LAPORAN AKHIR PENELITIAN TAHUN TUNGGAL

ID Proposal: 2d1b56aa-b13c-43c6-8156-3271f847d095
Laporan Akhir Penelitian: tahun ke-2 dari 2 tahun

1. IDENTITAS PENELITIAN

A. JUDUL PENELITIAN

SUSTAINABLE ENERGY TECHNOLOGIES TO IMPROVE FOOD SECURITY AND SUSTAINABILITY OF FOOD CHAINS IN INDONESIA

B. BIDANG, TEMA, TOPIK, DAN RUMPUN BIDANG ILMU

Bidang Fokus RIRN / Bidang Unggulan Perguruan Tinggi	Tema	Topik (jika ada)	Rumpun Bidang Ilmu
Energi	Teknologi Konservasi Energi	Teknologi hybrid dalam pemanfaatan sumber energi terbarukan	Teknik Refrigerasi

C. KATEGORI, SKEMA, SBK, TARGET TKT DAN LAMA PENELITIAN

Kategori (Kompetitif Nasional/ Desentralisasi/ Penugasan)	Skema Penelitian	Strata (Dasar/ Terapan/ Pengembangan)	SBK (Dasar, Terapan, Pengembangan)	Target Akhir TKT	Lama Penelitian (Tahun)
Penelitian Kompetitif Nasional	Penelitian Dasar	SBK Riset Dasar	SBK Riset Dasar	3	2

2. IDENTITAS PENGUSUL

Nama, Peran	Perguruan Tinggi/ Institusi	Program Studi/ Bagian	Bidang Tugas	ID Sinta	H-Index
I NYOMAN SUAMIR Ketua Pengusul	Politeknik Negeri Bali	Teknik Pendingin Dan Tata Udara		5979082	3
Dr Dr, I GUSTI AGUNG BAGUS WIRAJATI, ST, M.Eng S.T, M.T Anggota Pengusul 2	Politeknik Negeri Bali	Teknik Pendingin Dan Tata Udara	1) Review the current state of refrigerated storage, estimate the appropriate capacity and estimate the future demand of such facility; 2) Build a numerical model for analysing of the prediction of the	5986839	1

			future demand of refrigerated storages in Indonesia and for evaluating their energy consumption (EES model); 3) Data processing, analysis and reporting; 4) Publication through international journals and conferences		
I DEWA MADE CIPTA SANTOSA Dr.Phil Anggota Pengusul 1	Politeknik Negeri Bali	Teknik Pendingin Dan Tata Udara	1) Review the energy system apply in Indonesian food chain; 2) Investigate environmental impact and economic viability of the proposed energy system; 3) Data processing and analysis; 4) Reporting and publications	5976647	4

3. MITRA KERJASAMA PENELITIAN (JIKA ADA)

Pelaksanaan penelitian dapat melibatkan mitra kerjasama, yaitu mitra kerjasama dalam melaksanakan penelitian, mitra sebagai calon pengguna hasil penelitian, atau mitra investor

Mitra	Nama Mitra
Mitra Pelaksana Penelitian	Prof. Savvas Tassou

4. LUARAN DAN TARGET CAPAIAN

Luaran Wajib

Tahun Luaran	Jenis Luaran	Status target capaian (*accepted, published, terdaftar atau granted, atau status lainnya*)	Keterangan (*url dan nama jurnal, penerbit, url paten, keterangan sejenis lainnya*)
2	Publikasi Ilmiah Jurnal Internasional	accepted/published	International Journal of Refrigeration

Luaran Tambahan

Tahun Luaran	Jenis Luaran	Status target capaian (*accepted, published, terdaftar atau granted, atau status lainnya*)	Keterangan (*url dan nama jurnal, penerbit, url paten, keterangan sejenis lainnya*)
2	Prosiding dalam pertemuan ilmiah Internasional	sudah terbit/sudah dilaksanakan	International Join Conference on Science and Technology
2	Model	penerapan	-

5. ANGGARAN

Rencana anggaran biaya penelitian mengacu pada PMK yang berlaku dengan besaran minimum dan maksimum sebagaimana diatur pada buku Panduan Penelitian dan Pengabdian kepada Masyarakat Edisi 12.

Total RAB 2 Tahun Rp. 115,342,500

Tahun 1 Total Rp. 0

Tahun 2 Total Rp. 115,342,500

Jenis Pembelanjaan	Item	Satuan	Vol.	Biaya Satuan	Total
Analisis Data	Tiket	OK (kali)	1	3,200,000	3,200,000
Analisis Data	Penginapan	OH	3	800,000	2,400,000
Analisis Data	Biaya konsumsi rapat	OH	192	40,000	7,680,000
Bahan	ATK	Paket	1	1,581,000	1,581,000
Pelaporan, Luaran Wajib, dan Luaran Tambahan	Publikasi artikel di Jurnal Internasional	Paket	1	17,500,000	17,500,000
Pelaporan, Luaran Wajib, dan Luaran Tambahan	Biaya seminar internasional	Paket	2	3,500,000	7,000,000
Pengumpulan Data	Tiket	OK (kali)	1	18,200,000	18,200,000
Pengumpulan Data	Uang Harian	OH	12	4,815,125	57,781,500

6. KEMAJUAN PENELITIAN

A. RINGKASAN: Tuliskan secara ringkas latar belakang penelitian, tujuan dan tahapan metode penelitian, luaran yang ditargetkan, serta uraian TKT penelitian.

Introduction Indonesia is an agriculture country with population number of 258.5 million. Poultry, beef and veal production are anticipated to increase 3 to 5 percent annually through 2020, while consumption is expected to rise 4 to 6 percent annually [1]. The country has experienced unbalanced food supply and demand which may need to be well-adjusted through import policy. As an example, beef supply of the country in 2016 was estimated 348,020 tons, while the demand was 651,420 tons [2]. Furthermore, FAO [3] stated that Indonesia is the second highest producers of fishery and aquaculture products in the world. In 2016, the production reached 23.03 million tons which 27.6% came from marine fisheries and 72.4% from aquaculture [4]. Additionally, Indonesian territory consists of 2/3 of water, has given enormous benefits for Indonesia, especially fishermen. It is certainly need the support of the existence of various fishery facilities, one of which is cold storage [5]. With respect to environmental aspect, global trend of increasing consumption of food products has an increase impact on greenhouse gas emissions (GHG) due to energy consumption. It is estimated that for Western Europe the food industry is responsible for between 20% and 30% of GHG emissions [6]. A major source of emissions is energy use by manufacturing processes, food distribution and retail. In Indonesia, the government is committed to reduce GHG emissions by 26% (on the own) and by 41% (with international support) from emission baseline level in 2020. GHG emissions of the commercial sector was estimated for about 0.7% (accounted for 3.8 MtCO2-e) of the country’s emissions of 540 MtCO2-e [7]. Refrigeration technology is responsible for 15% of all electricity consumed worldwide [8] and approximately 72% of

the global warming impact of refrigeration plant is due to energy consumption [9]. There is little information in the current state of cold chain infrastructure in Indonesia and future needs to meet local food production and food security aspirations. This research project is planned to meet this gap through in-depth studies and the development of a roadmap for the development of cold chain infrastructure in Indonesia. There are also research and development activities on the development of solar powered refrigeration systems for food cooling and preservation applications but activities in Indonesia are limited. The current project will contribute to the international effort through the numerical study of innovative integrated renewable energy technologies that: a) minimize thermal energy requirements of cold storage facilities through the employment of advanced insulation materials, such as vacuum insulation; b) development and use of vegetable based phase change material (bio-PCM) storage to enable operation during periods of low solar insolation and maximum demand on the grid; c) use of solar powered refrigeration systems that employ natural refrigerants; can be easily tailored to specific food product needs and applications. Refrigeration is important in food chain both maintaining the safety and quality of many foods and enabling food to be supplied from productions to consumers. Refrigeration has also a vital role to play in reducing post-harvest losses. Less than 10% of such perishable foodstuffs are in fact currently refrigerated and it is estimated that post-harvest losses currently account for 30% of total production [8]. IIR [10] reported that total global food production was 5500 million tons, at least 33% required refrigeration but only 7% were preserved through refrigeration; this results in huge losses. It is also demonstrated that greater amounts of refrigeration system and a high-performance cold chain equate with lower post-harvest losses. Indonesia as one of lower-middle income economies is in the burgeoning stages of retail and cold chain development. In 2016, the country has cold storage capacity of 12.3 million m3 with Cold Chain Competiveness Scorecard 4 out of 7 [1, 11]. Indonesia needs extensive investment for efficient cold chain systems. Refrigeration in the food chain is necessary for maintaining the quality and prolonging the shelf-life of fresh, frozen and perishable products after harvest, after fishing, during transportation, store, display and consumers. Refrigeration, however, consumes considerable amount of energy in the food chain. Within refrigerated storage facilities, for example, 60-70% of the electrical energy used is for refrigeration [12]. Tassou, et al. [13] reviewed the potential of alternative refrigeration technologies to reduce energy consumption in food refrigeration. Their review focused on seven systems which include: trigeneration, air cycle, sorption systems, thermoelectric, Stirling cycle, thermoacoustic and magnetic refrigeration. Optimization of cold storage for improving energy performance also reported by Kozak et al. [14] that experimentally and theoretically study of cold storage packages containing PCM. The arrangement could sustain the product cold longer through taking advantage of the PCM latent heat. Oró, et al. [15] also reported that the implementation of PCM in cold storage could reduce CO2 emissions by a range between 5% and 22%. While utilization of solar radiation to provide cooling can be as an alternative technology to reduce energy use in food chain. Application of solar energy in cold storage utilizes both solar thermal and photovoltaic system was reported by Basu and Ganguly [16]. Wang and Dennis [17] investigated energy performance of battery storage and PCM storage in a PV cooling system. Research Aims The principal aim of the project is to set the foundations for long term collaboration between the Bali State Polytechnic and Institute of Energy Futures in the UK to make contributions to the improvement of the integrity of the cold food chain in Indonesia. Specific objectives include: (i) Develop and demonstrate to proof of concept stage an innovative cold storage system with sustainable energy technology that

minimizes environmental impacts and easily adaptable to specific conditions and product requirements. (ii) Raise awareness of policymakers on the potential impacts of the project and technologies to ensure speedy adoption and implementation. Research Methods The methods used to perform the investigation comprise stages which include: (1) collect data and information through survey and literature review about the current capacity of cold storages and food chain in Indonesia; (2) evaluating the data and designing approaches to estimate proper capacity of the cold storages in the future to develop a security and sustainable food chain; (3) identification of requirements, needs and technology; (4) investigation on innovative cold storage technologies powered by solar energy which includes designing a new technology approach of cold storage through utilizing renewable energy, efficient and environmentally friendly refrigeration system, and bio-PCM for cold thermal storage; (5) analysis the influence of the sutainable technology; (6) publications and reporting. The research was conducted at Bali State Polytechnic and the Institute of Energy Futures Brunel University London within 2 years. Targeted Research Outcomes Proof of concept of an innovative cold storage system with sustainable energy technologies employing solar energy and integrated thermal energy storage using bio-based phase change materials (bio-PCMs) and natural refrigerants such as hydrocarbons to minimize or eliminate grid energy demand and greenhouse gas (GHG) emissions. At least 2 publications in high quality international journals and 2 international conference publications. Alternative high quality international journals are detailed as follows: • Applied Thermal Engineering, international journal, publisher: Elsevier Ltd, ISSN: 1359-4311, impact factor: 3,043, SJR: 1,718. • International Journal of Refrigeration, publisher: Elsevier Ltd, ISSN: 0140-7007, impact factor: 2.291, SJR: 1,421. • Journal of Energy Storage, publisher: Elsevier Ltd, ISSN: 2352-152X, impact factor: 3.517, SJR: 1.055. Research Outcomes Year-1: Publication on: International Journal of Energy Storage, 15, 2018, pp. 368-378. status: published; https://www.sciencedirect.com/science/article/pii/S2352152X17301706; a Q1 journal; Title: The role of vegetable oil in water based phase change materials for medium temperature refrigeration Additional achievements: 1. Design concept of one proposed technology solar cold storage integrated with bio-PCM for food chain in Indonesia; 2. IOP Conference Series: Materials Science and Engineering, Volume 494 Number 1 : 012017, 2019; status: published; title: ‘Experimental Study on the Influences of Air Flow in an Integral Hydrocarbon Display Cabinet to its Temperature and Energy Performances’. 3. IOP Conf. Series: Materials Science and Engineering 494, 1, 012034, 2019; status: published; title: ‘Study on Thermal Properties of Bio-PCM Candidates in Comparison with Propylene Glycol and Salt Based PCM for sub-Zero Energy Storage Applications’, 4. Energy Procedia, 161, pp. 198-206, 2019; status: published; title: ‘Development of Corn-Oil Ester and Water Mixture Phase Change Materials for Food Refrigeration Applications’. Year-2: One paper has been submitted for International Journal of Refrigeration (a Q1 journal); Another paper is being prepared for Applied Thermal Engineering, a Q1 journal (Scopus and Scimago indexing). Additional achievements year 2: 1. A prototype of solar cold storage integrated with bio-PCM for food chain in Indonesia; 2. One paper has been presented in an international conference (ICOME = International Conference on Mechanical Engineering) Yogyakarta. The paper will be published in Materials Science Forum a Q3 journal (Scopus and Scimago indexing); status: under review. 3. Two papers have been presented in International Conference on Science and Technology (ICST part of IJCST) in Surabaya. The papers will be published in Journal of Physics (IOP Science) Q3 journal ((Scopus and Scimago indexing); status: under review. 4. One paper has been being prepared for Journal of

Advanced Research in Fluid Mechanics and Thermal Sciences, a Q3 journal (Scopus and Scimago indexing).

B. KATA KUNCI: Tuliskan maksimal 5 kata kunci.

Food chain; cold storage; renewable energy; bio-PCM

Pengisian poin C sampai dengan poin H mengikuti template berikut dan tidak dibatasi jumlah kata atau halaman namun disarankan seringkas mungkin. Dilarang menghapus/memodifikasi template ataupun menghapus penjelasan di setiap poin.

C. HASIL PELAKSANAAN PENELITIAN: Tuliskan secara ringkas hasil pelaksanaan penelitian yang telah dicapai sesuai tahun pelaksanaan penelitian. Penyajian dapat berupa data, hasil analisis, dan capaian luaran (wajib dan atau tambahan). Seluruh hasil atau capaian yang dilaporkan harus berkaitan dengan tahapan pelaksanaan penelitian sebagaimana direncanakan pada proposal. Penyajian data dapat berupa gambar, tabel, grafik, dan sejenisnya, serta analisis didukung dengan sumber pustaka primer yang relevan dan terkini.

Pengisian poin C sampai dengan poin H mengikuti template berikut dan tidak dibatasi jumlah kata atau halaman namun disarankan seringkas mungkin. Dilarang menghapus/memodifikasi template ataupun menghapus penjelasan di setiap poin.

C. **HASIL PELAKSANAAN PENELITIAN:** Tuliskan secara ringkas hasil pelaksanaan penelitian yang telah dicapai sesuai tahun pelaksanaan penelitian. Penyajian dapat berupa data, hasil analisis, dan capaian luaran (wajib dan atau tambahan). Seluruh hasil atau capaian yang dilaporkan harus berkaitan dengan tahapan pelaksanaan penelitian sebagaimana direncanakan pada proposal. Penyajian data dapat berupa gambar, tabel, grafik, dan sejenisnya, serta analisis didukung dengan sumber pustaka primer yang relevan dan terkini.

Output of the 1st year program: a design model of the proposed technology solar cold storage integrated with bio-PCM (Fig. 1), one international journal paper: International Journal of Energy Storage (Q1), one national non-accredited journal paper: Journal Matrix, two international conference papers: The 2nd International Conference on Sustainable Energy and Resource Use in Food Chains (Cyprus) and International Conference on Mechanical Engineering Research and Application, and the 1st year reports.

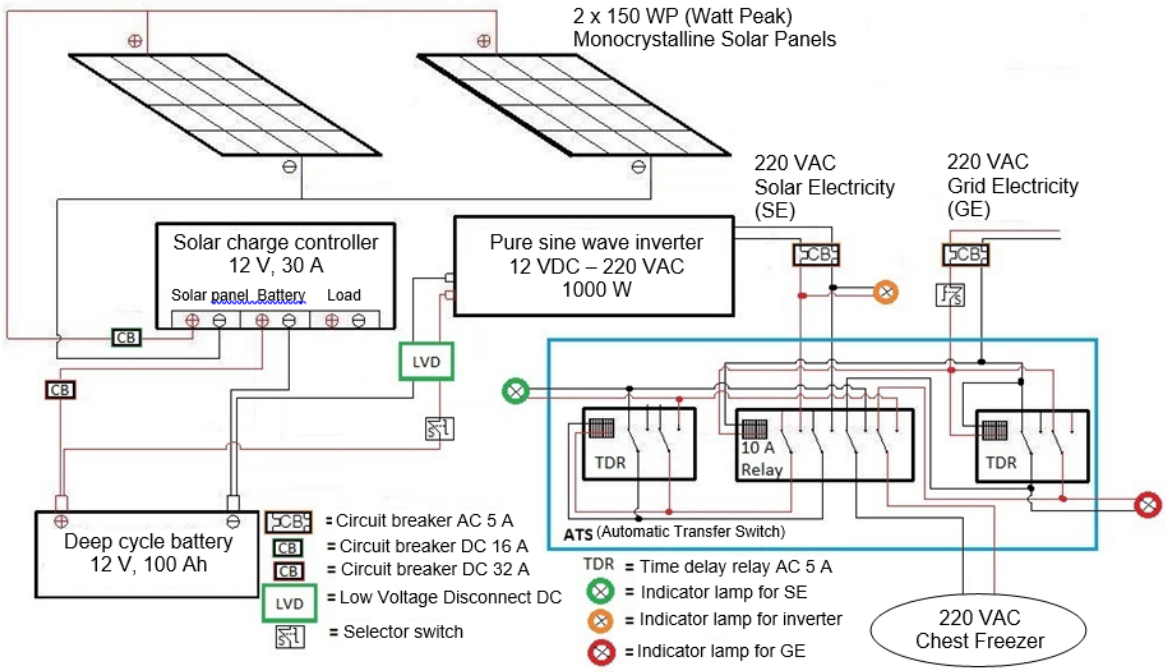

Fig.1 - Design of proposed technology applied for Indonesian Food chain

Schematic of the solar PV-powered chest freezer which comprises a PV power supply system and a chest freezer system is presented in Figure 1. The PV power supply system is composed of five main parts: i) the solar PV panels; ii) the solar charge controller; iii) the energy storage unit (100 Ah battery); iv) the pure sine wave inverter 12 VDC-220 VAC 1000 W; and v) the automatic transfer switch (ATS). The chest freezer used is an energy efficient and environmentally friendly standalone refrigeration unit charged with R600a (a natural refrigerant). The chest freezer is specified for 100 W power input and 220 VAC. Energy demand of PV-chest freezer system was provided by two photovoltaic panels 12VDC 150 Wp connected in parallel. Photovoltaic panels used are monocrystalline type due to higher efficiency compared with the polycrystalline type.

The solar charge controller unit regulates the DC output from the PV panels, and supplies solar energy to the battery unit. The control unit prevents the battery from over-charged and full discharged. The battery system consists of a single 100 Ah - 12 VDC dry-type battery. The pure sine wave inverter changes the voltage of 12 V power supplied from the battery system to 220 VAC delivered to the chest freezer through the ATS unit. The inverter unit has a capacity of 1000 W. This capacity is required to accommodate power demand fluctuation of the chest freezer especially during “start” in the cycling mode “on-off”. The ATS unit provided in the solar PV power supply system to make the system possible to use the power either supplied from the solar power supply system or national grid. This provides high flexibility to the PV-chest freezer unit. In the PV-chest freezer system, the selection and proper installation of appropriately-sized components directly affects system flexibility, reliability, lifetime, and initial cost. By using more batteries and increasing the number of PV panels array may extend the lifetime and reliability of a PV system designed for a specific use. This will, however, increase the initial cost of the solar PV power supply system. Number of panels in the PV power supply array and the size of battery storage capacity vary depending on site location

The 2nd year research program: Two main activities are set in the second year program. They are (i) Development of prototype the proof concept of the proposed technology as designed model in the first year for cold storage applied in the cold chain of food supply chain in Indonesia and conducting experimental testing on the prototype (Fig. 2); (ii) analysis of the research findings and energy performance of the proposed cold storage system. For publications, papers have been prepared for international journal. Others results can be detailed as below:

The research has achived: (i) comphrehensive energy analyses of supermall building in Indonesia as one component of food supply chain; (ii) a data set of energy and environmental impact of supermall in Indonesia with regards of food supply chain; (iii) a prototype of sustainable technology in cold storage for cold chain application: “A solar PV powered chest freezer utilizing electrical and thermal energy storage; (iv) a data set of data energy and environmental performance of the prototype for proof of concept of an innovative cold storage system with sustainable energy technologies employing integrated thermal and electrical energy storage;

Fig.2 - Photo of the solar cold storage integrated with bio-PCM

Publications of the second year include:

1. One paper has been presented in an international conference (ICOME = International Conference on Mechanical Engineering) Yogyakarta. The paper will be published in Materials Science Forum a Q3 journal (Scopus and Scimago indexing);

2. Two papers have been presented in International Conference on Science and Technology (ICST part of IJCST) in Surabaya. The papers will be published in Journal of Physics (IOP Science) Q3 journal ((Scopus and Scimago indexing);

3. One paper has been submitted for International Journal of Refrigeration (a Q1 journal);

4. One paper has been being prepared for Journal of Advanced Research in Fluid Mechanics and Thermal Sciences, a Q3 journal (Scopus and Scimago indexing).

D. **STATUS LUARAN**: Tuliskan jenis, identitas dan status ketercapaian setiap luaran wajib dan luaran tambahan (jika ada) yang dijanjikan pada tahun pelaksanaan penelitian. Jenis luaran dapat berupa publikasi, perolehan kekayaan intelektual, hasil pengujian atau luaran lainnya yang telah dijanjikan pada proposal. Uraian status luaran harus didukung dengan bukti kemajuan ketercapaian luaran sesuai dengan luaran yang dijanjikan. Lengkapi isian jenis luaran yang dijanjikan serta mengunggah bukti dokumen ketercapaian luaran wajib dan luaran tambahan melalui Simlitabmas mengikuti format sebagaimana terlihat pada bagian isian luaran

The required output of the research of the year 1 has been achieved:

Publication on: International Journal of Energy Storage, 15, 2018, pp. 368-378. status: published; https://www.sciencedirect.com/science/article/pii/S2352152X17301706; a Q1 journal; Title: The role of vegetable oil in water based phase change materials for medium temperature refrigeration

Additional achievements:

1. Design concept of one proposed technology solar cold storage integrated with bio-PCM for food chain in Indonesia;

2. IOP Conference Series: Materials Science and Engineering, Volume 494 Number 1 : 012017, 2019; status: published; title: 'Experimental Study on the Influences of Air Flow in an Integral Hydrocarbon Display Cabinet to its Temperature and Energy Performances'.

3. IOP Conf. Series: Materials Science and Engineering 494, 1, 012034, 2019; status: published; title: 'Study on Thermal Properties of Bio-PCM Candidates in Comparison with Propylene Glycol and Salt Based PCM for sub-Zero Energy Storage Applications',

4. Energy Procedia, 161, pp. 198-206, 2019; status: published; title: 'Development of Corn-Oil Ester and Water Mixture Phase Change Materials for Food Refrigeration Applications'.

For the second year (2019), the research has achieved: (i) comphrehensive energy analyses of supermall building in Indonesia as one component of food supply chain; (ii) a data set of energy and environmental impact of supermall in Indonesia with regards of food supply chain; (iii) a prototype of sustainable technology in cold storage for cold chain application: "A solar PV powered chest freezer utilizing electrical and thermal energy storage; (iv) a data set of data energy and environmental performance of the prototype for proof of concept of an innovative cold storage system with sustainable energy technologies employing integrated thermal and electrical energy storage.

Publications of the second year include:

The required output: One paper has been submitted for International Journal of Refrigeration (a Q1 journal);

Additional achievements year 2:

1. A prototype of solar cold storage integrated with bio-PCM for food chain in Indonesia;

2. One paper has been presented in an international conference (ICOME = International Conference on Mechanical Engineering) Yogyakarta. The paper will be published in Materials Science Forum a Q3 journal (Scopus and Scimago indexing); status: under review.

3. Two papers have been presented in International Conference on Science and Technology (ICST part of IJCST) in Surabaya. The papers will be published in Journal of Physics (IOP Science) Q3 journal ((Scopus and Scimago indexing); status: under review.

4. One paper has been being prepared for Journal of Advanced Research in Fluid Mechanics and Thermal Sciences, a Q3 journal (Scopus and Scimago indexing).

5. One paper has been being prepared for Applied Thermal Engineering, a Q1 journal (Scopus and Scimago indexing).

E. **PERAN MITRA:** Tuliskan realisasi kerjasama dan kontribusi Mitra baik *in-kind* maupun *in-cash* (jika ada). Bukti pendukung realisasi kerjasama dan realisasi kontribusi mitra dilaporkan sesuai dengan kondisi yang sebenarnya. Bukti dokumen realisasi kerjasama dengan Mitra diunggah melalui Simlitabmas mengikuti format sebagaimana terlihat pada bagian isian mitra

In the second year, the research partner has been contributing in-kind support such as opportunities to carry out and to use data of the research results at the Institute of Energy Futures, Brunel University London (UK), access to international journals through Brunel University e-journal system and an opportunity to join the next research collaboration through UK Innovation Funding Services Grant.

F. **KENDALA PELAKSANAAN PENELITIAN**: Tuliskan kesulitan atau hambatan yang dihadapi selama melakukan penelitian dan mencapai luaran yang dijanjikan, termasuk penjelasan jika pelaksanaan penelitian dan luaran penelitian tidak sesuai dengan yang direncanakan atau dijanjikan.

The difficulties found in preparing the paper for year two are the delay of data obtained from the experimental and from the research partner and the available data are not comprehensive enough for in depth analysis of a Q1 paper

G. **RENCANA TINDAK LANJUT PENELITIAN:** Tuliskan dan uraikan rencana tindaklanjut penelitian selanjutnya dengan melihat hasil penelitian yang telah diperoleh. Jika ada target yang belum diselesaikan pada akhir tahun pelaksanaan penelitian, pada bagian ini dapat dituliskan rencana penyelesaian target yang belum tercapai tersebut.

To complete the paper for submission on a Q1 international journal. Follow up the discussion results with the research partner about the next research collaboration fully funded by UK Government through UK Innovation Funding Services Grant, the proposal has been submitted

H. **DAFTAR PUSTAKA:** Penyusunan Daftar Pustaka berdasarkan sistem nomor sesuai dengan urutan pengutipan. Hanya pustaka yang disitasi pada laporan akhir yang dicantumkan dalam Daftar Pustaka.

[1] Feron S 2016 Sustainability of Off-Grid Photovoltaic Systems for Rural Electrification in Developing Countries: A Review Sustainability 8, 1326.

[2] Foley G 1995 Photovoltaic Applications in Rural Areas of the Developing World, World Bank Technical Paper Energy Series, number 304, 102 pgs.

[3] Santika W, Sudirman and Suamir I N 2016 Feasibility analysis of grid/wind/PV hybrid systems for industrial application ARPN J Eng Appl Sci 11, 857-862

[4] Aktacir M A 2011 Experimental study of a multi-purpose PV-refrigerator system International J Phys Sci 6, 746-757.

[5] Elias M S and Yilma T B 2019 Modelling and performance analysis of directly coupled vapor compression solar refrigeration system Author links open overlay panel Solar Energy 190, 228-238.

[6] Suamir I N 2014 Solar driven absorption chiller for medium temperature food refrigeration, a study for application in Indonesia Appl Mech Mater 493, 167-172.

[7] He H, Wang L, Yuan J, Wang Z, Fu W, and Liang K 2019 Performance evaluation of solar absorption-compression cascade refrigeration system with an integrated air-cooled compression cycle Energy Convers Manag 201, 112153.

[8] Bellos E and Tzivanidis C 2017 Optimum design of a solar ejector refrigeration system for various operating scenarios Energy Convers Manag 154, 11-24.

[9] Fellah A, Boukhchana Y, and Brahim A B 2019 Quasi-real performances of an irreversible solar absorption refrigeration cycle Int J Refrig 100, 21-26.

[10] Wang Y, Li M, Ji X, Yu Q, Li G, and Ma X 2018 Experimental study of the effect of enhanced mass transfer on the performance improvement of a solar-driven adsorption refrigeration system Appl Energy 224, 417-425.

[11] Chena Q F, Dua S W, Yuana Z X, Sunb T B, and Lia Y X 2018 Experimental study on performance change with time of solar adsorption refrigeration system Appl Therm Eng 138, 386-393.

[12] Rumbayan M, Abudureyimu A, Nagasaka K 2012 Mapping of solar energy potential in Indonesia using artificial neural network and geographical information system Renew Sustain Energy Rev 16, 1437-1449.

[13] Veldhuis A J, and Reinders A H M E 2015 Reviewing the potential and cost-effectiveness of off-grid PV systems in Indonesia on a provincial level Renew Sustain Energy Rev 52, 757-769.

[14] Yudiartono, Anindhita, Sugiyono A, Wahid L M A and Adiarso 2018 Indonesia Energy Outlook 2018. Center for Energy Resources Development Technology. Agency for the Assessment and Application of Technology, p. 117.

[15] FAO 2016 The State of World Fisheries and Aquaculture 2016. Contributing to food security and nutrition for all. Rome. 200 pp.

[16] MMAF-RI 2016 Capture and aquaculture production 2012-2016. Ministry of Marine Affairs and Fisheries Republic of Indonesia. Available at: http://statistik.kkp.go.id/sidatik-dev/2.php?x=2

[17] IARW 2016 Global cold storage capacity report: Capacity and growth of refrigerated warehousing by country, International Association of Refrigerated Warehouses.

[18] ASHRAE 2017 Fundamental Handbook American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc. 1791 Tullie Circle NE, Atlanta

[19] Kumar S 2016 Assessment of renewables for energy security and carbon mitigation in Southeast Asia: The case of Indonesia and Thailand Appl Energy 163, 63-70.

[20] Azzouz K, Leducq D, Gobin D 2009 Enhancing the performance of household refrigerators with latent heat storage: an experimental investigation Int J Refrig 32, 1634-44.

[21] Raeisi A, Suamir I N, Tassou S A 2013 Energy storage in freezer cabinets using phase change materials Proc. the 2nd IIR International Cold Chain Conference, Paris, pp. 187-194.

[22] Suamir I N, Rasta I M, Sudirman and Tsamos K M 2019 Development of Corn-Oil Ester and Water Mixture Phase Change Materials for Food Refrigeration Applications Energy Procedia 161, 198-206.

[23] Rasta I M and Suamir I N 2019 Study on Thermal Properties of Bio-PCM Candidates in Comparison with Propylene Glycol and Salt Based PCM for sub-Zero Energy Storage Applications IOP Conf. Series: Mater Sci Eng 494, 012024

[24] Rasta I M and Suamir I N 2018 Development of Corn-Oil Ester and Water Mixture Phase Change Materials for Low Temperature Refrigeration Applications Atlantis Highlights in Engineering (AHE) 1, 1017-1022.

[25] Rasta I M and Suamir I N 2018 The role of vegetable oil in water based phase change materials for medium temperature refrigeration J Energy Storage 15, 368-378.