oneself through giving back to the community. As the founder and Chair of a non-for-profit Madrasah i.e. an Islamic higher institution, namely the Darul-Uloom Falah-e-Darain BDC, Kuching, Sarawak (it was established in 2013 and JAIS certified) he aspires for the school to benefit the community (in particular children aged 10 years old and above) by the learning of Quran and promoting Islamic knowledge

1 He was drawn to Islamic practice and converted to Islam during his last year in college before furthering studies in UTM, Kuala Lumpur. He decided on Mohammad Omar Abdullah as his Islamic name. At times he uses both his Chinese name i.e. Mak Khoon Ling and Muslim name. For paper publication purposes however, he opted to use Mohammad Omar Abdullah or simply M.O.Abdullah or Abdullah, M.O.

and the practice of noble attributes as shown by Prophet Muhammad Sallallahu Alaihi Wasallam (SAW).

Mohammad Omar Abdullah is married to Dr Samirah Abdullah @ Sim Sai Peng 12 years ago and the couple is blessed with four beautiful children namely Yusuf, Mohammad Ilyas, Hafsah and Mohammad Musa aged of 11, 8, 6 and 4.

PROFESSIONAL LECTURE SERIES (INAUGURAL LECTURE)

Applied Energy and Environment: Past, Present and the Near Future

By

Prof Dr Hj Mohammad Omar Abdullah @ Mak Khoon Ling

Professor of Applied Energy

1 Introduction

Applied Energy refers to any energy conversion when applied to energy systems (Figure 1). It refers primarily to our daily domestic and industrial energy usage and applications in various areas of energy conversion and conservation, energy resources, energy processes, energy storage, safety, and transport, environmental energy pollutants, and sustainable energy systems, as well as techno-economics, energy innovation (Abdullah, 2013).

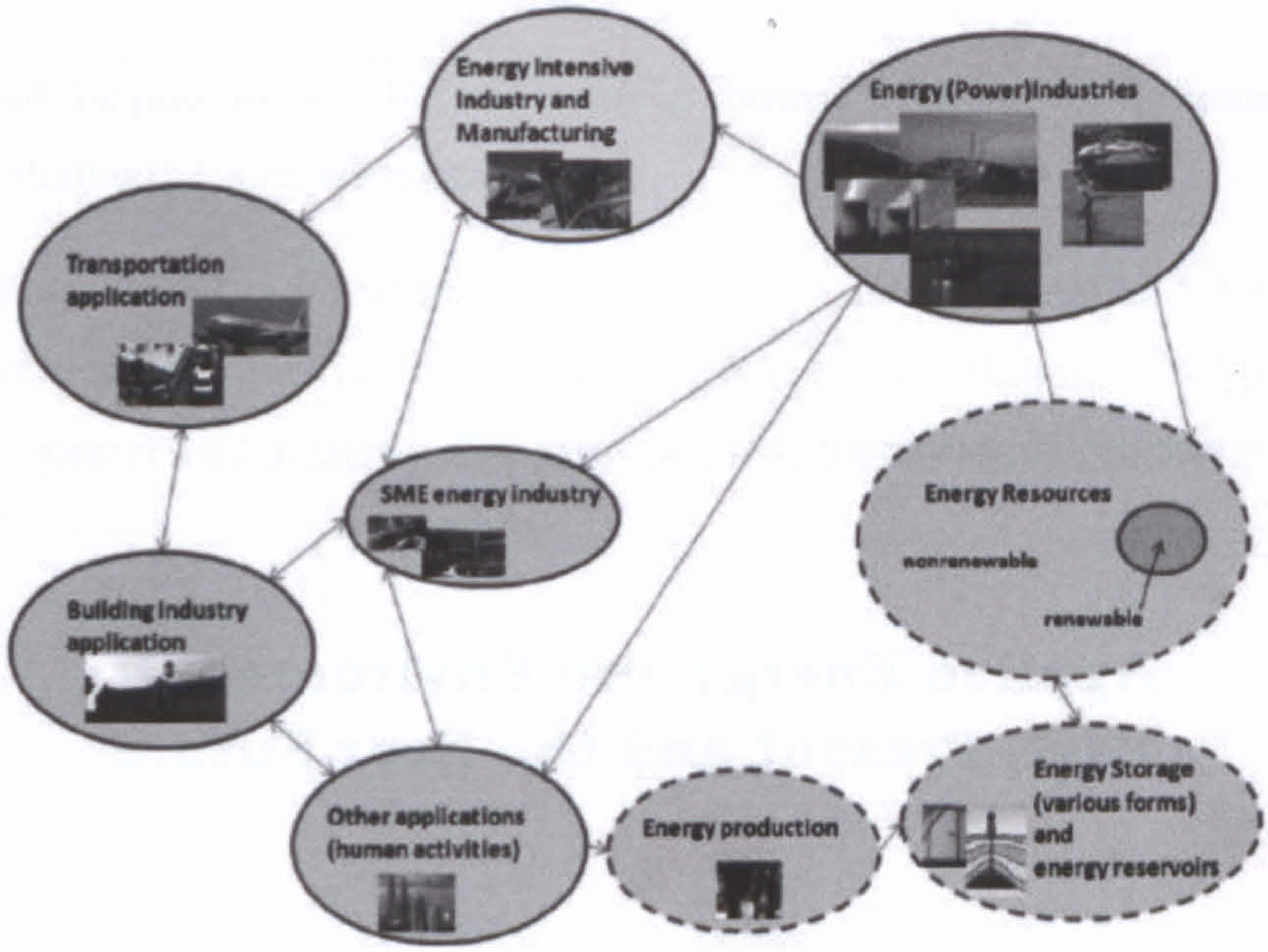

Figure 1 Applied Energy Study Diagram (Adopted from *Abdullah, M.O., 2013, Applied Energy: an introduction, CRC Press, Boca Raton, New York* pp. 2).

1.1 Energy Industry, energy power industry and Energy Intensive Industries

The energy industry can be classified into three main categories i.e. production of primary energy; conversion of energy and application, and generation & supply of electrical energy, which in turn comprises the following six main industry categories (Figure 2 (a)):

(1) Energy power industry;

(2) Electrical power industry;

(3) Energy-intensive industry;

(4) Small and medium enterprise (SME) energy-related industry;

(5) Building industry; and

(6) Transport industry.

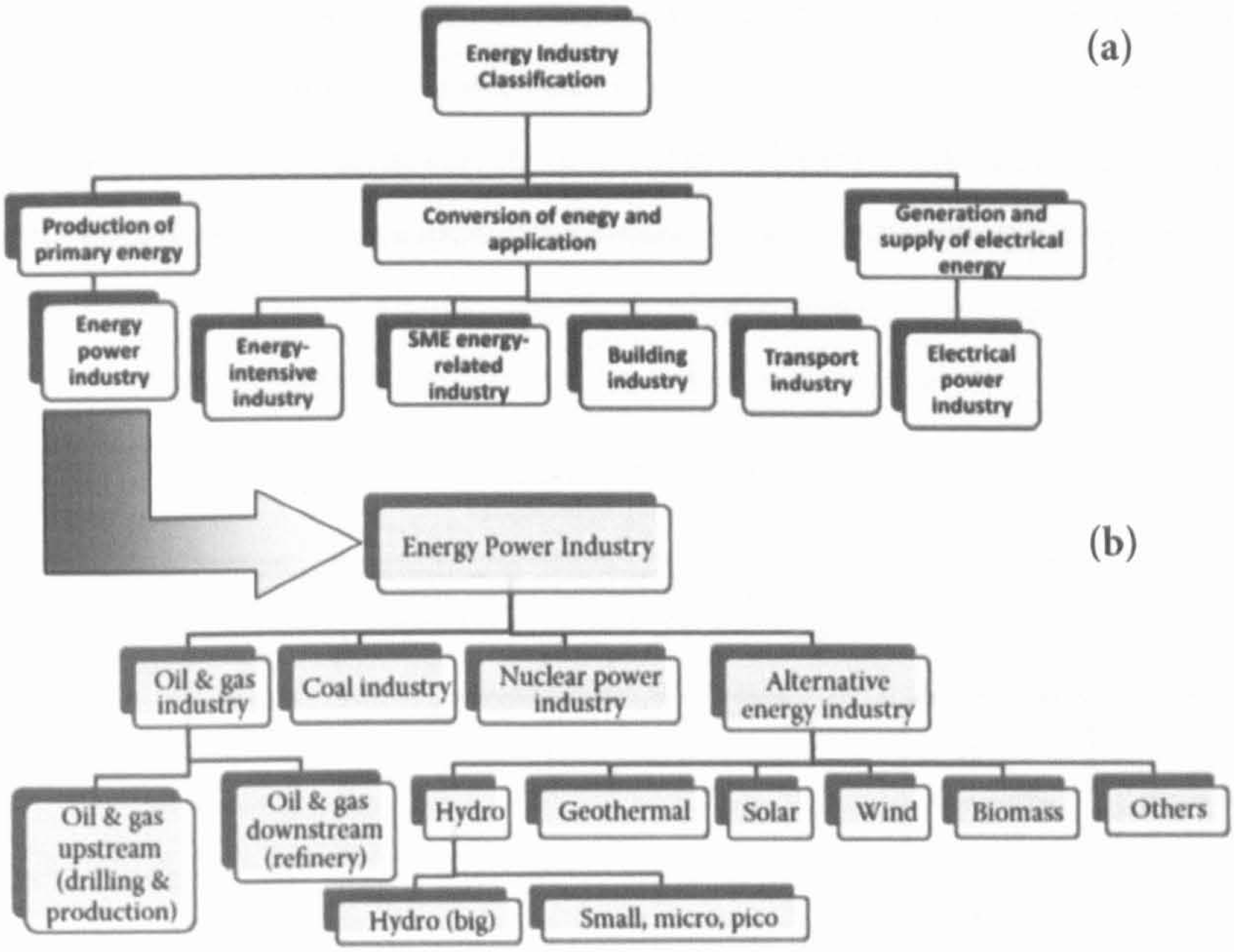

Figure 2 (a) Energy Industry; and (b) energy power industry classification (Adopted from *Abdullah, M.O., 2013, Applied Energy: an introduction, CRC Press, Boca Raton, New York* pp. 2).

Now, the energy power industry can be defined as the industries involved in the production of primary energy including fuel mining, extraction, and fuel refining. The energy power industry is one of the most crucial parts of the

energy infrastructure, which acts to retrieve useful fuels available in our Earth. Energy power industry comprises the following four main categories of industries (Figure 2 (b)):

(1) Oil and gas industry;
(2) Coal industry;
(3) Nuclear power industry; and
(4) Alternative/renewable energy industry.

Energy-intensive industries (Figure 3) are the industries that use large amounts of energy to transform energy processes or materials for our everyday use. Collectively, and depending on the countries, they supply 60–90% of the energy processes and materials vital to our world economy and applications.

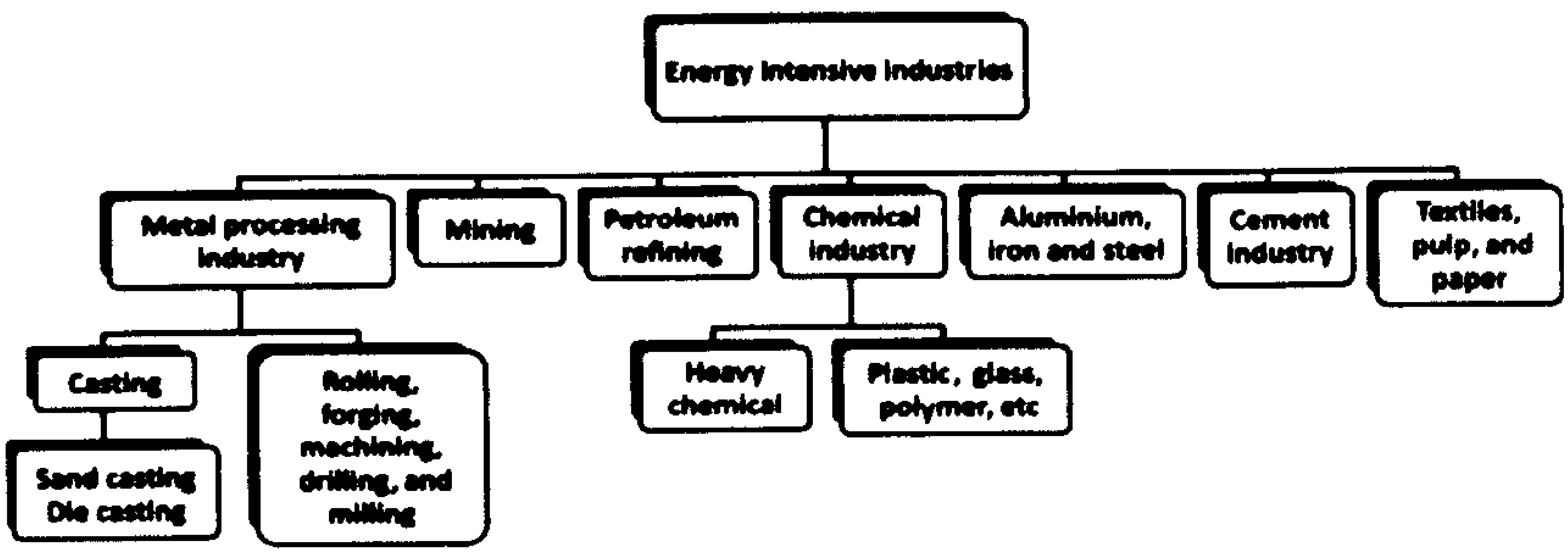

Figure 3 Energy Intensive Industry (Adopted from *Abdullah, M.O., 2013, Applied Energy: an introduction, CRC Press, Boca Raton, New York* page 42).

1.2 Renewable (alternative) energy

Alternative or renewable energy sources include biomass, geothermal energy, hydro power, solar energy, ocean energy, and wind energy (see Figure 2b). The term "alternative" energy is preferred by some as energy cannot actually be "renewed" but converted from one form to another. They are called renewable because they can be replenished or regenerated in a short time. We use renewable energy sources mainly to make electricity and provide thermal heat as well as for other energy applications (Abdullah, 2013).

Renewable energy in Sarawak

Since the adoption of Sarawak Corridor of Renewable Energy (SCORE) as one of the five economic corridors in Malaysia, our Sarawak State is very fortunate to adopt the large-scale renewable energy scheme in which the regional development plan was embarking since 2009; today SCORE has progressed from a rural to a modern, progressive and energy based industrialised sector (see Sarawak SCORE, 2015). It is embarking in terms of infrastructure and capacity building and to cater for investment requirements by multi-national investment entitles.

SCORE is a huge Corridor which covers an area of more than 70,000 square kilometres in the strategic aligned central region with a population of more than 600,000. Besides, SCORE has a long coastline of more than 1,000 km, over 8 million hectares of forests, almost 5 million hectares of different categories of land, making it ideal for various investment activities (Sarawak SCORE, 2015). SCORE related areas are rich in its renewable energy resource, came as the right time and as a significant grow engine in Sarawak in view of the depleting of other existing energy resources such as timber, oil, gas and coal. The main selling points of SCORE is its abundance of energy resources, including clean and safe renewable energy resources, in particular hydropower, that can offers commercial users clean energy at competitive rates thus techno-economical potential! This is crucial to cater for high energy-based industrial activities which have intensified over the last few years, ranging from Manganese processing, Aluminium smelting, silicone substrate manufacturing, and so forth.

As more energy intensive industries establish themselves in SCORE, they will form the bedrock of the SCORE strategy, which in turn will require training centres and technical colleges to train the population and create a core of skilled workers thereby raising the living standards of the population. This is in line with the 5 thrusts of the national mission and the key tenets of the State's ninth Malaysia plan.

To achieve this, it is timely for the University to actively participate in the State's agenda as described above by creating courses and research programmes relevance to the SCORE development. It is hoped that there will be collaboration between knowledge producers (academic/research institution such as UNIMAS) and knowledge users (industry players in SCORE) initiated to compliment State's efforts in SCORE development.

It would bring positive effects for both parties particularly on the innovation and competitiveness of energy resources and ultimately affects the sustainable growth of the Corridor. Bridging research institution and SCORE industry activities is utmost important, among the benefits that can be tapped are (adopted from Sarawak SCORE, 2015):

- Win-win situation for academia-industry co-operation through access to external support facilities, technology transfer, company spin off and so forth;
- Awareness raising on the importance of building R&D program as a supportive tools of industry innovation; and

- Building capacities and competencies in managing energy resource and its utilisation.

In the next sub-section, hybrid energy is introduced and discussed briefly.

1.3 Hybrid energy

A hybrid energy system usually consists of two or more energy sources used together, via suitable energy conversion techniques, to provide enhanced fuel savings or energy recovery, increased overall system efficiency, as well as accomplishing greater balance in energy supply and demand (Abdullah 2013).

Various hybrid energy application schemes can be essentially classified into the following five main energy application categories (Abdullah (2013) pp. 327):

(1) Energy intensive industries: hybrid geothermal/fossil, hybrid nuclear-fossil fuel, integrated gasification combined-cycle (IGCC), hybrid fuel cell/turbine (FCT) systems.

(2) SME industries energy applications (SME small/micro-scale hybrid energy systems).

(3) Transportation industries (automotive hybrid electric vehicles or HEVs).

(4) Building industries (building integrated PV or BIPV system).

(5) Hybrid energy for rural applications (hybrid wind/solar/ micro-hydro/fuel cell/diesel energy).

Figure 4 is a summary of some hybrid energy systems outlined by Energy Efficiency and Renewable Energy for a number of hybrid technologies together with their application range and application priority. Microturbine hybrids, for instance, are suitable and opted for commercial, industrial, and grid-distributed power; reciprocating engine hybrids can extend the applications for portable power and transportation usages. The renewable hybrids (PV-, wind-, and biomass-hybrids) would be targeted for grid-distributed applications; PV-hybrids would also have the added advantages for residential and building applications, e.g., Building-integrated photovoltaic (BIPV).

● Primary Target Market
○ Secondary Target Market

	Residential	Commercial	Industrial	Grid-distributed	Portable Power	Transportation	Typical Unit Size Range (installation size can be larger)
Microturbines		●	●	●	○	○	25 - 300 kW
Reciprocating Engines		●	●	●	●	●	5 kW - 50 MW
Low-Temperature Fuel Cells	●	●	○	●	○	●	2 - 250 kW
High-Temperature Fuel Cells		●	●	●	○		100 kW - 3 MW
Fuel Cell/Gas Turbine Hybrids		○	○	●			250 kW - 20 MW
Small Gas Turbines			●	●			500 kW - 5 MW
Photovoltaics	●	○	○	●			1 - 500 kW
Wind Power	○			●			50 kW - 2 MW
Biomass Power			●	●			250 kW - 50 MW

Figure 4 Various Hybrid Energy Technologies together with their application range and application priority (Adapted from Energy Efficiency and Renewable Energy (2011))

1.3.1 Energy Performance Curve for Hybrid Systems

The Energy Performance Equation[1] for a hybrid energy system is given by Equation (1).

$$E_I = E_I^o + \frac{E_O}{\varepsilon^o \left(1 - \frac{E_O}{E_{O,\max}}\right)} \quad (1)$$

Where, E_I = energy input, kWh; E_o = useful output, kWh; e = net energy input efficiency, dimensionless.

The associated Energy Performance Curves, in terms of energy input vs. useful energy output, can then be represented by Figure 5.

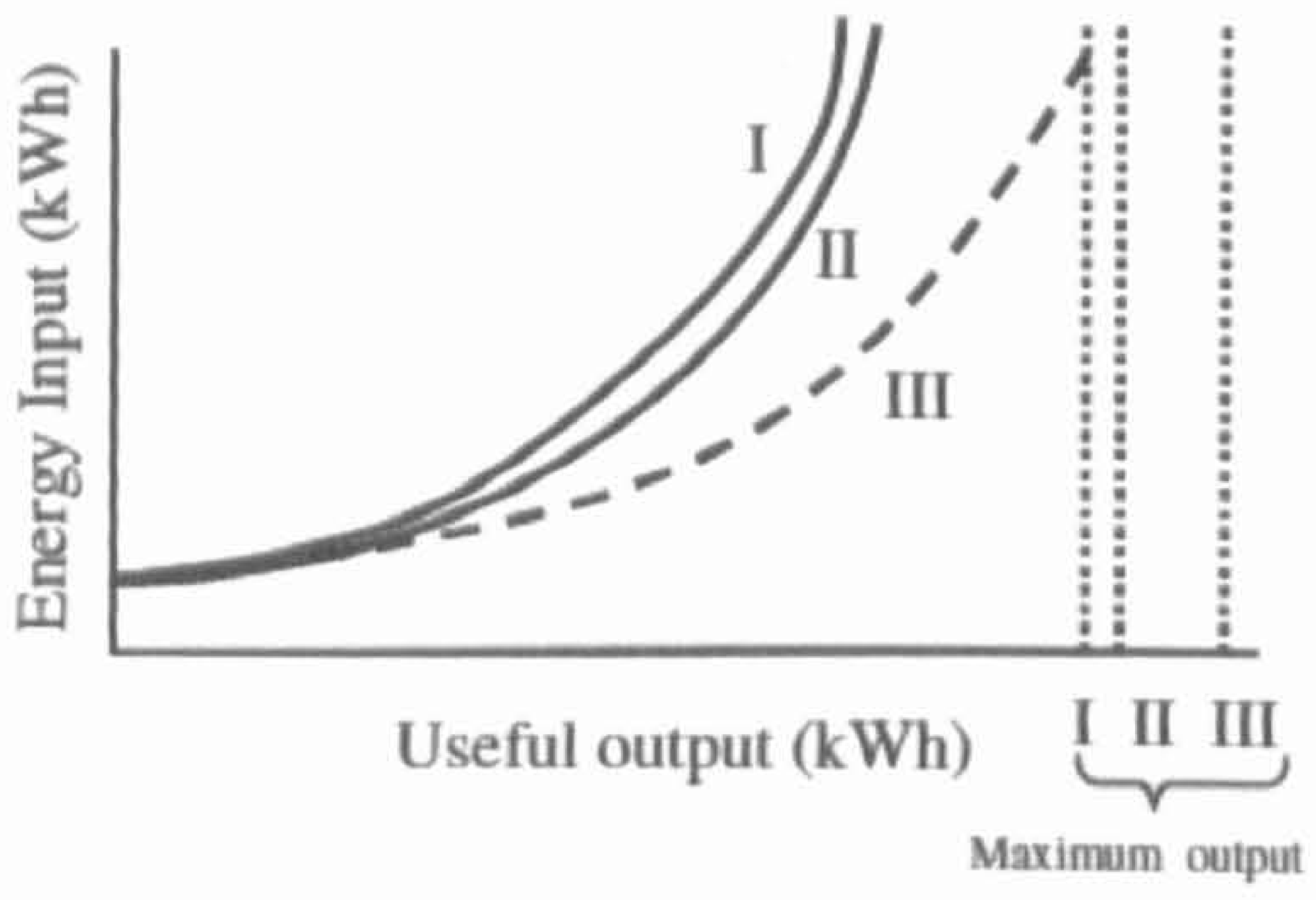

Figure 5 The Energy Performance Curves.

Source: Abdullah (2013)

The dashed lines (indicating maximum energy output) as shown in Figure 5 are all *dynamic* lines. The curves showed that the useful output of the hybrid energy system could be well improved by utilizing more combined total energy inputs.

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1 Adopted from Abdullah et al. (2010) and Abdullah (2013):

A typical example shows that the Hydro/PV scheme (II) has higher maximum output compared with the PV stand-alone (I); Likewise, the combined hydro/PV/fuel cell scheme (III) would be the most promising scheme, superior to both (I) and (II) schemes.

1.4 Energy Management and analysis

Energy management and analysis is one of the most important topics in applied energy. It covers all the energy management tools, such as energy audits and energy life-cycle analysis. This relates to the total environmental aspects of energy applications - which include energy pollutants, energy safety, control, and the impacts associated with energy applications. Of primary importance also are the various energy policies and planning for our future energy sustainability and promoting clean energy.

2 Refrigerating and air-conditioning research at UNIMAS

A lot of research works have been done in UNIMAS in relation to energy efficiency and energy consumption in buildings, refrigerators, for innovative automobile applications, etc.

2.1 Refrigerating and techno-economical study

A comparative analysis of performance and techno-economics for a H_2O–NH_3–H_2 absorption refrigerator driven by different energy sources had been reported by Abdullah and Tang (2010).

Results obtained have shown that performance of various components under different type of energy sources is almost coherent. For the evaporator, the system with electric supply has shorter starting time, around 6 min earlier than the system run with LPG. Meanwhile, the system powered by LPG produced a lower cooling temperature around - 9°C, compared to the system run with electric which produced temperature at around -7°C. Different energy sources attempted to influence various components to some but almost coherent behavior (e.g. see Figure 6) . Overall, the experiments have shown similar COP values (quite consistent) at a range of 0.75–0.8 under different energy sources. Thus, emphasis is put on the application of the absorption system, and on the transient behavior and cost of operations.

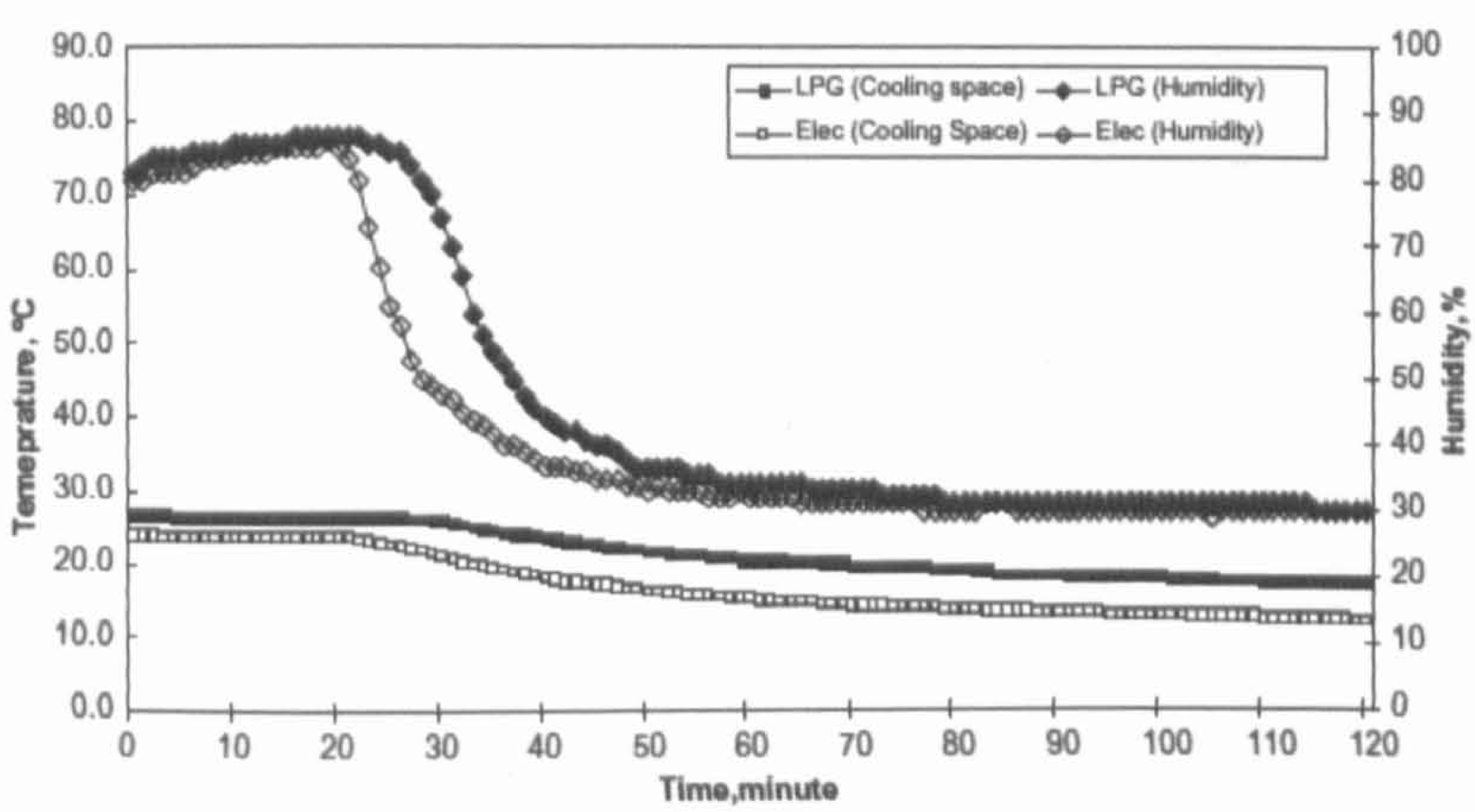

Figure 6 The comparison of LPG and electric (temperature of cooling space and humidity). *Source*: Abdullah and Tang (2010)

From the techno-economical analyzes, we found that the conventional electric from grid is still the best form of energy source for short-term