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PROGRAM INSINAS RISET PRATAMA KEMITRAAN

PENGEMBANGAN MODEL INFRASTRUKTUR ENERGI LISTRIK UNTUK MASYARAKAT KEPULAUAN

Tahun ke-3 dari rencana 3 tahun

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RINGKASAN

Permasalahan infrastuktur energi yang berdampak pada ketahanan sosial dan penguatan ekonomi pesisir khususnya pada masyarakat kepulauan di wilayah daerah Sulawesi Utara dicari solusinya. Sejalan dengan program Nawacita dan Rencana Induk Riset Nasional, maka riset mengenai teknologi kedaulatan daerah yang berfokus pada infrastuktur energi untuk masyarakat kepulauan khususnya di daerah 3 T (terdepan, terpencil dan terbelakang) menjadi prioritas penting untuk dikaji. Peningkatan kemampuan iptek dan inovasi di bidang teknologi energi perlu didukung dengan kemitraaan dan program kerjasama internasional sebagai pembelajaran (*lesson learnt*).

Kegiatan riset INSINAS dengan tema Pengembangan Model infrastruktur Energi Listrik untuk Masyarakat Kepulauan ini dilaksanakan dalam waktu tiga tahun. Tahun pertama, adalah melakukan pemodelan pada infrastuktur energi listrik yang berbasis energi baru terbarukan (EBT) beserta analisa potensi energi terbarukan yang tersedia di kepulauan Talaud di Sulawesi Utara. Luaran pada tahun pertama berupa publikasi internasional dengan judul "*Prospect of PV-Wind-Diesel Hybrid System as An Alternative Power Supply for Miangas Island in Indonesia*" telah dihasilkan sebagai publikasi bersama dengan mitra peneliti Professor Yosuke Nakanishi dari Universitas Waseda, Jepang.

Tahun kedua, adalah melakukan pengujian model sistem infrastuktur energi kelistrikan berbasis pemanfaatan energi terbarukan (EBT) yang tersedia secara lokal bagi masyarakat kepulauan. Pengujian model teknologi tepat guna yang berbasis EBT sudah dilakukan berupa penerapan *pilot plant* dan uji pada lingkungan yang sebenarnya di kepulauan Talaud. Luaran pada tahun kedua adalah publikasi internasional dengan judul "*Techno Economical Study of PV-Diesel Power System for a Remote Island in Indonesia: A Case Study of Miangas Island*" pada IOP Conferences Series Volume 150 (https://iopscience.iop.org/article/10.1088/1755-1315/150/1/012024).

Tahun ketiga, adalah pengembangan prototipe *portable solar luggage* yang merupakan pembangkit listrik mini dan mobile yang dapat diterapkan untuk masyarakat daerah kepulauan khususnya di pulau kecil dan remote yang memiliki keterbatasan akses pada jaringan listrik. Tingkat Kesiapan Teknologi (TKT) yang direncanakan pada tingkat 4 sebagai pengujian prototipe pada lingkungan yang sebenarnya yaitu masyarakat kepulauan di pulau Bunaken sebagai daerah tujuan pariwisata.

Hasil riset kemitraan ini berupa publikasi pada jurnal internasional tentang pengembangan prototipe solar luggage dan penerapannya di daerah kepulauan, hak cipta prototipe sistem monitoring portable solar luggage dan penerapan Teknologi Tepat Guna (TTG) prototype yang digunakan pada masyarakat kepulauan, khususnya di Pulau Bunaken. Luaran berupa publikasi ilmiah pada jurnal internasional sudah dimasukan dengan judul "*Model of Solar Energy Utilization in Bunaken Island Communities for Tourism Spot*". Selain itu keberlanjutan program kerjasama dengan tim mitra dari Universitas Waseda Jepang telah dilaksanakan dan ditindaklanjuti melalui *international conference* di Manado, Indonesia.

Hasil riset pratama ini siap untuk dikembangkan ke jenjang riset utama untuk penerapan teknologi energi terbarukan dalam rangka pengembangan infrastuktur energi kelistrikan pada masyarakat kepulauan, khususnya pulau-pulau kecil dan terdepan yang terletak di wilayah Sulawesi Utara yang mengalami krisis energi listrik.

PRAKATA

Puji Syukur kepada Tuhan yang Maha Kuasa untuk kesempatan yang diberikan dalam melaksanakan riset Insentif Riset Sistem Inovasi Nasional ini. Terima kasih kepada semua pihak yang telah membantu sehingga laporan akhir riset INSINAS Pratama Kemitraan dengan judul "Pengembangan Model Infrastruktur Energi Listrik untuk Masyarakat Kepulauan" bisa diselesaikan.

Secara khusus, penulis memberikan apresiasi kepada Ketua dan Sekretaris LPPM Unsrat dan staff LPPM Unsrat yang telah membantu dan memberi masukan yang berarti sehingga laporan ini bisa dibuat dan dimasukan sebagai salah satu kelengkapan proses pelaksaan Riset INSINAS. Juga bagi para reviewer INSINAS dan staf administrasi di Direktorat Pengembangan Teknologi Industri, Direktorat Jenderal Penguatan Riset dan Pengembangan yang telah mensupport dan mengarahkan pelaksanaan riset INSINAS dari tahun I, II dan III sehingga luaran-luaran riset bisa terlaksana dengan baik.

Besar harapan kami sebagai periset, kiranya hasil inovasi dan penelitian yang sudah dilaksanakan dapat dikembangkan dan dimanfaatkan untuk masyarakat.

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LAMPIRAN (bukti luaran yang didapatkan)
- Artikel ilmiah (*draft*, status *submission* atau *reprint*), dll.
- HKI, publikasi dan produk penelitian lainnya

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BAB 1. PENDAHULUAN

1.1 Latar belakang

Pengembangan model infrastruktur energi listrik untuk masyarakat kepulauan sudah dilakukan pada riset tahun pertama dan tahun kedua. Hasil kajian secara teknis dan ekonomis model pembangkit listrik berbasis sumber daya lokal untuk pulau-pulau kecil dan seperti pulau Miangas, pulau Kokorotan dan Pulau Makalehi yang terletak di kepulauan Talaud yang merupakan perbatasan Indonesia dan Filipina sudah dilakukan. Berdasar hasil simulasi diperoleh model sistem pembangkit listrik berbasis energi terbarukan yang optimal untuk kebutuhan energi listrik untuk masyarakat kepulauan.

Status kemajuan yang telah dicapai pada tahun pertama adalah pengembangan model infrastruktur energi listrik berbasis energi terbarukan yang telah dipublikasikan pada jurnal internasional IJRDO edisi November 2017 dengan judul "*Development of Power System Infrastructure Model for the Island Communities: A Case Study of Kokorotan Island in Indonesia*" dapat dilihat pada halaman berikutnya dan seminar internasional di Seoul, Korea Selatan tanggal 28 Agustus -1 September 2017 dengan judul "*The Role of Renewable Energy in Island Communities : The Experiences from Makalehi Island*".

Status kemajuan yang telah dicapai pada tahun kedua adalah kajian teknis dan ekonomis model infrastruktur energi listrik berbasis energi terbarukan yang telah dipublikasikan pada jurnal internasional IOP Publikasi artikel ilmiah terindeks Scopus di IOP Environmental and Earth Volume 150 (http://iopscience.iop.org/article/10.1088/1755-1315/150/1/012024) dengan judul "Techno Economical Study of PV-Diesel Power System for a Remote Island in Indonesia: A Case Study of Miangas Island" dan publikasi ilmiah dipresentasikan pada seminar internasional ICRCE di Tokyo, Jepang tanggal 28 Maret -1 April 2018 dengan judul "*Prospect of PV-Wind-Diesel Hybrid System as An Alternative Power Supply for Miangas Island in Indonesia*".

Tantangan selanjutnya pada riset tahun ketiga adalah penerapan teknologi energi baru terbarukan (EBT) yang berfokus pada kedaulatan daerah 3T (Terdepan, Terpencil, Terbelakang). Ibarat teras rumah yang perlu penerangan, demikian juga pulau-pulau perbatasan yang terdepan di wilayah Indonesia. Infratruktur energi listrik untuk pulau-pulau perbatasan perlu mendapat perhatian demi keamanan dan kesejahteraan masyarakat kepulauan. Tujuan riset ini adalah untuk pengembangan prototipe model infrastruktur energi listrik berbasis energi terbarukan yang tersedia secara lokal di suatu wilayah kepulauan. Luaran yang direncanakan adalah dokumen prototipe dari model portable solar luggage sebagai sumber pembangkit listrik off-grid di daerah pulau perbatasan yang terbatas akses listrik terhadap infrastruktur jaringan listrik.

Karakteristik negara Indonesia yang berpenduduk banyak dan keadaan geografis yang terdiri dari berbagai pulau besar dan kecil memerlukan penanganan khusus dalam hal menghadapi masalah energi. Ketergantungan terhadap pasokan bahan bakar fosil dari pulau ke pulau yang memiliki biaya transportasi yang tinggi dan menghasilkan gas rumah kaca perlu diminimalkan. Untuk itulah pemanfaatan energi terbarukan sebagai sumber energi alternatif untuk ketahanan energi perlu dibahas dan dikaji.

Ketahanan energi adalah keadaan suatu kawasan yang bisa memenuhi kebutuhan energinya secara mandiri baik dalam bentuk energi bahan bakar primer atau energi kelistrikan. Ketahanan energi dianggap penting karena energi merupakan komponen penting dalam produksi barang dan jasa.

1.2 Deskripsi Teknologi yang Dihasilkan dan Manfaatnya

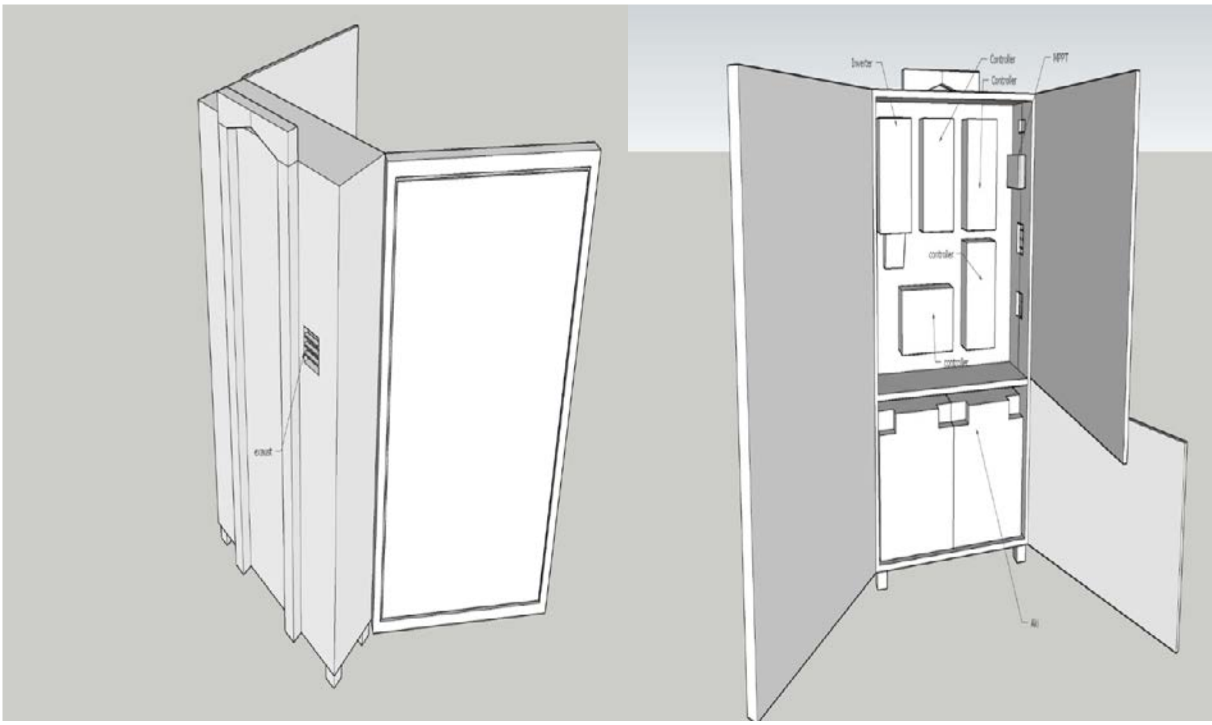
Teknologi yang dihasilkan pada tahun ketiga ini adalah berupa prototype/purwarupa teknologi tepat guna (TTG) yang dapat dimanfaatkan oleh masyarakat kepulauan yang terbatas akses listriknya pada jaringan PLN. Prototype teknologi solar luggage portable yang dirangkai dari beberapa komponen seperti panel photovoltaic, battere, controller, inverter dan lampu penerang dilengkapi dengan alat monitoring jarak jauh berbasis android yang dapat dipantau unjuk kerja arus dan tegangannya melalui telepon genggam.

Manfaat dari teknologi ini sebagai teknologi tepat guna (TTG) sebagai sumber listrik dari tenaga surya yang mandiri (off-grid) karena tidak terhubung pada jaringan listrik PLN untuk masyarakat kepulauan. Prototype TTG ini diujicoba pada lingkungan yang sebenarnya yaitu di Pulau Bunaken sebagai remote island tujuan pariwisata namun sering mengalami pemadaman listrik dari jaringan PLN yang bersumber dari bahan bakar diesel yang mahal dan tidak ramah lingkungan.

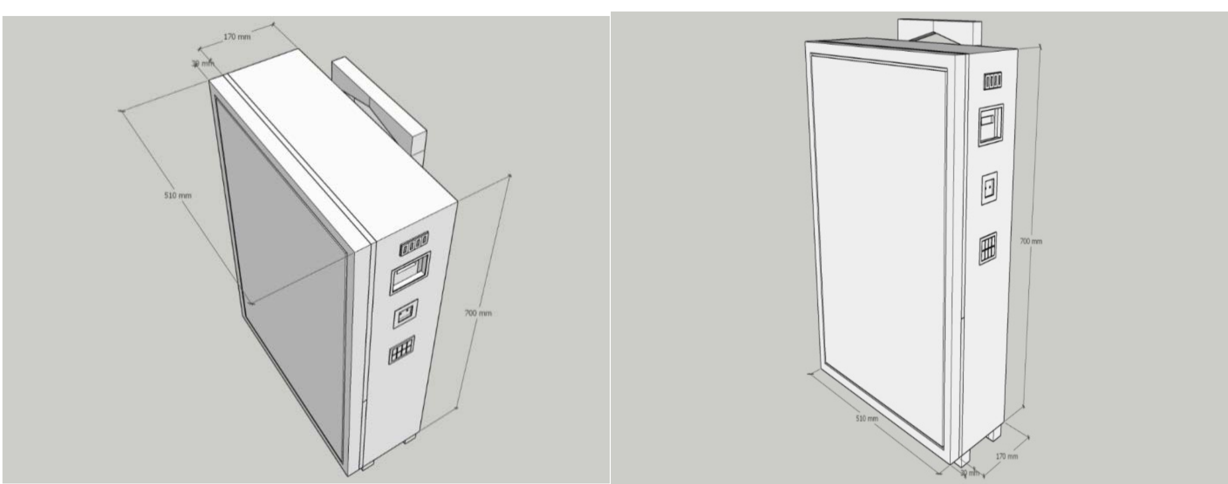
Deskripsi teknologi yang dihasilkan dan manfaatnya:

1. Perancangan purwarupa (prototipe) *portable solar luggage*

Gambar desain prototipe *portable solar luggage* dipresentasikan pada Gambar 1 dan Gambar 2 berikut:



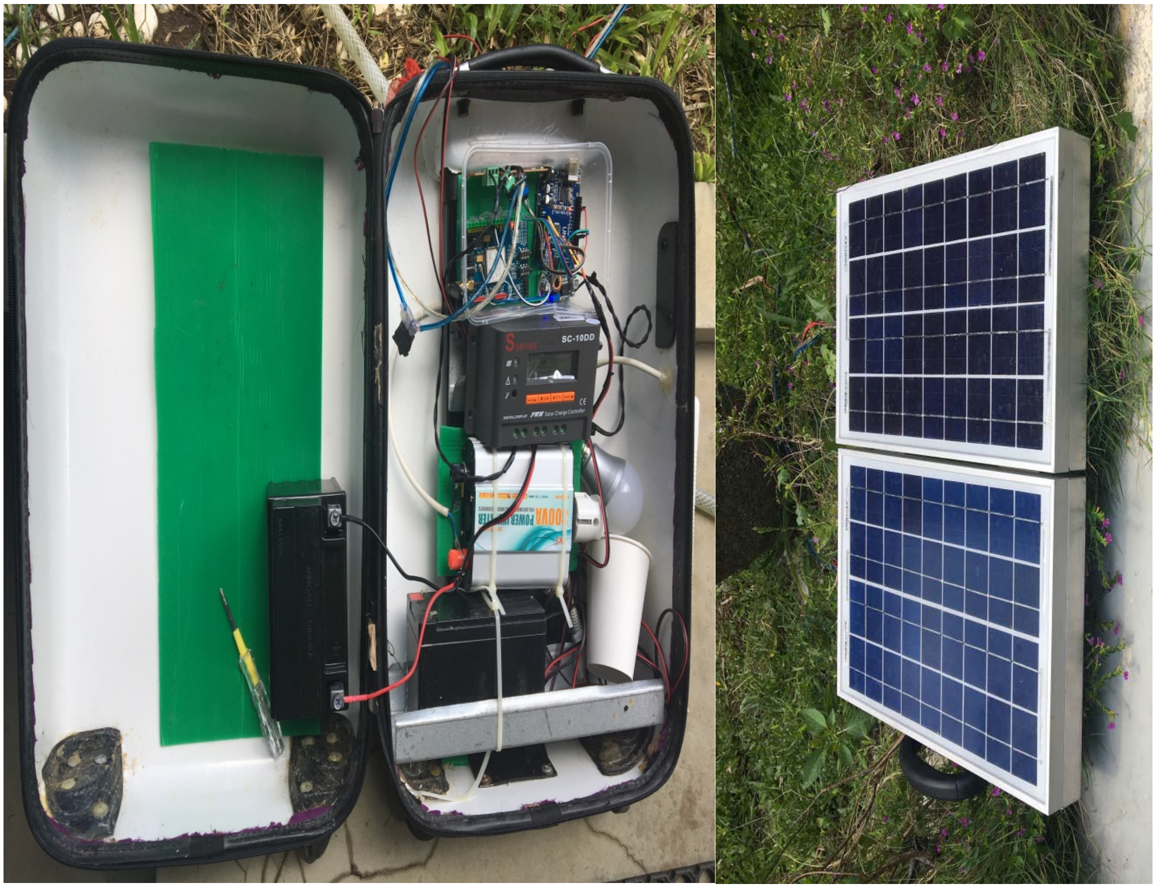
Gambar 1. Gambar tampak belakang dan tampak depan *portable solar luggage*



Gambar 2. Dimensi *portable solar luggage*

2. Pembuatan prototype/ purwarupa *portable solar luggage* dengan sistem monitoring

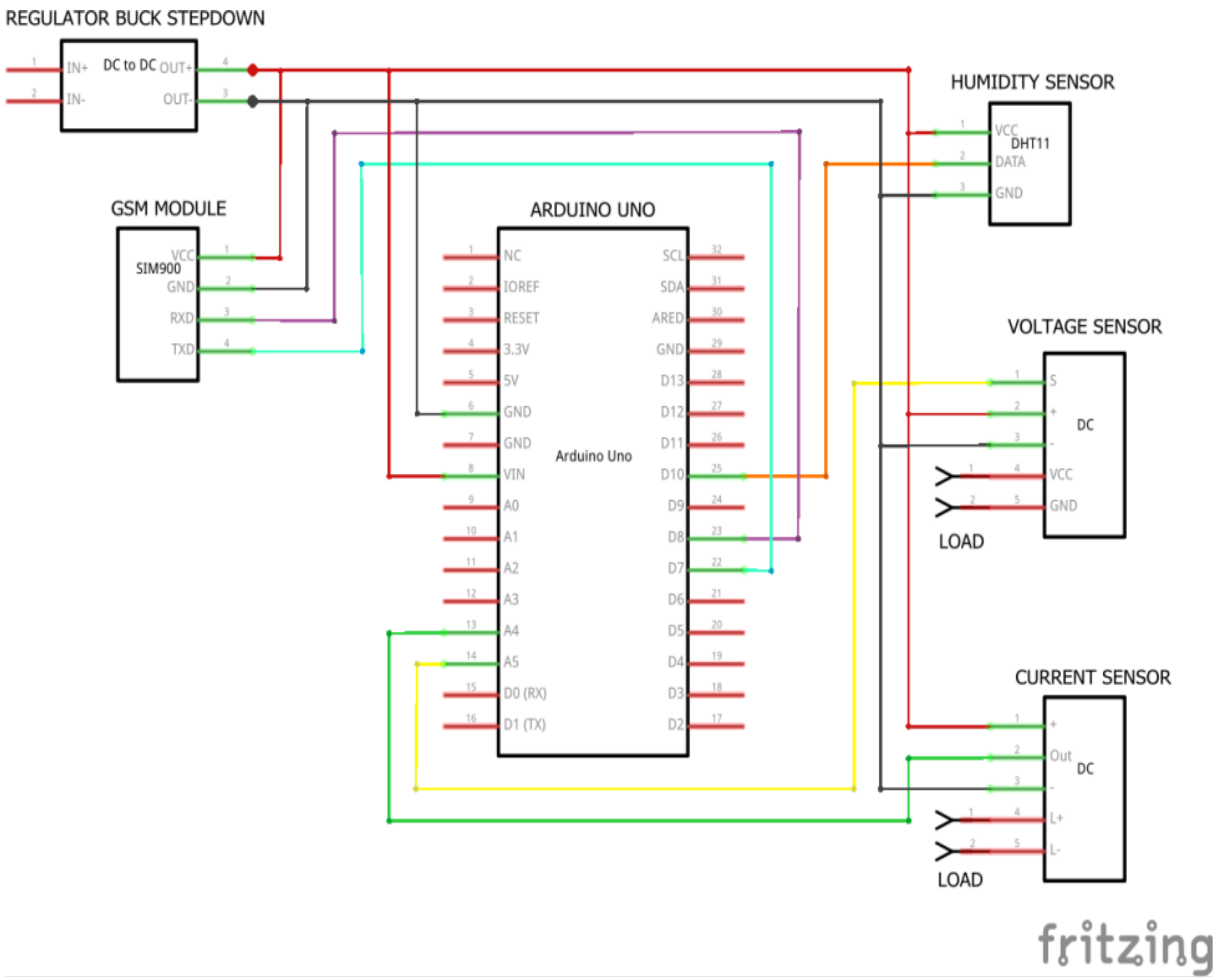
Model prototype solar luggage dipresentasikan pada Gambar 3 berikut:



Gambar 3. Model prototype *portable solar luggage* dengan sistem monitoring

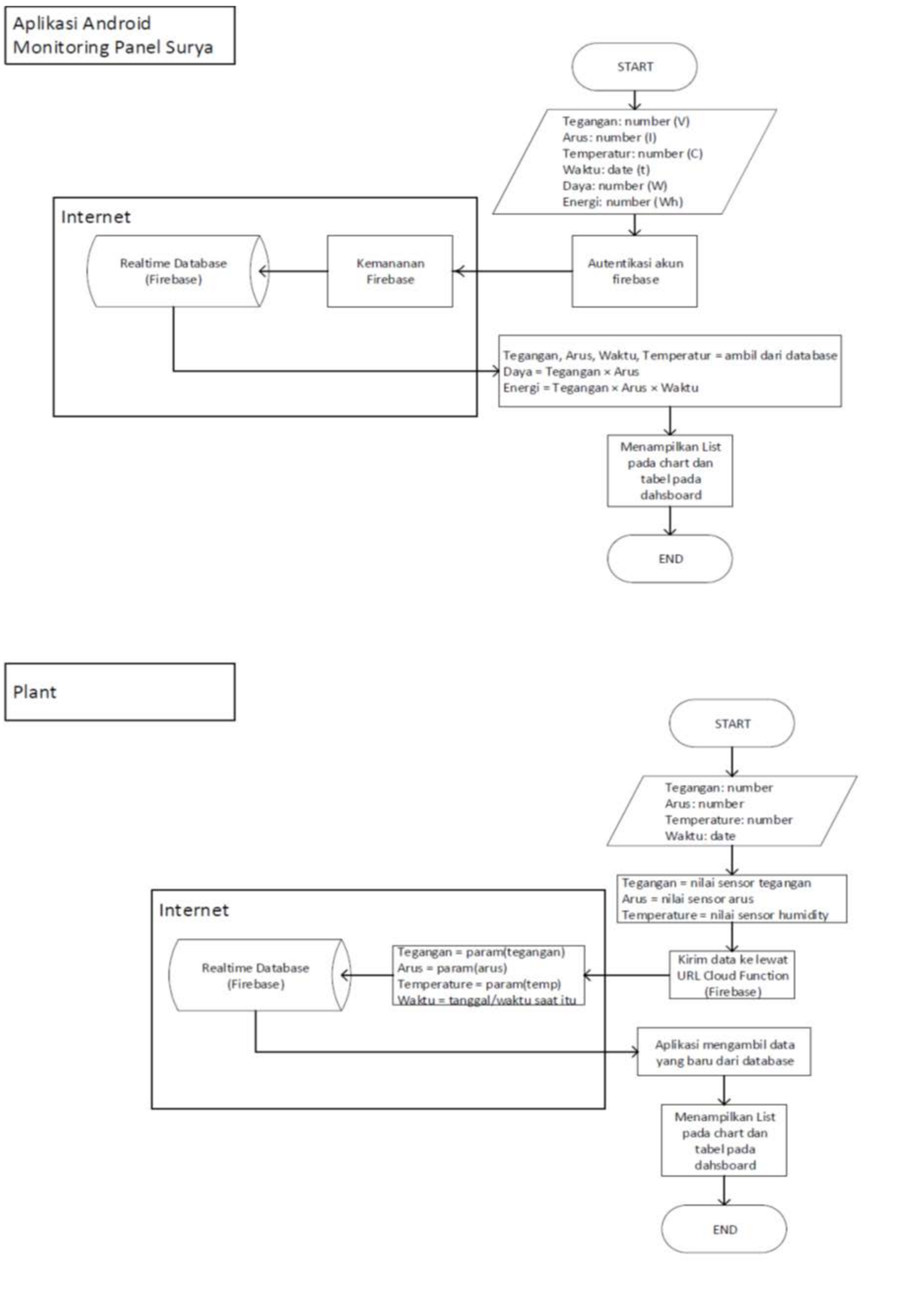
Solar luggage memiliki kelebihan yakni dilengkapi dengan sistem monitoring berbasis android. Tujuan solar luggage ini dilengkapi sistem monitoring agar supaya unjuk kerja/ performance pembangkit listrik tenaga surya portable ini dapat dimonitor secara jarak jauh apabila ditempatkan pada lokasi yang jauh (*remote*).

Pada sistem monitoring ini memerlukan 3 sensor, 1 controler, 1 media penngiriman antaranya, DHT11 untuk teperatur,Voltage 25V Sensor untuk tegangan, ACS712 05b untuk arus, Arduino Uno untuk mengolah data dari sensor dan kirim melalui modul GSM SIM900 ke internet. Pada skema tersebut juga terdapat 1 unit Regulator Buck StepDown untuk menyuplai sistem Monitoring ini.



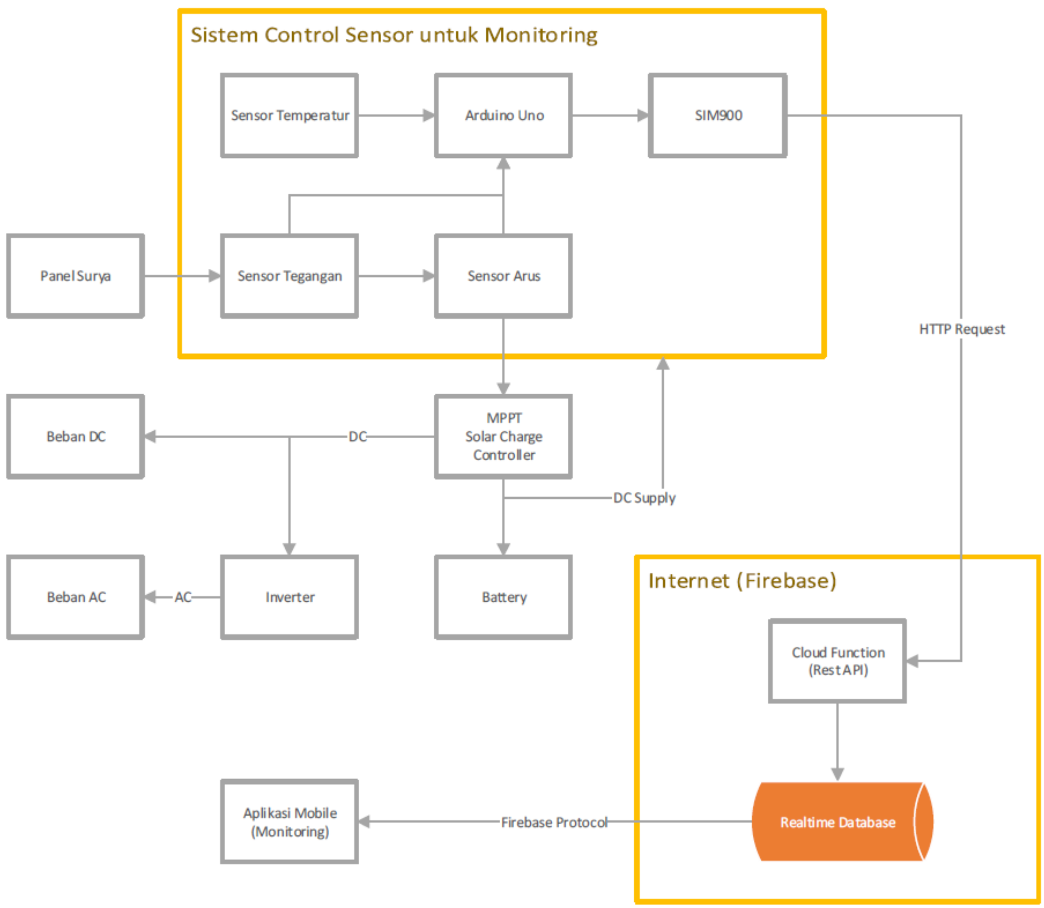
Gambar 4. Skema sistem monitoring arus dan tegangan panel surya

Diagram alir aplikasi monitoring panel surya berbasis android yang dibuat sebagai berikut:



Gambar 5. Diagram alir Sistem Monitoring unjuk kerja *portable solar luggage*

Sistem monitoring solar luggage portable berbasis android dirancang untuk melakukan pencatatan data dari panel surya yang terintegrasi menjadi solar luggage portable. Tujuan sistem monitoring solar luggage portable ini untuk melakukan pencatatan data arus, data tegangan dan data suhu yang terukur pada lingkungan dimana solar luggage ditempatkan pada lokasi tertentu. Dengan sistem monitoring ini, unjuk kerja dari solar luggage portable dapatdiukur dan diamati melalui telepon genggam.



Gambar 6. Sistem monitoring solar luggage portable berbasis android

BAB 2. TUJUAN DAN MANFAAT PENELITIAN

2.1 Tujuan Penelitian

Tujuan penelitian pada tahun ketiga ini adalah :

1. Melakukan penerapan teknologi tepat guna (TTG) yang berupa prototipe *portable solar luggage* yang dilengkapi dengan sistem monitoring sebagai pembangkit listrik mandiri sebagai model penerapan untuk mayarakat kepulauan di Indonesia.
2. Melakukan kajian teknis dan ekonomis pada prototipe *portable solar luggage system* sebagai penerapan infrastuktur energi listrik untuk masyarakat kepulauan yang berbasis Energi Baru dan Terbarukan (EBT).
3. Melaksanakan riset kemitraan dalam *eASIA Joint Research Program* berupa kolaborasi penelitian dengan tim riset dari Waseda University, Japan.

2.2 Manfaat Penelitian

Riset pada tahun ketiga ini menjadi pengembangan prototipe *portable solar luggage* sebagai model sistem infrastruktur energi kelistrikan berbasis pemanfaatan teknologi energi terbarukan pada masyarakat kepulauan.

Pemanfaatan portable solar luggage pada masyarakat kepulauan khususnya pada pulau remote yang terbatas akses listriknya sangat perlu dan penting. Pada pemelitian ini purwarupa/prototype yang dibuilt up berupa sistem pembangkitan mini bersama dengan sistem monitoringnya diujicoba pada lingkungan yang sebenarnya di Pulau Bunaken. Pulau Bunaken dipilih sebagai lokasi pengujian karena bersifat remote island dan pulau ini terkenal sebagai lokasi pariwisata namun menghadapi masalah terbatasnya akses listrik.

Namun adopsi teknologi perlu mempertimbangkan kondisi lokal memerlukan studi pendahuluan berupa kondisi eksisting produksi dan konsumsi energi listrik, pertumbuhan kebutuhan energi, pemetaan potensi energi, situasi geografis, kajian teknis dan ekonomis, analisa resiko dari pemanfaatan konsep dan pengembangan teknologi. Hasil riset berupa model infratruktur energi listrik yang berbasis energi terbarukan untuk masyarakat kepulauan, publikasi pada jurnal dan seminar internasional serta teknologi tepat guna berupa prototipe mobile solar luggage berupa sistem pembangkit listrik tenaga surya (PLTS) dengan memanfaatkan sumber energi secara lokal di pulau.

Manfaat penelitian dari teknologi solar luggage sebagai pembangkit listrik mandiri (off-grid) yang dilengkapi dengan sistem monitoring berbasis android telah diterapkan pada masyarakat Bunaken dengan pemasangan lampu tenaga surya yang berfungsi sebagai penerangan di mushola, usaha kecil menengah dan toilet sebagai fasilitas umum.

Gambar 7. Pemanfaatan solar luggage portable di salah satu UKM di Pulau Bunaken sebagai contoh

Gambar 8. Pemanfaatan solar luggage portable di mushola di Pulau Bunaken

Gambar 9. Pemanfaatan di toilet sebagai fasilitas umum

BAB 3. METODE PENELITIAN

Bab ini terdiri dari beberapa bagian yaitu telaah literatur, Tingkat Kesiapterapan Hasil Riset dan Pengembangan, Peta rencana pengembangan Teknologi dan Metode Penelitian.

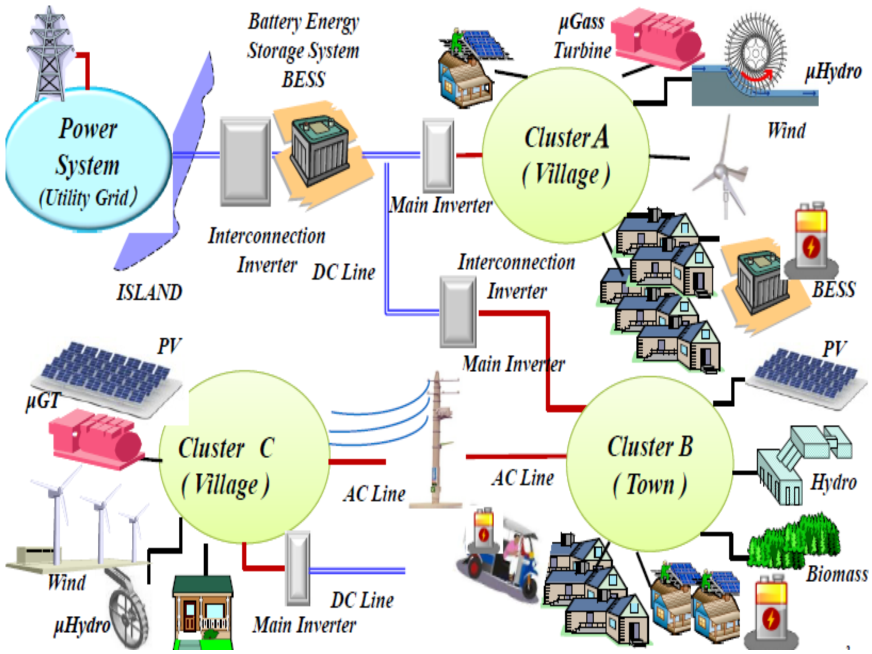
3. 1 Telaah Literatur

Berdasarkan penelitian sebelumnya oleh Rumbayan dan Nagasaka (2010), pemanfaatan teknologi sel surya di daerah terpencil di Indonesia dalam jangka panjang bisa menjadi lebih murah dibandingkan dengan bensin untuk pembangkit listrik karena biaya yang tinggi dalam transportasi. Namun penerapan teknologi energi terbarukan yang sangat kompleks dan padat modal memerlukan pemodelan sistem sebagai kajian awal.

Kajian teknis dan ekonomis dari penerapan sistem teknologi energi terbarukan di beberapa negara seperti India (Kolhe dkk, 2002), Saudi Arabia (Shaahid dan Amin, 2009), Palestina (Mahmoud dan Ibrik, 2006), Spain (Bernal dan Lopez, 2006) diulas pada beberapa literatur. Analisis suatu sistem teknologi energi terbarukan bersifat spesifik bergantung pada lokasi penerapan teknologi energi terbarukan, maka penelitian ini menangkap peluang analisis untuk melakukan kajian teknis dan ekonomis di Indonesia, khususnya dengan studi kasus pulau-pulau kecil di Sulawesi Utara.

Penerapan sistem teknologi energi terbarukan bergantung pada parameter seperti populasi, konsumsi dan jarak distribusi. Sistem dapat dikaji untuk potensi radiasi dan variasi beban konsumen dan kondisi sosio demografi berdasarkan aplikasi studi kasus pada lokasi penerapan teknologi energi terbarukan (Drennen dkk, 1996).

Konsep “Expandable Cluster-Oriented Network” (Gambar 10) yang dikembangkan oleh pakar di Environemtal and Energy Engineering Research telah menjadi proyek contoh diterapkan di Jepang (Konayagi dkk. 2010). Model ini akan dikaji penerapannya untuk lokasi pulau-pulau kecil di Indonesia berdasarkan kajian teknis dan ekonomis sehingga bisa diadopsi penerapannya berdasarkan kondisi eksisting wilayah Indonesia, keadaan masyarakat dan potensi energi yang tersedia secara lokal.



Gambar 10. Model "*Expandable Cluster Oriented Network*"

(Sumber : Yokoyama, R, 2010)

3.2 Tingkat Kesiapterapan Teknologi (TKT) hasil riset dan pengembangan

Tingkat Kesiapan Teknologi (TKT) pada riset tahun ketiga adalah sebagai berikut**:**

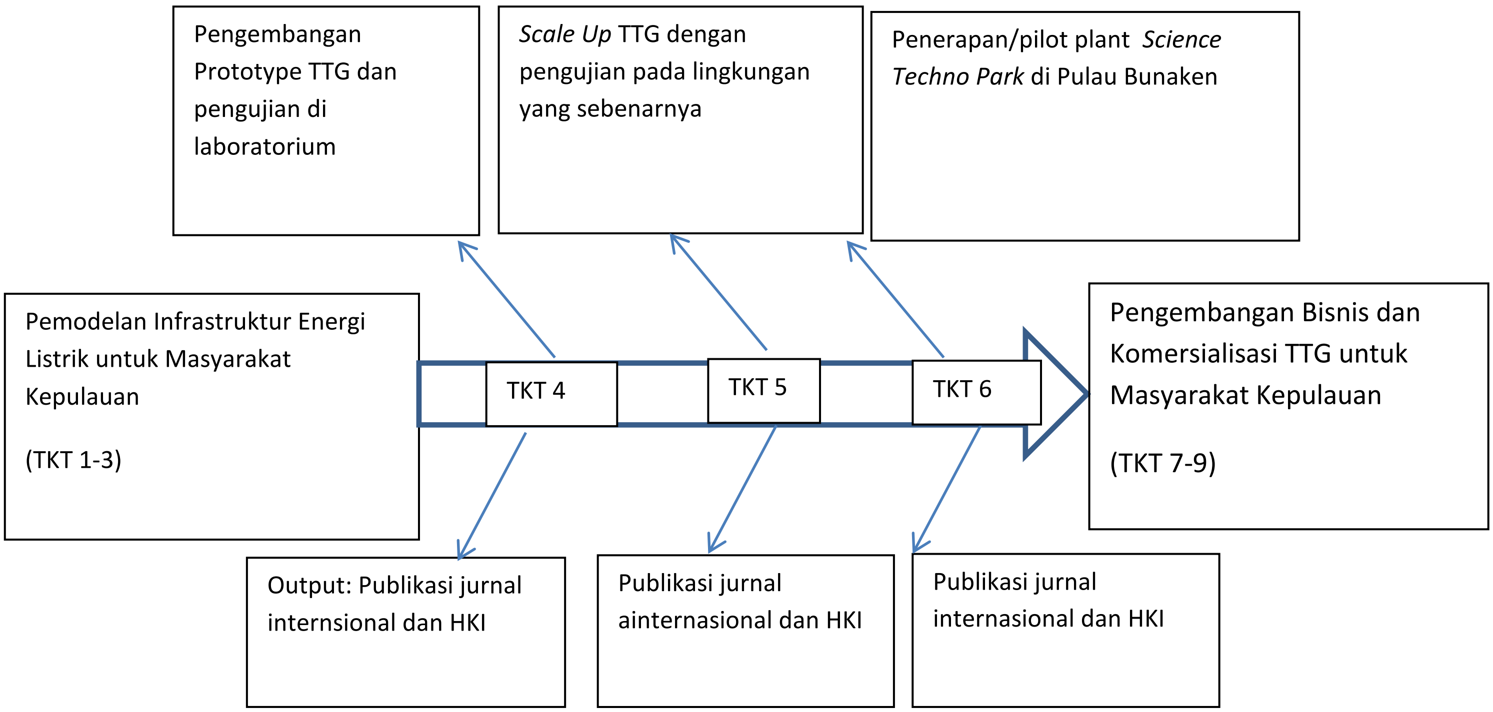
1. Melakukan studi analitik yang mendukung prediksi kinerja elemen-elemen teknologi berupa sistem pembangkit listrik tenaga surya skala kecil yang portable berbentuk *solar luggage.*
2. Mengidentifikasi dan memprediksi karakteristik dan sifat serta unjuk kerja sistem teknologi EBT di lingkungan pulau-pulau kecil.

Kegiatan pelaksanaan riset pada tahun ketiga berada pada TKT 3 yang dilakukan dilakukan pada beberapa tahap yaitu:

1. Desain purwarupa (prototype) portable solar luggage dilengkapi dengan sistem monitoring berbasis android.
2. Pembuatan prototype portable solar luggage dilengkapi dengan sistem monitoring berbasis android.
3. Pengujian prototype portable solar luggage dilengkapi dengan sistem monitoring berbasis android.

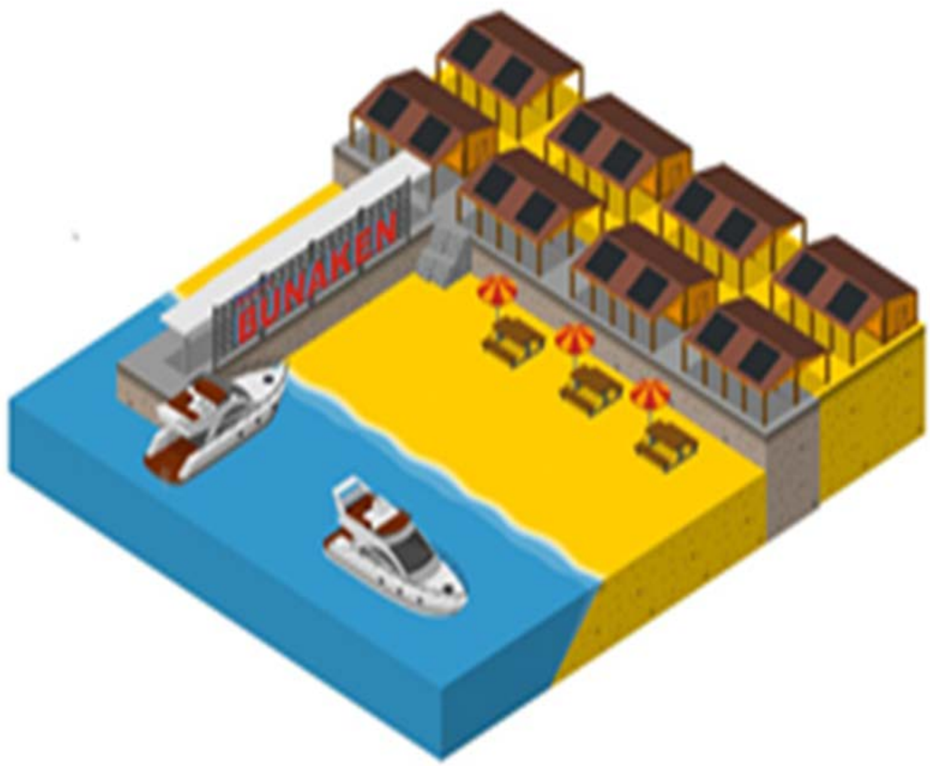
3.3 Peta rencana pengembangan teknologi menurut TKT

Peta rencana pengembangan teknologi (*roadmap*) ini disusun dengan blok riset yang telah dilakukan, riset yang diusulkan dan luarannya, riset yang akan datang sebagai keberlanjutan riset menurut TKT yang diusulkan seperti pada Gambar 11.



Gambar 11. Peta rencana pengembangan teknologi menurut TKT yang sudah dilakukan dan akan dilakukan

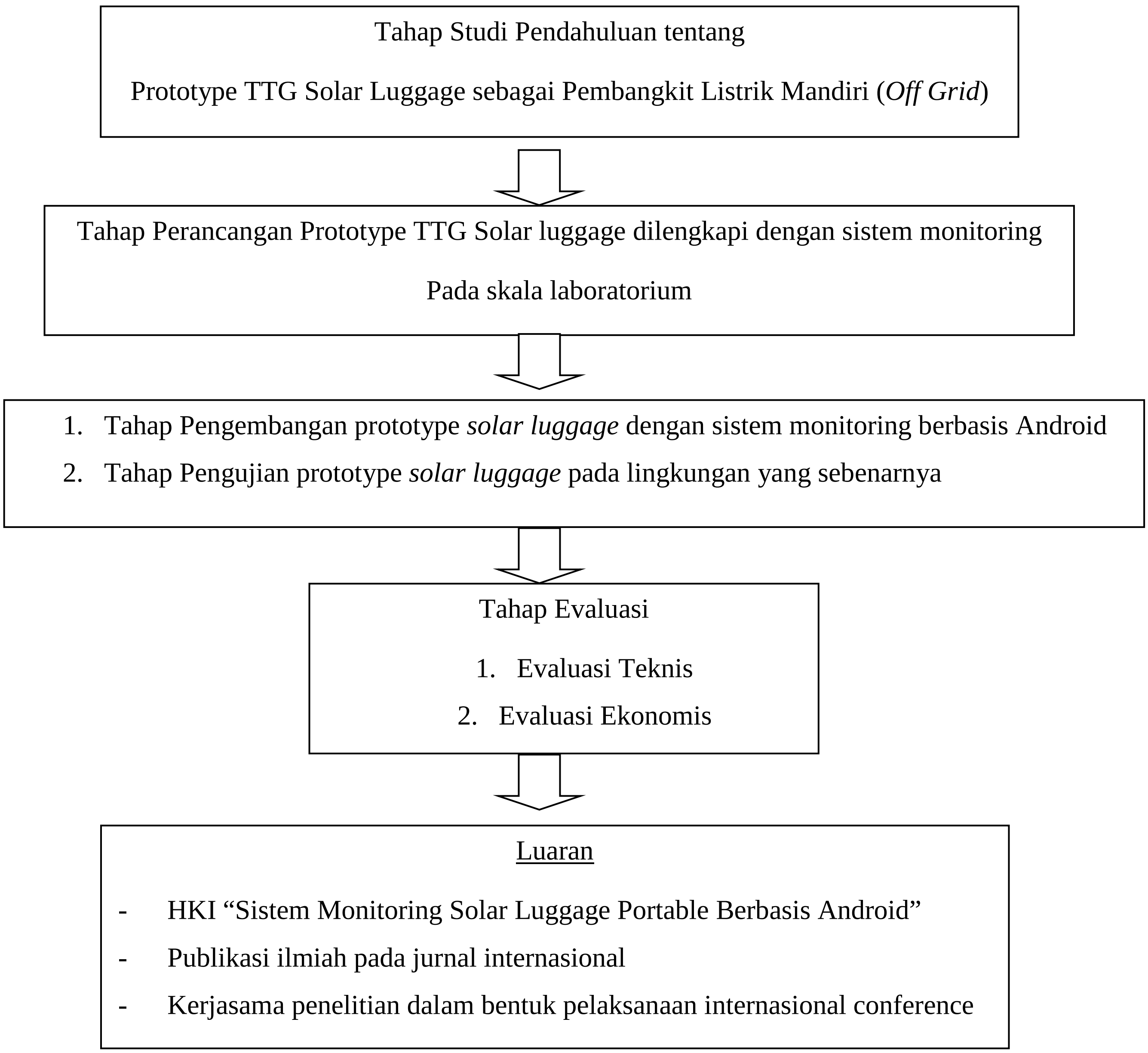
Penerapan Scale Up Teknologi Tepat Guna Pembangkit Listrik *off grid* pada lingkungan sebenarnya berupa proyek contoh /pilot plant *Science Techno Park* yang akan dikembangkan di lokasi pulau terpilih di Bunaken dipresentasikan seperti pada Gambar 12.



Gambar 12. Pengembangan prototype Science Techno Park di Pulau Bunaken

3.4 Metode Penelitian

Metode pada penelitian ini terdiri dari beberapa tahap seperti yang ditunjukan pada blok diagram alir penelitian di Gambar 13.



Gambar 13. Bagan alur kegiatan riset

Penjelasan mengenai bagan alir tahapan riset lengkapnya adalah sebagai berikut:

1. Tahap pendahuluan

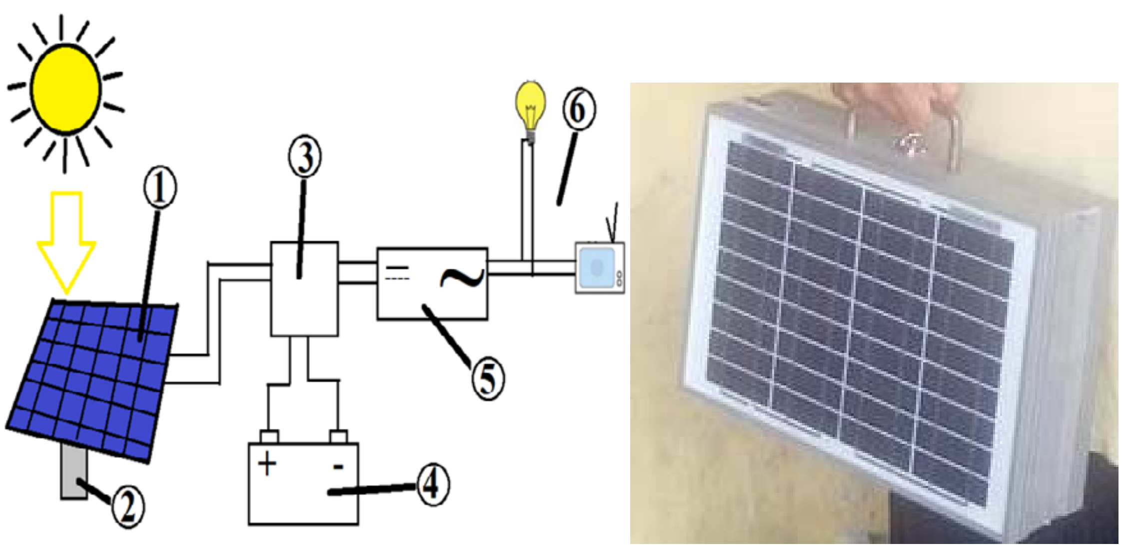
Tahap pendahuluan meliputi terdiri dari proses studi literatur tentang prinsip pemodelan sistem infrastuktur energi berbasis energi terbarukan. Peralatan dan bahan-bahan yang dibutuhkan dalam tahap ini adalah buku text, jurnal-jurnal dan artikel-artikel yang berkaitan dengan tema penelitian yang dibahas. Selain itu dilakukan komunikasi untuk kerjasama penelitian dalam hal penggunaan laboratorium Environmental and Energy Engineering di Waseda University, Japan yang juga melakukan penelitian mengenai energi terbarukan secara internasional.

2. Tahap pengumpulan data untuk pemodelan.

Data-data yang perlu dikumpul adalah sebagai berikut: kondisi eksisting infrastuktur energi kelistrikan yang ada, data konsumsi listrik, data beban listrik dan sosio demografi data di kepulauan Talaud yang menjadi studi kasus untuk pemodelan sistem insfrastuktur energi.

3. Tahap pengembangan prototipe *portable solar luggage* sebagai pembangkit listrik mobile.

Tahap ini dilakukan rancang bangun prototipe portable solar luggage seperti yang ditunjukan pada Gambar 14:

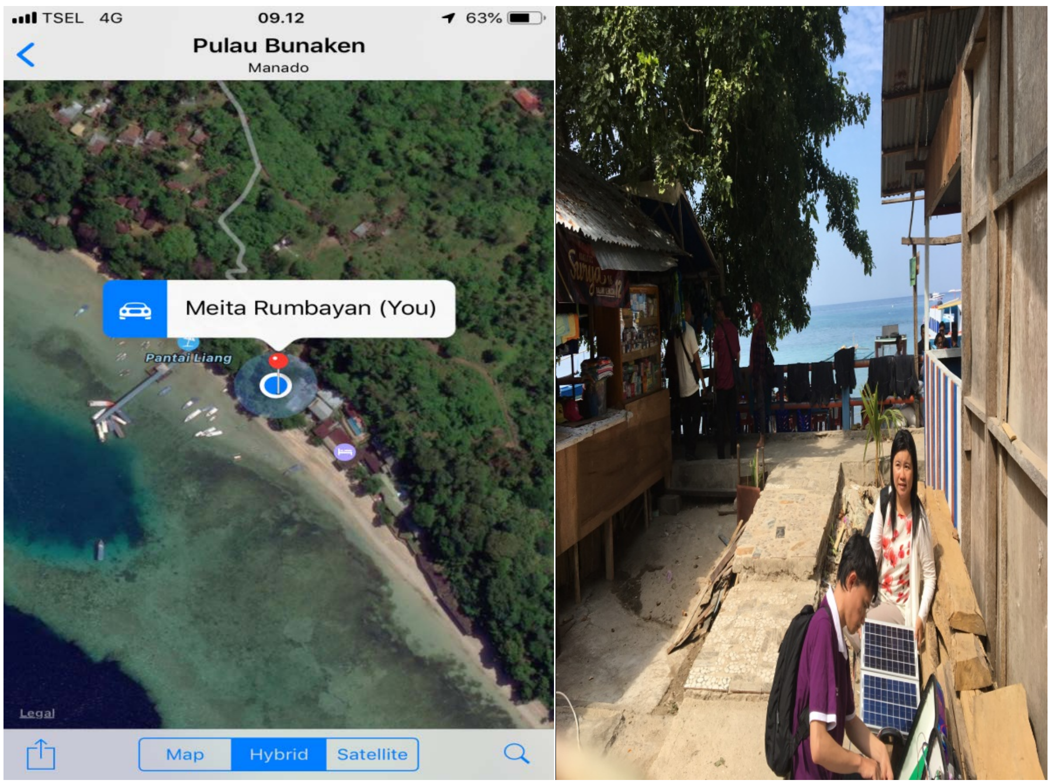


Gambar 14. Desain Prototipe Portable Solar Luggage

4. Tahap kajian dan pengujian prototipe *portable solar luggage*

Tahap ini merupakan pengujian model dari prototipe portable solar luggage untuk masyarakat kepulauan untuk melihat hasil unjuk kerja protype TTG yang dibuat pada lingkungan sebenarnya.

Lokasi pengujian dilakukan di beberapa tempat di kawasan pesisir pulau-pulau di daerah Sulawesi. Untuk tahap awal, dipilih pulau Bunaken sebagai pulau kecil yang berjarak 1 jam dari kota Manado.



Gambar 15. Lokasi pengujian alat prototype solar luggage portable di Pulau Bunaken

Hasil pengujian alat prototype ini bekerja dengan menggunakan sensor arus, sensor tegangan, sensor suhu dipresentasikan pada Gambar 16.

Gambar 16. Cuplikan layar hasil pencatatan data monitoring arus, tegangan dan suhu panel surya

5. Tahap Menghasilkan Output

Output atau luaran yang akan dihasilkan pada tahun ketiga riset pratama kemitraan adalah sebagai berikut:

- *Prototipe* Teknologi Tepat Guna (TTG) portable solar luggage dengan sistem monitoring sebagai pembangkit listrik mandiri untuk masyarakat kepulauan.
- Publikasi ilmiah pada jurnal internasional.
- Kerjasama penelitian dengan mitra berdasarkan letter of invitation dari Prof. Yosuke Nakanishi di Waseda University laboratorium Power System and Environment, Universitas Waseda Jepang. Akses sarana prasarana laboratorium dan konsultasi pakar untuk pengembangan model infrastruktur diberikan sebagai bantuan fasilitas in-kind. Terlampir *letter of support* dari Prof. Yosuke Nakanishi sebagai mitra dan kepala penelitian kolaborasi *eAsia Joint Research Program* dari Japan sebagai bukti komunikasi dalam kemitraan riset yang dilaksanakan (Terlampir).

Kajian ekonomis produk prototype Solar Luggage dihitung dengan analisa Life Cycle Cost (LCC) dengan menggunakan persamaan (1)-(4) sebagai berikut :

$$LCC\ Fuel\ Cost = Annual\ \ Fuel\ Cost \times \left[\left(\frac{1+Fe}{Dr-Fe}\right) \times \left\{1 - \left(\frac{1+Fe}{Dr-Fe}\right)^{period}\right\}\right] \quad (1)$$

Dimana Annual Fuel Cost adalah the annual fuel expenditure, *Fe* adalah fuel escalation, *Dr* adalah discount rate.

Biaya pemeliharaan dihitung dengan Persamaan 2 sebagai berikut:

$$LCC\ Maint.Cost = Ann.Maint.Cost \times \left[\left(\frac{1+Ge}{Dr-Ge}\right) \times \left\{1 - \left(\frac{1+Ge}{1+Dr}\right)^{period}\right\}\right] \quad (2)$$

dimana Annual Maintenance Cost adalah the annual non-fuel expenditure dan *Ge* adalah general escalation.

Persamaan untuk menghitung biaya-biaya non-recurring menggunakan Persamaan 3:

$$LCC\ Repl.Cost = \sum \left[Item\ Cost \times \left\{1 + \left(\frac{1+Ge}{1+Dr}\right)^{Ry}\right\}\right] \quad (3)$$

Dimana Item Cost adalah pembelanjaan non-recurring, *Ge* adalah general escalation, *Dr* adalah discount rate dan *Ry* adalah replacement year.

The Life Cycle Energy Cost (LCC) dihitung dengan menggunakan Persamaan 4.

$$LCC\ = \frac{Capital\ costs + LCC\ Fuel\ Cost + LCC\ Maint.Costs + LCC\ Repl.Costs}{Period \times 365\ kWh/day} \quad (4)$$

Hasil analisa Biaya Siklus life cycle cost (LCC) per kWh dengan 3 skenario pilihan harga produk berdasarkan biaya material dicantumkan pada Tabel 2.

Table. 2 Hasil analisa biaya siklus Life Cycle Cost (LCC) per kWh dari Produk Solar Luggage

Material	***Harga rendah***	***Harga Medium***	***Harga Tinggi***
	[Rp]	**[Rp]**	**[Rp]**
Photovoltaic panel	650,000	1,160,000	1,300,000
Battere	1,500.000	1,750,000	3,850,000
Controller	350,000	650,000	750,000
Lamps	100,000	200,000	250,000
Cable	120,000	150,000	240,000
Total capital cost	2,720,000	3,910,000	6,390,000
Recurring maintenance cost	459,244	575,744	1,078,887
Grand Total cost	5,606,960	7,415,896	13,731,356
Life Cycle Cost (LCC) [Rp/KWh]	4390	5807	10752

BAB 4. HASIL DAN LUARAN YANG DICAPAI

Luaran yang direncanakan pada pelaksanaan riset pratama kemitraan ini adalah produk iptek yang berupa prototipe TTG solar luggage dilengkapi dengan sistem monitoring beserta surat pencatatan ciptaan dengan judul ciptaan “Sistem Monitoring Solar Luggage Portable Berbasis Android” (Terlampir).

Kegiatan riset berupa penerapan TTG pembangkit listrik *portable* untuk pemanfaatan infrastuktur energi pada masyarakat kepulauan, pengujian protipe melalui pilot plant infrastruktur energi berbasis EBT pada lingkungan kepulauan dan publikasi riset internasional di jurnal energi terbarukan mengenai hasil riset dicantumkan pada Tabel 1.

Tabel 1. Luaran Pelaksanaan Riset

Luaran	Status		
	Draft	Submit/Review	Accepted/Publish
Jurnal Nasional			
Jurnal Internasional		1	3
Paten (Hak Cipta)			1
Prototipe	Lab	Scale Up	Sebenarnya

Hasil kegiatan riset INSINAS pada tahun pertama (2017) berupa output sebagai berikut:

1. Publikasi pada jurnal internasional IJRDO dengan judul “*Development of Power System Infrastructure Model for the Island Communities: A Case Study of Kokorotan Island in Indonesia*” dapat diakses online di https://www.ijrdo.org/index.php/eee/article/view/294/(Lampiran)
2. Pemakalah pada seminar internasional di Seoul, Korea Selatan tanggal 28 Agustus-1 September 2017.
3. Start up Meeting eAsia Joint Research Program dalam payung kolaborasi Japan Science Technology (JST) dan Ristekdikti tanggal 11-13 Desember 2017.

Hasil kegiatan riset INSINAS pada tahun kedua (2018) berupa output sebagai berikut:

1. Pemakalah pada International Conference of Renewable and Clean Energy di Tokyo Japan tanggal 30 Maret-1 April 2018.

2. Publikasi terindeks Scopus pada IOP Earth and Environmental Science Vol. 150 dengan judul "*Techno Economical Study of PV-Diesel Power System for a Remote Island in Indonesia: A Case Study of Miangas Island*" dapat diakses online di (http://iopscience.iop.org/article/10.1088/1755-1315/150/1/012024).
3. Kerjasama riset eAsia Joint Research Program dalam payung kolaborasi *Japan Science Technology (JST)* dan Ristekdikti, progress meeting di Waseda Univ, Japan bulan Juli 2018.

Hasil kegiatan riset INSINAS pada tahun ketiga (2019) berupa output sebagai berikut:

1. Publikasi terindeks Scopus pada IOP Earth and Environmental Science Vol. 257 dengan judul "*Empowering remote island communities with renewable energy : a preliminary study of Talaud island.*" dapat diakses online di (https://iopscience.iop.org/article/10.1088/1755-1315/257/1/012024).
2. Hak Cipta Nomor 000158651 dengan judul ciptaan "Sistem Monitoring Solar Luggage Portable Berbasis Android" (Terlampir).
3. Penerapan TTG pembangkit listrik *portable* untuk pemanfaatan infrastuktur energi pada masyarakat kepulauan, pengujian protipe melalui pilot plant infrastruktur energi berbasis EBT pada lingkungan sebenarnya di Pulau Bunaken.
4. Publikasi ilmiah pada jurnal internasional dengan judul "*Model of Solar Energy Utilization in Bunaken Island Communities for Tourism Spot*" dalam status submitted (Terlampir).

Selain rencana luaran tersebut, riset ini merupakan bagian dari penerapan membangun jejaring kerjasama riset untuk *eAsia Joint Research Program* oleh Kemenristekdikti dan *Japan Science and Technology* (JST). Pelaksanaan pertemuan internasional conference dengan mengundang Prof. Yosuke Nakanishi sebagai pembicara kunci menjadi outcome kerjasama antara Universitas Sam Ratulangi dengan Waseda University, yang dilaksanakan di Universitas Sam Ratulangi pada tanggal 23 September 2019 (http://iconsep.unsrat.ac.id/2019/) . Selain itu Tim dari Waseda melaksanakan field trip ke pembangkit listrik berbasis energi terbarukan yaitu pembangkit listrik tenaga air (PLTA) di Tonsea Lama dan panas bumi (PLTPB) di Lahendong, Sulawesi Utara. Kelanjutan kerjasama mitra ditindaklanjuti dengan pembuatan proposal riset dalam tema "*Develop Sustainable and Renewable Energies for Island Communities in the Small*

Island of North Sulawesi Indonesia” di bawah payung kerjasama JSPS dan Kemenristekdikti, Indonesia.

BAB 5. KESIMPULAN DAN SARAN

Masalah keterbatasan akses listrik untuk masyarakat pesisir di daerah kepulauan dapat dicari solusinya dengan penerapan listrik mandiri (off grid) dari sumber energi terbarukan termasuk energi matahari. Pada riset tahun ke-3 telah dibuat model purwarupa dari *solar luggage portable* yang bisa dikembangkan menjadi produk yang bermanfaat bagi masyarakat kepulauan.

Riset yang dikembangkan ini melalui tahap pemodelan, purwarupa/prototype dan pengujian berhasil dengan luaran/output yang diharapkan, yaitu Hak Kekayaan Intelektual (HKI) terdaftar dan produk prototype solar luggage portable dilengkapi dengan sistem monitoring berbasis android yang sudah diterapkan dan diuji pada lingkungan sebenarnya yaitu di Pulau Bunaken.

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LAMPIRAN

WASEDA UNIVERSITY

GRADUATE SCHOOL OF ENVIRONMENT AND ENERGY ENGINEERING
Power System Environment Lab. 55th Building, S-wing, Room 909
3-4-1 Okubo, Shinjuku-ku, Tokyo 169-8555, JAPAN tel +81-3-5286-3126

10 August, 2018

Dear Dr. Meita Rumbayan,
Department of Electrical Engineering
Sam Ratulangi University
Fakultas Teknik, Kampus Unsrat Bahu, Manado 95000 - INDONESIA

Prof. Yosuke Nakanishi,
Graduate School of Environment and Energy Engineering, Waseda University
3-4-1 Ohkubo, Shinjuku-ku, Tokyo 169-8555
JAPAN

I am a Lead PI of collaborative research project, "Research of expandable cluster-based Energy Infrastructure in e-Asia Countries" on the e-Asia Joint Research Program (e-Asia JRP),
which was approved by following four organizations,
Ministry of Research, Technology and Higher Education (RISTEKDIKTI) Indonesia,
Department of Science and Technology (DOS), The Philippines,
National Science and Technology Development Agency (NASDA), Thailand,
and The Japan Science and Technology Agency (JST), Japan.

I am writing this letter of support to conduct research collaboration under e-Asia Joint Research topic as a team member based on your country budget if you could gain the the research funding from RISTEKDIKTI, Indonesia.

Yours Sincerely

中西要祐

Yosuke Nakanishi, Ph.D.

REPUBLIK INDONESIA
KEMENTERIAN HUKUM DAN HAK ASASI MANUSIA

SURAT PENCATATAN CIPTAAN

Dalam rangka pelindungan ciptaan di bidang ilmu pengetahuan, seni dan sastra berdasarkan Undang-Undang Nomor 28 Tahun 2014 tentang Hak Cipta, dengan ini menerangkan:

Nomor dan tanggal permohonan	:	EC00201975398, 10 Oktober 2019
Pencipta		
Nama	:	**Meita Rumbayan, Imanuel Efrat Pujiko Pundoko,**
Alamat	:	Crystal Park 3 No.7. Citraland, Manado, Sulawesi Utara, 95000
Kewarganegaraan	:	Indonesia
Pemegang Hak Cipta		
Nama	:	**Sentra Kekayaan Intelektual Universitas Sam Ratulangi**
Alamat	:	Gd.LPPM Lt-1. Jln. Kampus Unsrat, Manado, Sulawesi Utara, Manado, Sulawesi Utara, 95115
Kewarganegaraan	:	Indonesia
Jenis Ciptaan	:	**Program Komputer**
Judul Ciptaan	:	**Sistem Monitoring Solar Luggage Portable Berbasis Android**
Tanggal dan tempat diumumkan untuk pertama kali di wilayah Indonesia atau di luar wilayah Indonesia	:	10 Oktober 2019, di Manado
Jangka waktu pelindungan	:	Berlaku selama 50 (lima puluh) tahun sejak Ciptaan tersebut pertama kali dilakukan Pengumuman.
Nomor pencatatan	:	000158651

adalah benar berdasarkan keterangan yang diberikan oleh Pemohon.
Surat Pencatatan Hak Cipta atau produk Hak terkait ini sesuai dengan Pasal 72 Undang-Undang Nomor 28 Tahun 2014 tentang Hak Cipta.

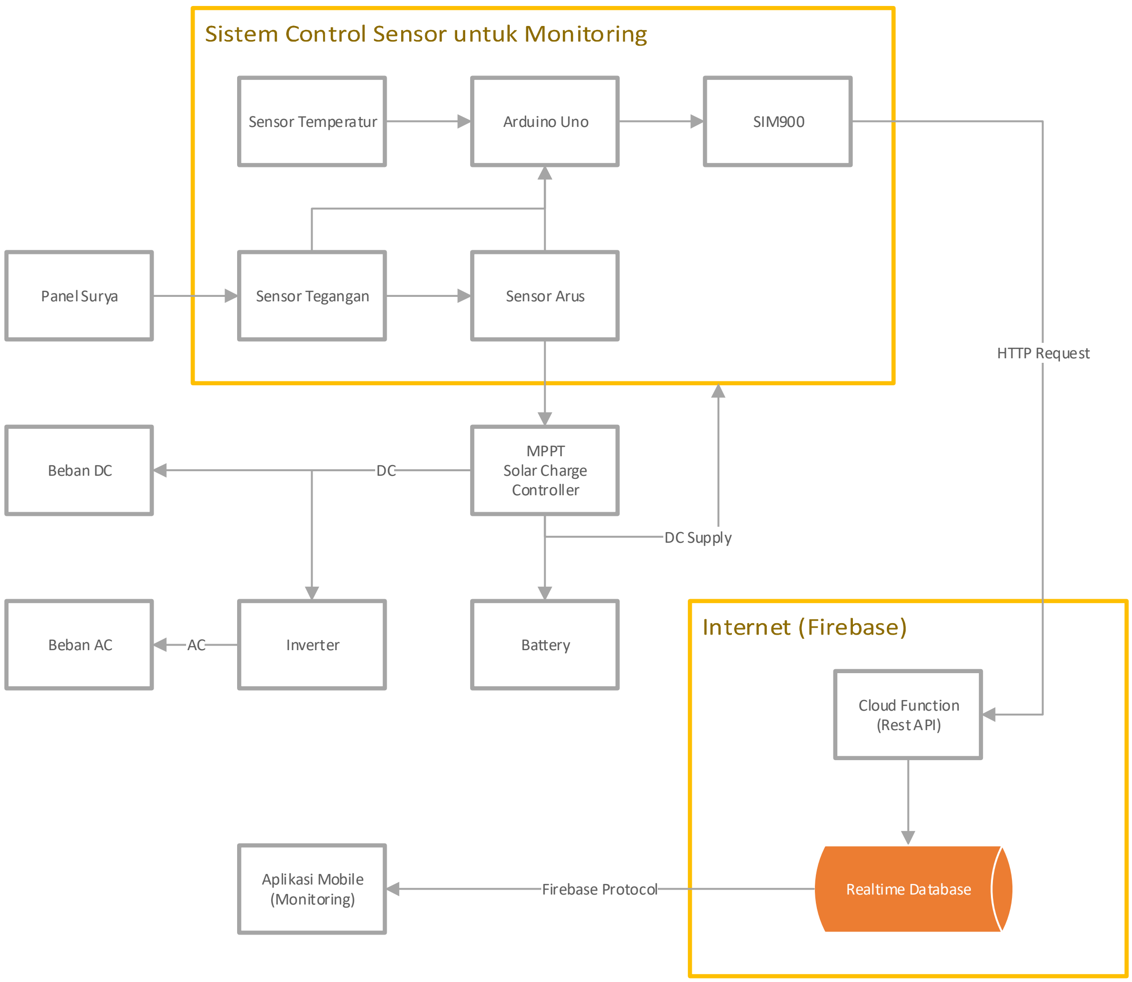
a.n. MENTERI HUKUM DAN HAK ASASI MANUSIA
DIREKTUR JENDERAL KEKAYAAN INTELEKTUAL

Dr. Freddy Harris, S.H., LL.M., ACCS.
NIP. 196611181994031001

Deskripsi

Sistem Monitoring Solar Luggage Portable Berbasis Android

Oleh: Meita Rumbayan, Imanuel E.P Pundoko



Sistem monitoring solar luggage portable berbasis android dirancang untuk melakukan pencatatan data dari panel surya yang terintegrasi menjadi solar luggage portable. Tujuan sistem monitoring solar luggage portable ini untuk melakukan pencatatan data arus, data tegangan dan data suhu yang terukur pada lingkungan dimana solar luggage ditempatkan pada lokasi tertentu. Dengan sistem monitoring ini, unjuk kerja dari solar luggage portable dapat diukur dan diamati melalui telepon genggam.

Manual

Tampilan (Icon) aplikasi pada halaman utama android.

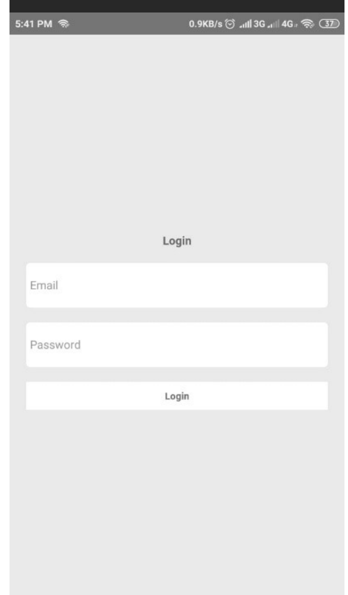
Ketuk icon untuk memulai aplikasi

Tampilan Halaman Login Aplikasi

Untuk melihat hasil monitoring dalam bentuk visualisasi grafis:

1. Email dan Password yang telah terdaftar.
2. Login untuk masuk ke aplikasi.

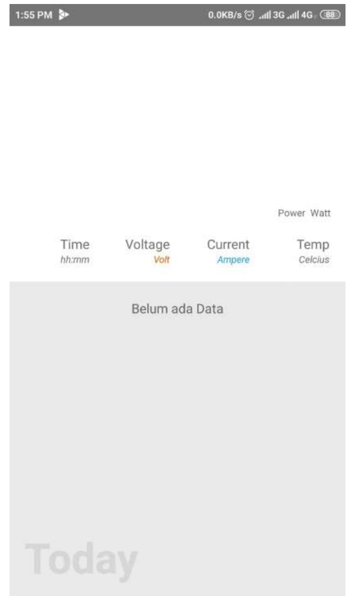
*) Ini adalah halaman utama jika belum ada akun yang ter-login pada aplikasi ini di perangkat



Tampilan halaman data perdetik yang masih kosong (belum ada data).

*) Ini adalah halaman yang akan di tampilkan setelah melewati proses Login.

**) Ini adalah halaman awal aplikasi ketika aplikasi pada perangkat telah melakukan proses Login

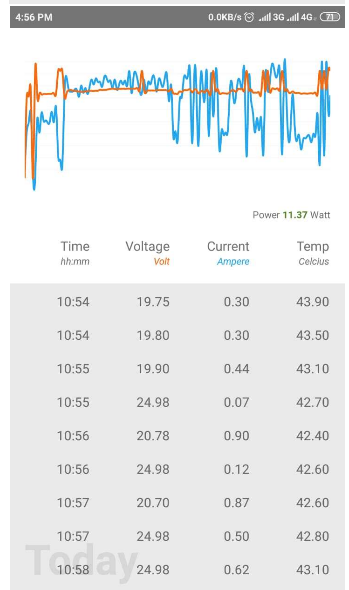


Tampilan halaman data perdetik yang masih sudah ada data.

Untuk melihat data perhar, usap layar dari kanan ke kiri.

*) Ini adalah halaman yang akan di tampilkan setelah melewati proses Login

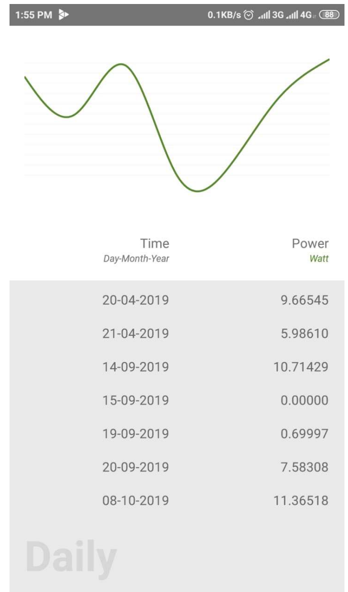
**) Ini adalah halaman awal aplikasi ketika aplikasi pada perangkat telah melakukan proses Login



Tampilan halaman data perhari

Untuk kembali ke halaman data perdetik, usap layar dari kiri ke kanan.

*) Ini adalah halaman yang akan di tampilkan setelah mengusap layar dari kanan ke kiri



Kode Sumber

Kode Sumber pada Plant (Arduino)

```
#include <DHT.h>
#include "ACS712.h"
#include <SoftwareSerial.h>
SoftwareSerial mySerial(7, 8);
int pinTegangan = A5;
int pinArus = A4;
int pinTemperatur = A0;
float tegangan,arus, temperatur;
DHT asd(pinTemperatur, DHT11);
ACS712 arusACS(ACS712_05B, pinArus);
void setup() {
  Serial.begin(9600);
  mySerial.begin(9600)
  Serial.println("Initializing...");
  asd.begin();
  delay(1000);
  initSIM();
  Serial.println("Callibrating...");
  int zero = arusACS.calibrate();
  Serial.println("Done!");
}
void loop() {
  delay(5000);
  tegangan = bacaTegangan(pinTegangan);
  arus = bacaTegangan(pinTegangan);;
  temperatur = asd.readTemperature();
  Serial.print("Tegangan :");
  Serial.print(tegangan);
  Serial.print("| Arus :");
  Serial.print(arus);
  Serial.print("| Temperature :");
  Serial.println(temperatur);
  sendData(tegangan, arus, temperatur);
}
void initSIM() {
  mySerial.println("AT");
  updateSerial(500);
  mySerial.println("AT+CSQ");
  updateSerial(500);
  mySerial.println("AT+CCID");
  updateSerial(500);
  mySerial.println("AT+CREG?");
  updateSerial(500);
  mySerial.println("AT+CGATT=1");
  updateSerial(500);
}
```

```
void updateSerial(int d) {
  delay(d);
  while (Serial.available()) {
    mySerial.write(Serial.read());
  }
  while(mySerial.available()) {
    Serial.write(mySerial.read());
  }
}
void sendData(float voltage, float current, float temp) {
  Serial.println("Sending data.");
  mySerial.println("AT+SAPBR=3,1,\"Contype\",\"GPRS\"");
  delay(500);
  mySerial.println("AT+SAPBR=3,1,\"APN\",\"\"");
  delay(500);
  mySerial.println("AT+SAPBR=1,1");
  delay(500);
  mySerial.println("AT+SAPBR=2,1");
  delay(3000);
  mySerial.println("AT+HTTPINIT");
  delay(500);
  mySerial.println("AT+HTTPPARA=\"CID\",1");
  delay(500);

  mySerial.print("AT+HTTPPARA=\"URL\",\"http://us-central1-monitoring-panel-
surya.cloudfunctions.net/addData?");
  mySerial.print("current=");
  mySerial.print(current);
  mySerial.print("&voltage=");
  mySerial.print(voltage);
  mySerial.print("&temperature=");
  mySerial.print(temp);
  mySerial.println("\"");
  delay(3000);

  mySerial.println("AT+HTTPACTION=0");
  delay(15000);
  mySerial.println("AT+HTTPTERM");
  delay(500);
  mySerial.println("AT+SAPBR=0,1");
  delay(500);
  Serial.println("Finish.");
}
```

```
float bacaTegangan(int pin) {
  float R1 = 30000.0;
  float R2 = 7500.0;
  float value = analogRead(pin);
  float vOUT = (value * 5.0) / 1024.0;
  float vIN = vOUT / (R2/(R1+R2));
  delay(500);
  return vIN;
}

int bacaArus() {
  return arusACS.getCurrentDC();
}
```

Kode sumber pada Server (Firebase Cloud Function)

```
const functions = require('firebase-functions');
const moment = require('moment');

const admin = require('firebase-admin');
admin.initializeApp();

exports.transformToPower = functions.database.ref('/daily/{docs}/data/{id}').o
nCreate((snap) => {
  const ref = snap.ref.parent.parent;
  return admin.database().ref(snap.ref.parent.parent.child('data')).once('valu
e').then(snap => {
    let arr = [];
    snap.forEach((a) => {
      arr.push(a.val().power);
    })
    const power = arr.reduce((a, b) => a + b) / arr.length;
    return admin.database().ref(ref).update({ power });
  })
});

exports.addData = functions.https.onRequest((req, res) => {
  const time = moment();
  const { current, temperature, voltage } = req.query;
  const power = current * voltage;
  const docs = moment(time.format('YYYY-MM-DD')).unix();
  const id = time.unix();
  console.log(docs);
  console.log(id);
  return admin
    .database()
    .ref(`/daily/${docs}/data/${id}`)
    .set({
      current: Number(current),
      temperature: Number(temperature),
      timestamp: time.unix(),
      voltage: Number(voltage),
      power
    }).then(() => {
      return res.send(`Voltage: ${voltage} || Current: ${current} || Temperatu
re: ${temperature} || Power: ${power} || Time: ${time.format('HH-
mm')} || Timeoffset: ${time.utcOffset()}`);
    });
});
```

Model of Solar Energy Utilization in Bunaken Island Communities for Tourism Spot

Meita Rumbayan

***Abstract*: The ambitious planning of renewable energy utilization in Indonesia to achieve 23% in the country's energy mix by 2025 push the development of model community using Photovoltaics stand alone system. The issue about island electricity access is happening in Bunaken as one of the famous tourism spot in Indonesia. Island communities is facing the limited access toward the availability of electrical energy in day and night time. This article is aims to develop a model for solar energy utilization in Bunaken island communities for tourism spot. The design and cost benefit analysis have been done for Bunaken community for lighting and handpone charging. The result indicated that the utilization of PV stand alone system in Bunaken can be introduced by solar luggage package for the communities who willing to support their small medium entreprise.**

***Keywords* : Island Communities, Bunaken, Solar Energy utilization, Photovoltaics stand alone system.**

I. INTRODUCTION

The utilization of solar energy in island communities is increasing time by time due to the necessity of energy electricity access. The challenge in this research is the adoption of new renewable technology that supports the communities in Bunaken as the tourism spot. Like a terrace of house that needs lighting, so the small islands in the Indonesian territory need to be electrified well. Electric energy infrastructure for the islands needs to get attention for the security and welfare of the island communities.

The objective of this study was to design the prototype of solar luggage as the photovoltaic stand-alone system to supply lighting and hand phone charging . Also the economic analysis based on cost benefit analysis was done to calculate the price of the solar luggage prototype.

The location of Bunaken island as the tourism spot ……This coastal area is facing limited access to electrical energy grid. Based on survey to this area, it is found that there is no 24 hours electricity supply from the grid. The fact this community located in this spot tourism that run the business of restaurant need the electricity. Therefore the solution for independent electricity supply becomes important and urgent.

Geographically, Bunaken island is located between $124^{0}04'$-$124^{0}48'$ E and $1^{0}37'$-$1^{0}47'$ N. It takes 30 minutes by boat from Manado, the capital city of North Sulawesi province. The map of Bunaken island is shown in Figure 1.

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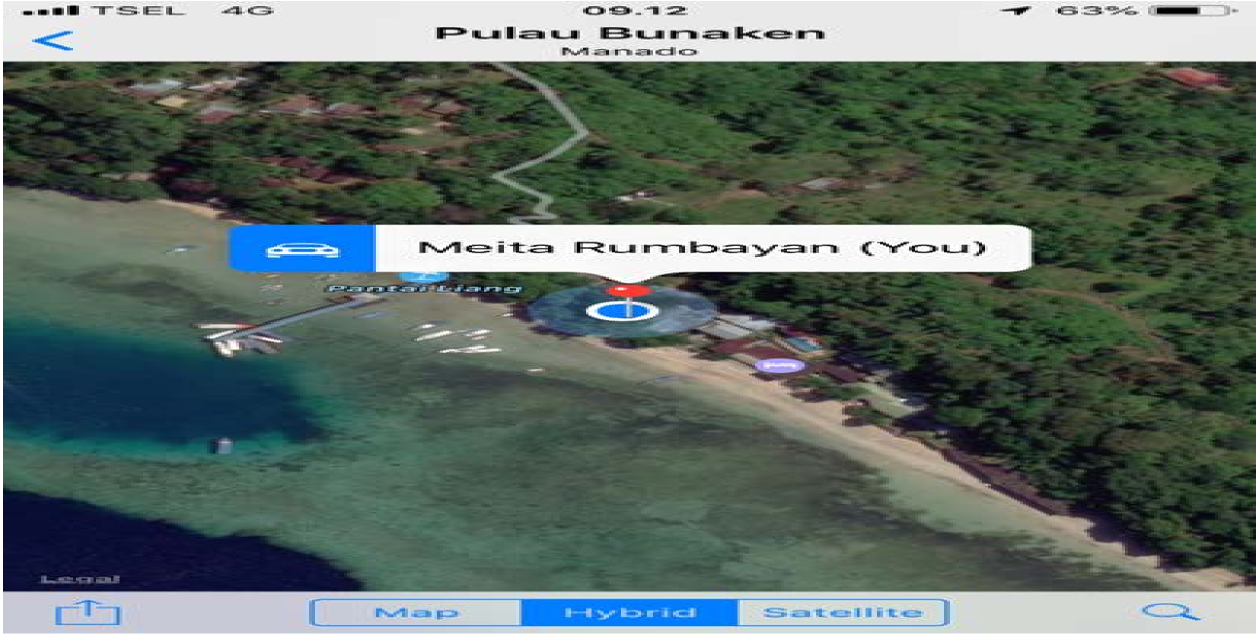

Fig. 1. The Mapof Bunaken Island as The Tourism Spot
in North Sulawesi Indonesia

II. LITERATURE REVIEW

A. The Design of Photovoltaics Stand Alone System

A. The Design of Photovoltaics Stand Alone System

The potentials of solar energy has been analyzed [1]. Another reference that is reviewedthe usage of solar home system in rural Bangladesh [2]. This canse is for a reference for the implementation of solar power plant systems in rural Indonesia.

Rumbayan and Nagasaka [3] reported that the cost of generating electrical energy with renewable energy is relatively high and so, there is a need to implement policies and strategies for the induction of renewable energy in the archipelago. Such policies include: cooperation with parties that have been successful with the implementation of renewable energy technologies, increased priority implementation of renewable energy-based energy infrastructure for potential locations. The adoption of a pro-island energy policy in the foremost island as a terrace that needs to be enriched for the sake of security, welfare and beauty as an added value in Indonesia's border region.

Many small islands around the world currently use/propose to use renewable energy: the Azores and Canary islands in the North Atlantic, Gotland and Samsoe in the Baltic, Sardinia and Sicily in the Mediterranean, Mauritius and Reunion in the Indian Ocean, Fiji and the Hawaiian islands in the Pacific, as well as Dominica and the Guadeloupe islands in the Caribbean. Many small islands have achieved their goal of transitioning to renewable energy [4].

References [4] show that around the world, a few islands have already become a Renewable Energy Island (REI) in a short or medium term. Samsoe (Denmark), Pellworm (Germany), Aeroe (Denmark), Gotland (Sweden), El Hierro (Spain), Dominica and St. Lucia have an explicit target of becoming 100% self sufficient from renewable energy sources. Nearly 70% of the islands in the overview that are utilising renewables for electricity generation are producing between 0.7-25% of their electricity from renewable energy sources.

B. Life Cycle Cost Analysis

Life Cycle Cost analysis is defined as a tool used to compare the ultimate delivered costs of technologies with different cost structures. The function of LCC analysis is to calculate the cost of delivering over the life of the projects, is is not only calculate the initial costs or operating cost [5].

The Life Cycle Cost is calculated using Equations (1)-(4).

The equation representing the life cycle fuel costs is the life cycle period in year.

$$LCC\,Fuel\,Cost = Annual\;\;Fuel\;Cost \times \left[\left(\frac{1+Fe}{Dr-Fe}\right) \times \left\{1-\left(\frac{1+Fe}{Dr-Fe}\right)^{period}\right\}\right] \quad (1)$$

where Annual Fuel Cost is the annual fuel expenditure, *Fe* represents fuel escalation, *Dr* represents discount rate, and Period is

Recurring maintenance cost is presented by Equation 2.

$$LCC\,Maint.\,Cost = Ann.\,Maint.\,Cost \times \left[\left(\frac{1+Ge}{Dr-Ge}\right) \times \left\{1 - \left(\frac{1+Ge}{1+Dr}\right)^{period}\right\}\right] \qquad (2)$$

where Annual Maintenance Cost is the annual non-fuel expenditure *Ge* represents general escalation.

The equation for non-recurring costs is presented by Equation 3:

$$LCC\,Repl.\,Cost = \sum \left[Item\ Cost \times \left\{1 + \left(\frac{1+Ge}{1+Dr}\right)^{Ry}\right\}\right] \qquad (3)$$

where Item Cost is the non-recurring expenditure in present day costs, *Ge* represents general escalation, *Dr* is the discount rate and *Ry* is the replacement year.

The Life Cycle Energy Cost is presented by Equation 4.

$$LCC = \frac{Capital\ costs + LCC\ Fuel\,Cost + LCC\ Maint.Costs + LCC\ Repl.Costs}{Period \times 365\ kWh/day} \qquad (4)$$

in which LCC is the life cycle cost per kWh of energy [5].

III. THE DESIGN OF SOLAR LUGGAGE SYSTEM

The model of solar luggage system as the independent power source is considered to be installed in the coastal area of tourism spot in Bunaken island is described in Figure 2.

It is planned to be develop the independent solar photovoltaics system in the tourism spot of Bunaken island described as in the Figure 3.

Figure 3. The Model of Independent Solar PV System in Tourism Spot at Bunaken Island

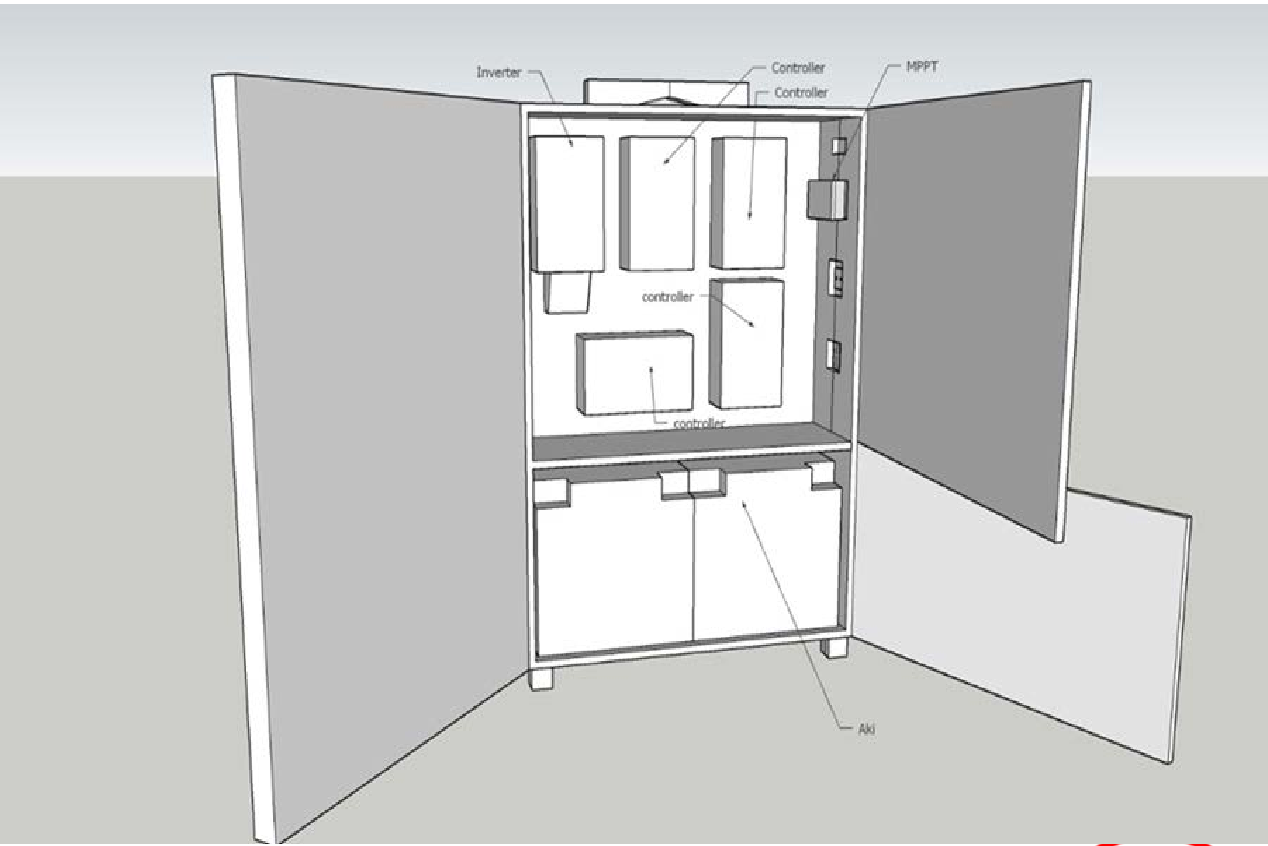

Fig. 2. The Design Model of Solar Luggage of Photovoltaic System

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Table- I: The Result of Life Cycle Cost Calculation of Solar Luggage

Material	*Low Price*	*Medium Price*	*High Price*
	[Rp]	**[Rp]**	**[Rp]**
Photovoltaic panel	650,000	1,160,000	1,300,000
Battere	1,500.000	1,750,000	3,850,000
Controller	350,000	650,000	750,000
Lamps	100,000	200,000	250,000
Cable	120,000	150,000	240,000
Total capital cost	2,720,000	3,910,000	6,390,000
Recurring maintenance cost	459,244	575,744	1,078,887
Grand Total cost	5,606,960	7,415,896	13,731,356
Life Cycle Cost (LCC) [Rp/KWh]	4390	5807	10752

IV. FINANCIAL ANALYSIS

The Life Cycle Cost Analysis is estimated using Equations 1-4. The following economic factors are assumed as life cycle is 10 years, discount rate (*Dr*) is 10 %, annual inflation or cost escalation (*Ge*) is 5%. The replacement cost is assumed as zero.

Thus the total energy generated by system is 365 days /year times 350 Wh equal to 1277.5 kWh in 10 years. The capital cost of solar luggage system is given in the Table I.

The Life Cycle Cost for the three options of solar luggage packet is shown in Table 1. The cost of Rupiah per KWh is equal to 2 times, 3 times and 5 times compare to electricity price from the grid that serve by diesel powerplant.

V.CONCLUSIONS

This study was proposed a model of solar energy utilization in Bunaken island communities. A solar luggage model was developed using solar panel, controller and battery. The solar luggage model with its panel were built for supplying the lighting and handphone charging demand.

The model economic was analyzed by cost benefit analysis. It was found that the solar luggage model developed was interested to introduce for Bunaken island communities to support electrical energy demand for tourism spot.

The results from the cost benefit analysis showed the model was interested to be a business model development for island communities in order to supply lighting and charging on the spot.

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AUTHORS PROFILE

Meita Rumbayan studied in Energy Engineering at Asian Institute of Technology, Thailand for her Master degree and completed her Doctor of Engineering in 2013 at Tokyo University of Agriculture and Technology, Japan. She works as Researcher and Lecturer at Electrical Engineering Department, Sam Ratulangi University, Manado, Indonesia. She actively participates in community service in the field of renewable energy.

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Empowering remote island communities with renewable energy : a preliminary study of Talaud Island

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Empowering remote island communities with renewable energy : a preliminary study of Talaud Island

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Abstract. This paper describes a preliminary study of the empowering remote island communities with renewable energy. This research is a case study for Talaud island which is located in the border island between Indonesia and Philipines. It is located in Kiama village Talaud Island regency of North Sulawesi province of Indonesia. Method of implementation of this program consists of several stages, namely: (1) Implementation of small-scale solar home system and a wind turbine; (2) Through technology transfer in the capacity building activities to the selected community, in order to provide the skill and knowledge to island community in Kiama Village, Talaud Islands of Indonesia. It is expected that technology implementation will be maintained in the future and sustainable. The life cycle cost analysis is done by comparing two system of pilot projects, namely solar home system and solar home system with a wind turbine. The cost of generating electrical energy with renewable energy is relatively high then it is necessary to provide strategies for the development of power infrastructure for the sake of the energy security of island communities in Indonesia. Further both monitoring and evaluation of the renewable energy system implementation should be conducted for the detail report and analysis.

1. Introduction

The eastern region of Indonesia, especially the island which is the outermost island that becomes the front border requires special attention in the case of energy problems. Dependence on the supply of fossil fuels from the island to the island that have high transportation costs and produce greenhouse gases need to be minimized. For this reason the utilization of renewable energy as an alternative energy source for energy generation needs to be studied.

Talaud island was chosen as the location to be studied because of its specificity located on the border between Indonesia and the Philippines is the outermost island which became the front porch of Indonesian territory. Geograpphically, Talaud island is located between 125° 9'28" – 125° 24'25" E and 02° 4'13" – 02° 52'47" N. Talaud island is situated in regency of Talaud Island. It takes 10 hours by boat or 1 hour by flight from Manado, the capital city of North Sulawesi provience. The island of of Talaud islands is shown in Figure 1.

Figure 1. Map of Talaud Islands

Talaud islands are facing the high cost of diesel fuel due to remoteness from Sulawesi mainland. This paper presents a preliminary study of renewable energy utilization based on local availability of renewable energy resources in the remote island of Indonesia for an independent system electrical power on a rural house scale.

2. Literature Reviews

Analysis of solar energy potential has been done through a research [1]. The implementation of solar home system in rural Bangladesh [2] has also been reviewed as a reference for the implementation of solar power plant systems in rural Indonesia.

Many small islands in every region in the world use or propose to use renewable energy: the Azores and Canary islands in the North Atlantic, Gotland and Samsoe in the Baltic, Sardinia and Sicily in the Mediterranean, Mauritius and Reunion in the Indian Ocean, Fiji and the Hawaiian islands in the Pacific, as well as Dominica and the Guadeloupe islands in the Caribbean. Many small islands have achieved their goal of transitioning to renewable energy [3].

References [3] stated that around the world a few islands already have taken the decision to become a Renewable Energy Island (REI) in the short or medium term. Samsoe (Denmark), Pellworm (Germany), Aeroe (Denmark), Gotland (Sweden), El Hierro (Spain), Dominica and St. Lucia have an explicit target of becoming 100% selfsufficient from renewable energy sources. Nearly 70% of the islands in the overview that are utilising renewables for electricity generation are producing between 0.7-25% of their electricity from renewable energy sources.

References [4] states “Life cycle cost (LCC) analysis is a tool used to compare the ultimate delivered costs of technologies with differenr cost structures”. The function of LCC analysis is to calculate the cost of delivering over the life of the projects, is is not only calculate the initial costs or operating cost.

The life cycle cost (LCC) analysis which is consist of capital cost, recurring maintenance cost, fuel cost and replacement cost has been used for economic evaluation of a stand alone residential of photovoltaic for remote area in Bangladesh [5]. The LCC was analyzed by considering 20 years of life cycle, discount rate as 7%, general inflation as 3% and the estimated of the load power supply as 640 Wh per day. In this analysis, the result indicated the LCC to be economically feasible compare to conventional electricity using diesel generator.

The cost of generating electrical energy with renewable energy is relatively high then there is a need for policies and strategies for the implementation of renewable energy in the archipelago, among others: cooperation with parties that have been successful with the implementation of renewable energy technologies, increased priority implementation of renewable energy-based energy infrastructure for potential locations. The adoption of a pro-island energy policy in the foremost island as a terrace that needs to be enriched for the sake of security, welfare and beauty as an added value in Indonesia's border region [6].

3. Methods

The data collected for the input, in the form of population data, the existing condition of electricity in Miangas island are given in Table 1.

Table 1. Communities Data in Talaud Island

Number of People	775
Number of Households	324
Daily Load Average	500 kWh
Installed Capacity of Diesel Powerplant	250 kW

Feasibility of solar energy system mainly depends on solar radiation available at the specific location [7]. Data of solar energy sources in term of solar irradiation in Talaud island have been taken from NASA (*National Aeronautics and Space Administration*) website by input the latitude and longitude of the location. The average annual solar radiation equals to 5.53 kWh/m^2/day. NASA also gives the wind speed data for Talaud island. The data of solar radiation and wind speed in Talaud island are presented in Table 2.

Table 2. Average Monthly Solar Irradiation and Wind Speed Data in Talaud island

Month	Average Solar Irradiation (KWh/m^2/day)	Average Wind Speed (m/s)
January	5.01	2.57
February	5.43	2.57
March	6.05	2.57
April	6.40	2.57
May	5.73	2.57
June	5.00	3.08
July	5.32	3.59
August	5.50	4.11
September	5.84	3.08
October	5.71	3.08
November	5.38	2.05
December	5.01	2.57

The implementation of solar home system technology in coastal communities of Talaud island provides measurable outcomes that affects the application of appropriate technology to the community and improves the welfare and convenience of the community in Kiama village as described in Figure 2.

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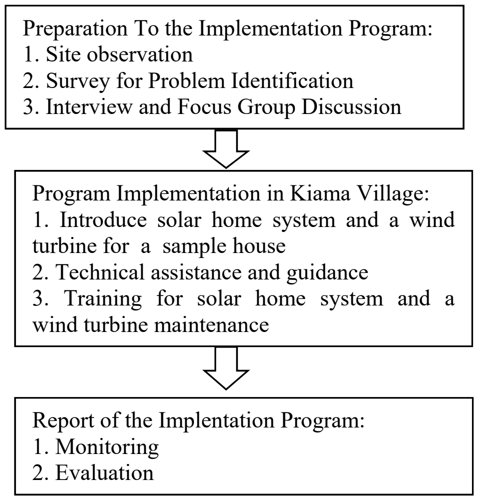

Figure 2. Implementation Method of the Hybrid Home System Program Activities

Implementation of solar home system technology in Kiama village has been done in several stages as described below:

3.1. Introduces small-scale solar wind power plant technology.
Implementation of solar home system as a small pilot in a home which is located in Kiama village in Talaud island has been done by using a solar panel 50 Wp, batterey, inverter and system controller. The total capital cost of equipments and installation are counted about Rp. 5.000.000,-. The cost of wind turbine with capacity 50 Watt and the simple tower are counted about Rp. 5.000.000,-.

3.2. Technical assistance and guidance on small-scale solar power plant operation.
Assistance on how to operate an installed solar power plant at sample houses has been done by the team who has knowledge of this technology. A standard operating guide has been written and taught to small home-scale solar power plant users. Assistance was carried out after the installation of the solar power plant at the sample house was done.

First, the approach methods are survey, interview and field visit. Based on preliminary survey, site observation, and data collection in Kiama village, identificate the problem by Implementation Team.

Second, at this stage the approach method is to conduct a focus group discussion between implemention teams and partners in Kiama village for finding solutions to the problems of coastal communities in the demand of energy.

Third, the approach method is the application of appropriate technology through the design of the installation of solar home system as a solution in solving communities's problems, mentoring and technical guidance, as well as counseling for increasing the knowledge and skills of the community on technology and given solutions.

From the results of observation and interviews, it is known that this village has a problem of limited access of houses to the electricity grid. In the initial discussion, implementedon team offered a solution that introduces the community to small-scale solar power plant technology. Through the introduction of small scale home system technology, the problem of limitation of electricity accsess in the village could be solved.

Since Hybrid Home System technology is still relatively expensive, the team decided to install the system at the sample house located in Kiama village, which is located in Talaud island, one of the remote island in North Sulawesi provience of Indonesia.

Installation of a small-scale SHS system in a Kiama village in Talaud island is followed by mentoring and technical guidance on the operation of the system and training on how to treat the SHS and wind turbine for rural and remote communities.

4. Results
The proposed of hybrid power generation model based on PV and wind energy for a rural house in Talaud island as shown in Figure 3.

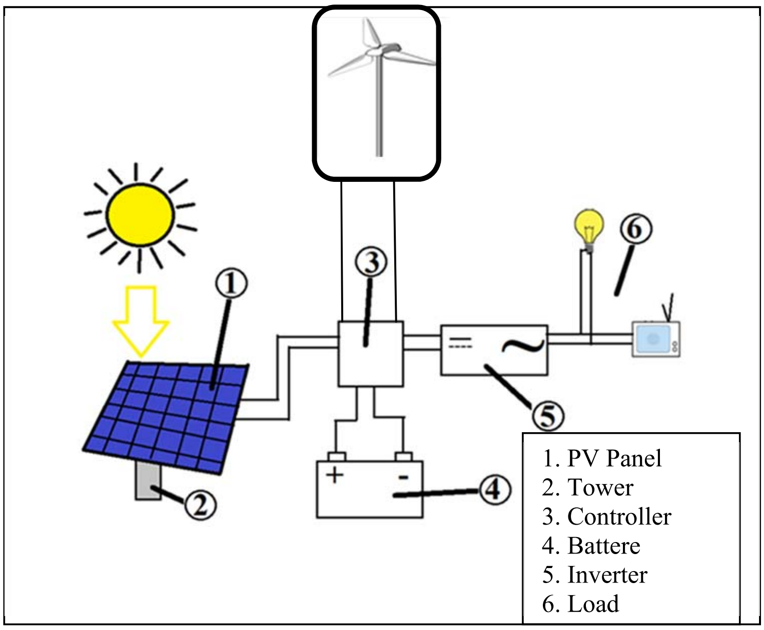

Figure 3. The Proposed of Hybrid Home System Model for A Rural House in Talaud Island

The installation results of system model are shown Figure 4.

Figure 4. The result of Implementation for the Model of Wind Solar Power System in Talaud Island

Monitoring and evaluation of program implementation of solar wind power model for a rural house in Kiama village are done by observation and economic evaluation through life cycle cost analysis. The sustainability of this program can be sustained through the transfer of knowledge and skills regarding the operation and maintenance of technologies that already introduced to the coastal communities in Kiama village, Talaud island.

The results of economic evaluation of a stand-alone solar home system in Talaud island are presented in Table 3.

Table 3. Economic Evaluation of a SHS in Talaud Island

	Daily Energy Generated (Wh)	Total Energy in 20 years (kWh)	LCC of SHS only (Rp/ kWh)	LCC of SHS with wind turbine (Rp/ kWh)
1	200	1460	3424	6848
2	300	2190	2283	4566
3	400	2920	1712	3424
4	500	3650	1369	2738
5	600	4380	1141	2282

The economic evaluation analysis of a Solar Home System in Kiama Village which is located in Talaud island has been presented in Table 3. It is found that the Life Cycle Cost of a SHS will be varied depend on the daily energy generated to supply energy for a home. The more energy generated for this system installed, the more total energy could be generated for 20 years of the system life. The life cost for this SHS will be achieved good price in the below of 2000 Rp/ kWh as compare to the electricity price from the grid of PLN. The LCC analysis shows double cost of Solar Home System with a wind turbine installation to power a rural house in Kiama village. Through direct observation of wind turbine indicates frequently work due to the wind has no occur in the area of installation.

5. Conclusion

The problem of limited access of electricity for the coastal community in Kiama village, which is located in Talaud island has been searched to find the solution. Implementation of small scale solar home system technology has been introduced in a house as a small pilot project. In the future, detail data will be collected from the implementation in order to monitor and evaluation of the practices.
The implementation of SHS in Kiama village which is located in Talaud island have been done through the introduction and capacity building of SHS technology and a wind turbine in a sample house as a small pilot.
The outcomes the implementations of SHS system in coastal communities are as follows: design and installation of SHS technology for a small pilot home as well as improvement of the community's knowledge and skills about SHS technology by a training.

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Techno Economical Study of PV-Diesel Power System for a Remote Island in Indonesia : A Case Study of Miangas Island

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Techno Economical Study of PV-Diesel Power System for a Remote Island in Indonesia : A Case Study of Miangas Island

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Abstract. The purpose of this study is to conduct the techno economical study of PC-Diesel power system based on renewable energy available locally in a remote island. This research is a case study for Miangas island which is the border island between Indonesia and Philipines. It is located in Talaud Island regency of North Sulawesi province of Indonesia. The monthly average daily radiation in Miangas island is 5.52 kWh/m^2.The research methods used are data collection and data analysis using software HOMER. Based on the simulation result, the techno economic study of PV-Diesel power plant system based on energy demand in Miangas island can be obtained. The Cost of Energy (COE), Net Present Cost (NPC) and operating cost for proposed hybrid PV-Diesel power generation can be assessed for the design power systems uses Canadian solar Max Power C56x-325P of 150 KW PV, 18 string of Surette 6CS25P, Diesel Generator 50 kW and converter Magnum MS4448PAE 25 kW. The annual electricity production from the PV Diesel system for Miangas island is 309.589 kWh in which 80.7% electricity comes from PV, 19.3% electricity comes from diesel with the 109.063 kWh excess electricity. The cost of generating electrical energy in the term of cost of energy (COE), Net Present Cost (NPC) and operating cost are 0.318 US$/kWh, 719.673 US$ and 36.857 US$ respectively.

1. Introduction

The eastern region of Indonesia, especially the island which is the outermost island that becomes the front border requires special attention in the case of energy problems. Dependence on the supply of fossil fuels from the island to the island that have high transportation costs and produce greenhouse gases need to be minimized. For this reason the utilization of renewable energy as an alternative energy source for energy generation needs to be studied.

Miangas island was chosen as the location to be studied because of its specificity located on the border between Indonesia and the Philippines is the outermost island which became the front porch of Indonesian territory. Miangas island is situated in regency of Talaud Island. It is located at latitudes 05^0 33’ 20.8’’ North and longitudes 127^0 09’ 6.8’’ East. It takes 3 hours by boat from Malonguane (the nearest city as the capital of Talaud region). The total land area is approximately 3.2 km^2. According to the data from Statistics Centre, the communities of Miangas island consists of 881 people in 324 households. The island of Miangas as the part of Talaud archipelagos is a northest border of Indonesia is shown in Figure 1.

Figure 1. Location of Miangas Island as the northest border of Indonesia
Source: https://www.google.com/maps

Miangas island is facing the high cost of diesel fuel due to remoteness from Sulawesi mainland. This paper presents a techno economical study of PV-Diesel power system for the study of Miangas island in Indonesia.

2. Literature Reviews

This section presents literature review about the analysis works for power system infrastructure model for island communities by utilizing HOMER (Hybrid Optimization of Multiple Energy Resources) software from National Renewable Energy Laboratory (NREL).HOMER software has been used to perform the techno economic feasibility of possible models in developing the power system infrastructures. HOMER is an optimization software package, which can handle different technologies (including PV, wind, hydro, fuel cells) and evaluate design options for both off-grid and grid-connected power systems for remote, stand alone and distributed generations applications [1].

There are many studies has been conducted to study of HOMER utilization for analysing the model of power system generation. Dursun et al [2] studied a micro-grid wind-PV hybrid system for a remote community with 50 houses in order to find the optimal configuration and present a techno-economic analysis for the considered power generating system by the HOMER software. Bekel and Palm [3] presented a feasibility study for a stand-alone solar-wind based hybrid energy system for a model community of 200 families using HOMER software. Shaahid et al [4] evaluated the technical and economic potential of hybrid-wind-PV-diesel power systems to meet electrical energy demand of a remote village by using HOMER software. Sen and Bhattacharya [5] state a hybrid system design can overcome the problem of intermittency of renewable energies and increase reliability of supply. In their research for electrification of remote villages they carry out a case study of an Indian village using HOMER software and find that hybrid system ae technically and economically viable in many locations.

Many studies have been reported analysing renewable energy based on power generation using HOMER. Himri et al. [6] study of hybrid power system for a remote village in Algeria, while Nandi and Gosh [7] present a study of a Bangladesh village and Nfah et al [8] report case study of Ethiophia.

Homer's software capability for modeling has been demonstrated, through two experiments on small-scale systems by comparing HOMER modeling results with direct measurement results [9].
The location of the community is important to know as electricity demand patterns differ with geograhical site and cultural habits [10]. HOMER uses the optimizer propietary algoritm to search for the lowest net present cost system for the specific load and condition [11].

3. Methods

The method to conduct the techno economic study of hybrid power generation for communities in the remote island of Indonesia is using HOMER software. This software developed by the National Renewable Energy Laboratory (http://www.homerenergy.com) a division of the US Department of Energy used to design a hybrid power plant system using renewable energy.
The monthly load profil of electricity demand for Miangas island community for one year that used in HOMER simulation as shown in Figure. 2

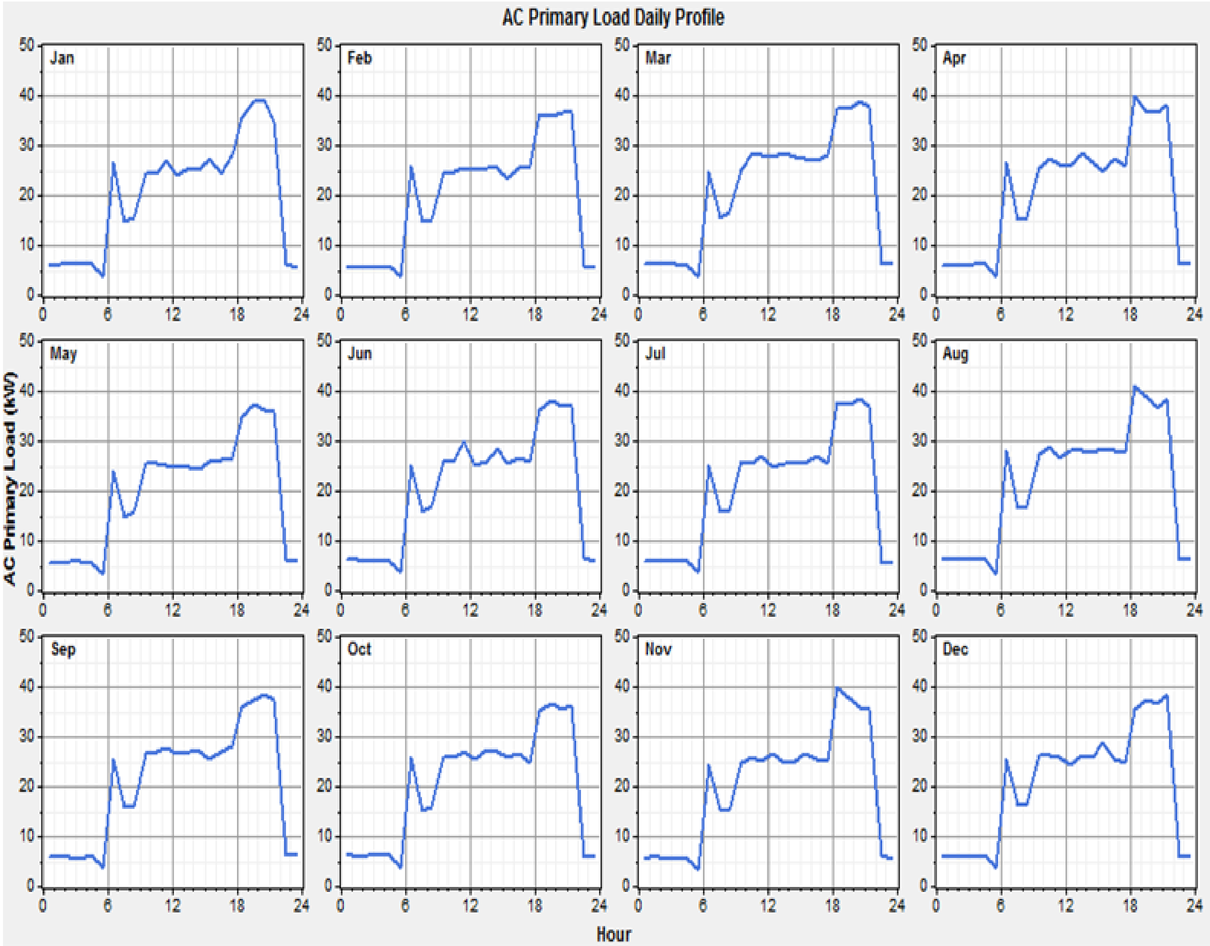

Figure 2. The Monthly Load Profile for Miangas Island

Feasibility of solar energy system mainly depends on solar radiation available at the specific location [12]. Data of solar energy sources in term of solar irradiation in Miangas island have been taken from NASA (National Aeronautics and Space Administration) website by input the latitude and longitude of the location. The average annual solar radiation equals to 5.53 kWh/m^2/day. HOMER also gives the clearness index data for Miangas island. Clearness index is the amount of global solar radiation on the surface of the earth divided by the extra-terrestrial radiation at the top of the atmosphere [1]. The data of solar radiation and cleaness index in Miangas island are presented in Table 1.

Table 1. Average Monthly Solar Irradiation in Miangas island

Month	Solar Irradiation ($KWh/m^2/day$)	Clearness Index
January	5.01	0.53
February	5.43	0.54
March	6.05	0.58
April	6.40	0.62
May	5.73	0.56
June	5.00	0.50
July	5.32	0.51
August	5.50	0.54
September	5.84	0.57
October	5.71	0.57
November	5.38	0.56
December	5.01	0.54

4. Results

The schematic of hibryd power generation model based on PV and diesel for Miangas island as shown in Figure 3.

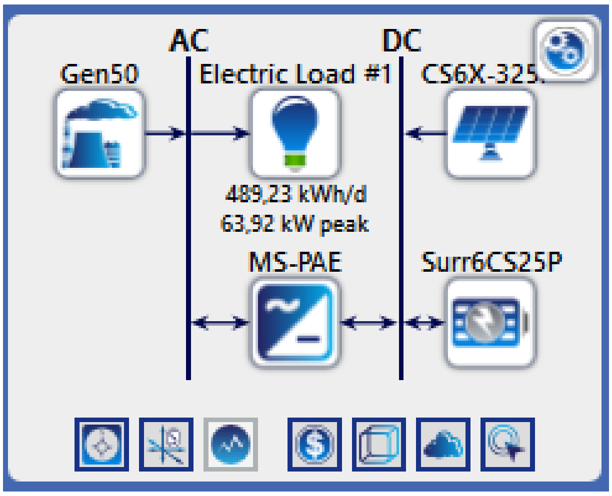

Figure 3. The Schematic of PV-Diesel Power System for Miangas Island

The design for PV-Diesel power systems uses Canadian solar Max Power C56x-325P of PV, battery Surette 6CS25P, Diesel Generator 50 kW and converter Magnum MS4448PAE. HOMER determines the value of the appropriate component capacity so as to produce a good and reliable power system in serving the load in terms of capacity of power plant component, yearly electric energy production, cost of energy (COE), total Net Present Cost (NPC), and operation cost. Techno Economic Analysis of PV Diesel Power System for Miangas Island are shown in Table 2.

Table 2. Techno Economic Analysis of PV-Diesel Power System for Miangas Island

Capacity of PV	150 kW
Capacity of Diesel	50 kW
Capacity of Battery	80 string
Capacity of Converter	25 kW
Yearly energy production from PV	249.688 kWh
Yearly energy production from Diesel	59.901 kWh
Energy cost per kWh (COE)	0.3118 US$
Net Present Cost (NPC)	719.673 US$
Operating Cost	36.857 US$

The simulation results of the electricity production of PV-Diesel power system and monthly average electricity generation are shown in Figure 4.

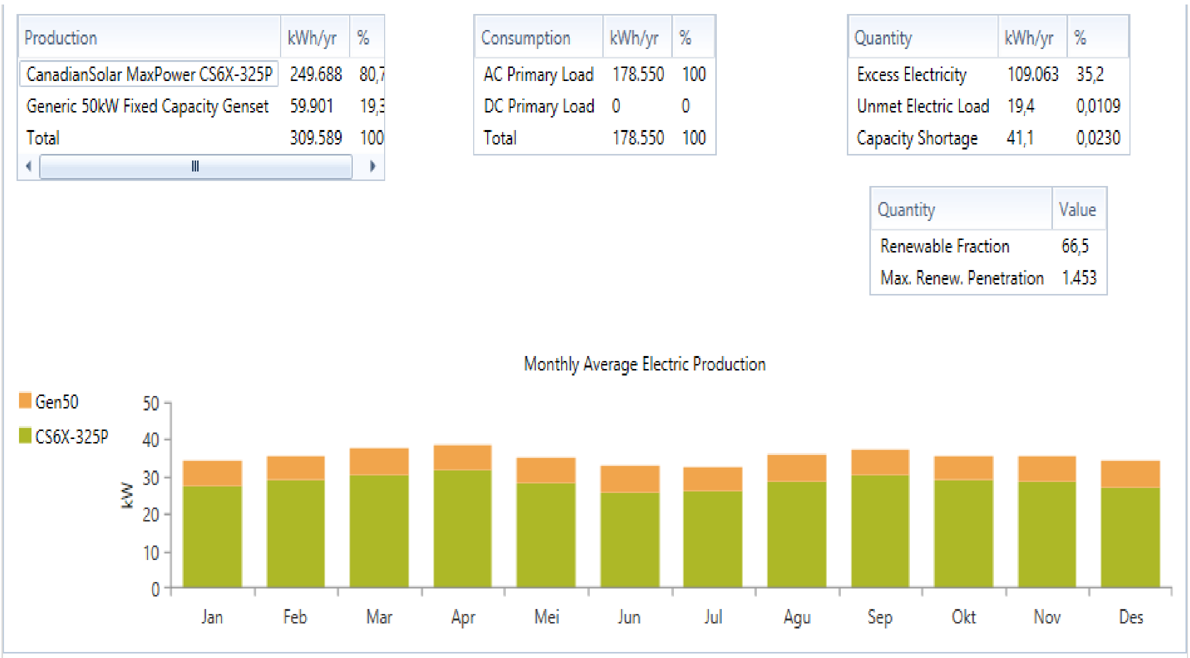

Figure 4. The Simulation Results for the PV Diesel Power System in Miangas Island

The annual electricity production from the PV Diesel system for Miangas island is 309.589 kWh in which 80.7% electricity comes from PV, 19.3% electricity comes from diesel with the 109.063 kWh excess electricity.

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5. Conclusion

Based on the simulation result using HOMER software, the techno economic study of PV-Diesel power plant system based on energy demand in Miangas island can be obtained. The Cost of Energy (COE), Net Present Cost (NPC) and operating cost for proposed hybrid PV-Diesel power generation can be assessed for the design power systems uses Canadian solar Max Power C56x-325P of 150 KW PV, 18 string of Surette 6CS25P, Diesel Generator 50 kW and converter Magnum MS4448PAE 25 kW.

The cost of generating electrical energy with renewable energy is relatively high then there is a need for policies and strategies for the implementation of renewable energy in the archipelago, among others: cooperation with parties that have been successful with the implementation of renewable energy technologies, increased priority implementation of renewable energy-based energy infrastructure for potential locations. The adoption of a pro-island energy policy in the foremost island as a terrace that needs to be enriched for the sake of security, welfare and beauty as an added value in Indonesia's border region.

6. References

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Development of Power System Infrastructure Model for the Island Communities: A Case Study of Kokorotan Island in Indonesia

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Abstract—The purpose of this study is to develop a model of power system infrastructure based on renewable energy available locally in a remote island. This research is a case study for Kokorotan Island that located in eastern Indonesia region of Talaud Island regency of North Sulawesi province in Indonesia. The research methods used are data collection and data analysis using software HOMER. The monthly average daily radiation is 5.62 kWh/m^2, while the wind speed ranging from 3 to 5.3 m/s in Kokorotan island. The proposed hybrid power system model consists of a PV component of Canadian Solar Max Power C56x-325P of 150 KW PV, 70 string of Surette 6CS25P, 1 wind turbine of 1.5 kW Pika T701, Diesel Generator 50 kW and converter Magnum MS4448PAE 25 kW. The annual electricity production from the PV Diesel system for Kokorotan island is 312.595 kWh in which 80% electricity comes from renewable energy (PV and Wind energy) as well as 20% electricity comes from diesel. The cost of generating electrical energy in the term of cost of energy (COE), Net Present Cost (NPC) and operating cost are 0.314 US$/kWh, 725.086 US$ and 37.973 US$ respectively. The cost of generating electrical energy with renewable energy is relatively high then it is necessary to have policies and strategies for the development of power infrastructure for the sake of the energy security of island communities in Indonesia.

Keywords—Renewable Energy; infrastructure model ; island communities; remote island; Indonesia

I. INTRODUCTION

The eastern region of Indonesia, especially the island which is the outermost island that becomes the front border requires special attention in the case of energy problems. Dependence on the supply of fossil fuels from the island to the island that have high transportation costs and produce greenhouse gases need to be minimized. For this reason the utilization of renewable energy as an alternative energy source for energy infrastructure needs to be discussed and studied.

Renewable and locally available renewable energy infrastructures for island communities need to be assessed and developed. Talaud Islands was chosen as the location to be studied because of its specificity located on the border between Indonesia and the Philippines is the outermost island which became the front porch of Indonesian territory.

Kokorotan island, which is one of the remote island on the border of Indonesia with the Philippines, situated in regency of Talaud Island It is located at latitudes 04^0 37'North and longitudes 127^0 09'East. It takes 3 hours by boat from Malonguane (the nearest city as the capital of Talaud region). The total land area is approximately 1710 km^2. According to the data, the communities of Kokorotan island consists of 232 households. The island of Kokorotan as the part of Talaud islands is shown in Figure 1.

Figure 1. Map of Talaud Islands and Kokorotan Island [1]

Kokorotan island is facing the poor electricity accsess due to geographical inaccessibility, lack of electrical infrastructure and low population condition. However this island has chosen to be analysis as a model for power system infrastructure based on renewable energy availability for island communities. This paper presents a power system infrastructure model for island communities based on renewable energy that locally available for Kokorotan island as the remote island which is situated in the border of Indonesia and Phillipines. The adoption of a pro-island energy policy in the foremost island as a terrace that needs to be enriched for the sake of security, welfare and beauty as an added value in Indonesia's border region.

II. POWER SYSTEM INFRASTRUCTURE MODEL FOR ISLAND COMMUNITIES

This section presents literature review about the analysis works for power system infrastructure model for island communities by utilizing HOMER (Hybrid Optimization of Multiple Energy Resources) software from National Renewable Energy Laboratory (NREL).

HOMER software has been used to perform the techno economic feasibility of possible models in developing the power system infrastructures. HOMER is an optimization software package, which can handle different technologies (including PV, wind, hydro, fuel cells) and evaluate design options for both off-grid and grid-connected power systems for remote, stand alone and Distributed Generations applications [2].

There are many studies has been conducted to study of HOMER utilization for analysing the model of power system infrastructure. Dursun et al [3] studied a micro-rid wind-PV hybrid system for a remote community with 50 houses in order to find the optimal configuration and present a techno-economic analysis for the considered power generating system by the HOMER software. Bekel and Bjorn [4] presented a feasibility study for a stand-alone solar-wind based hybrid energy system for a model community of 200 families using HOMER software. Shaahid et al [5] evaluated the technical and economic potential of hybrid-wind-PV-diesel power systems to meet electrical energy demand of a remote village by suing HOMER software.

The location of the community is important to know as electricity demand patterns differ with geograhical site and cultural habits [6].

III. METHODS

The research method used is primary and secondary data collection, data analysis using HOMER software. The data collected in this study, in the form of population data and the power electricity demand of electricity in Kakorotan island [7] are given in Table 1.

Table 1. Communities Data in Kokorotan Island

Number of People	881
Number of Households	232
Power Electricity Demand	260 W/ day/ household

Feasibility of solar-wind hybrid renewable energy system mainly depnds on solar radiation and wind energy potential available at the specific location [8]. Data of renewable energy sources in term of solar irradiation and wind speed in Kokorotan island have been taken from NASA (National Aeronautics and Space Administration) website through HOMER are summarized in Table 2.

Table 2. Average Monthly Solar Radiation an Wind Speed in Kakorotan Island [9]

Month	Solar Radiation(KWh/m^2)	Wind Speed (m/s)
Jan	4.527	2.57
Feb	4.953	2.57
March	5.583	2.57
April	5.714	2.57
May	5.094	2.57
June	4.466	3.08
July	4.601	3.59
August	4.850	4.11
Sept	5.418	3.08
October	5.125	3.08
Nov	4.648	2.05
Dec	4.719	2.57

The monthly power electricity demand in Kokorotan island is decribed in Figure 2.

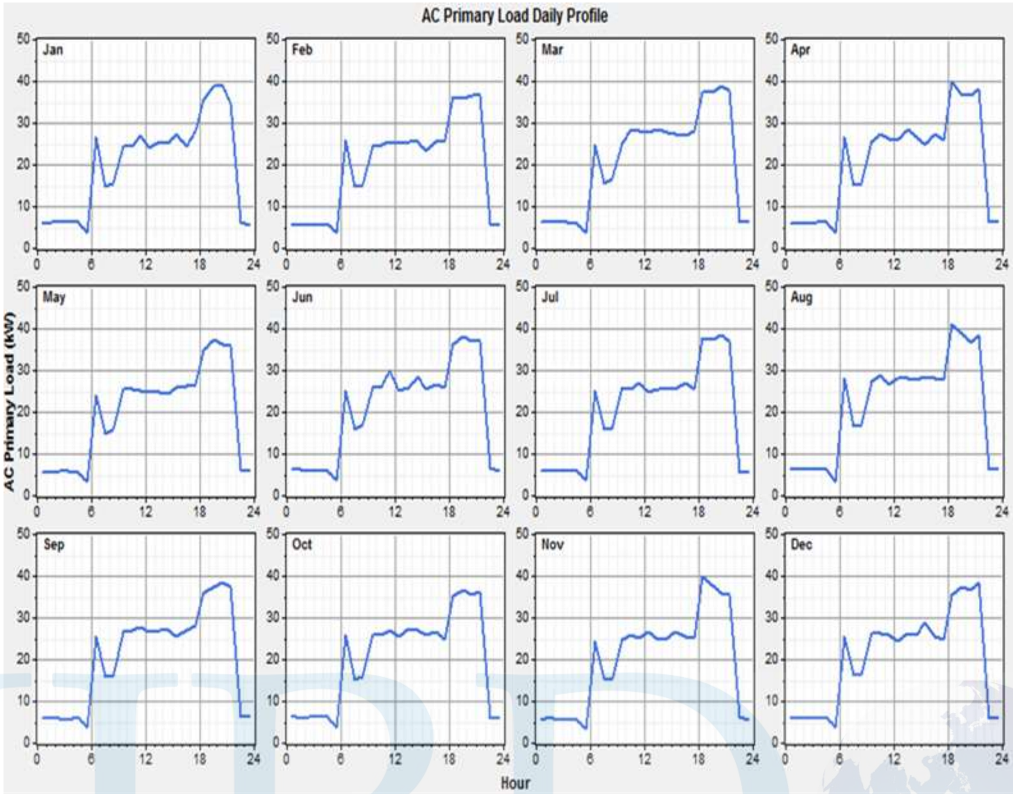

Figure 2. Monthly Load Profile of Power Demand for Kokorotan Island

This data collection required for input to software HOMER is primary data, secondary data and literature study. This software developed by the National Renewable Energy Laboratory (http://www.homerenergy.com) a division of the US Department of Energy used to design a hybrid power plant system using renewable energy. Homer's software capability for modeling has been demonstrated, through two experiments on small-scale systems by comparing Homer modeling results with direct measurement results [10].

IV. SIMULATION RESULTS

For the determination of the type of wind turbine to be proposed, the average wind speed in the Kakorotan islands is crucial in the selection of wind turbines. This is done to optimize the existing wind potential in Kakorotan Island. It is proposed that turbine type Pika T701 (1,5 kW) with consideration of wind speed that exist in Kakorotan island.

The design for solar power systems uses 150 kW solar panels with a polycrystalline silicon type. The batteries used in this system simulation are battery type Surrette 4KS25P deep cycle batteries that have a normal voltage of 4 volts, capacity 1.350 Ah.

Input parameters required on HOMER software are load data, wind speed, solar radiation, and component data used such as capital cost, replacement, O & M and others. The proposed of power system infrastructure model based on renewable energy that consist of renewable energy in terms of wind energy and PV as well as Diesel Generator for Kakorotan island as shown in Figure 3.

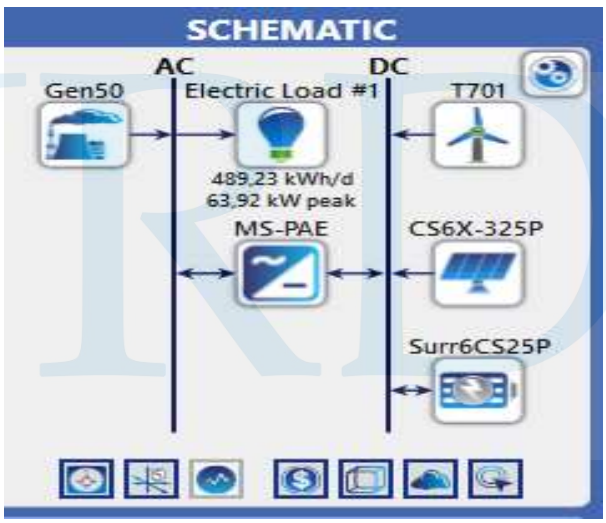

Figure 3. The Proposed of Power System Infrastructure Model based on Renewable Energy for Kakorotan Island

HOMER determines the value of the appropriate component capacity so as to produce a good and reliable power system in serving the load in Kokorotan island based on PV-Wind-Diesel power system. The simulation results in term of capacity of components, energy production, cost of energy (COE), total Net Present Cost (NPC) and operating cost are presented in Table 3.

Table 3. The simulation results in term of capacity of components, energy production, cost of energy (COE), total Net Present Cost (NPC) and operating cost

Capacity of PV	150 kW
Capacity of Wind Power	1.5 kW
Capacity of Diesel	50 kW
Capacity of Battery	70 string
Capacity of Converter	25 kW
Yearly energy production from PV	249.688 kWh
Yearly energy production from Diesel	61.538 kWh
Yearly energy production from Wind Turbine	1369 kWh
Energy cost per kWh (COE)	0.3141 US$
Net Present Cost (NPC)	725.086 US$
Operating Cost	37.973 US$

The results of monthly average electricity production from proposed hybrid power system configuration in Kakorotan island are shown in Figure 4.

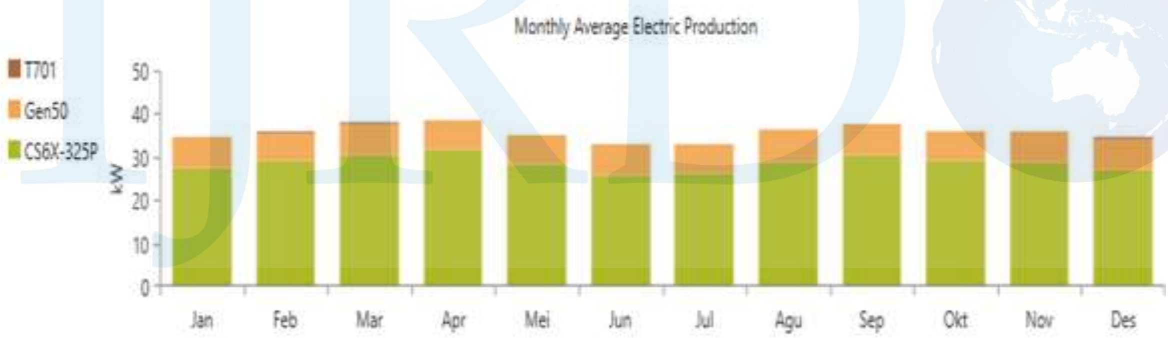

Figure 4. The monthly average electric production from PV-Wind-Diesel system for Kokorotan Island

The annual electricity production from the hybrid system for Kokorotan island as 312.595 kWh in which 79.5% electricity comes from PV, 20% electricity comes from diesel and the remaining comes from wind energy. From the simulation results, the excess electrical energy generated by PV and wind turbine generators can be use for backup electrical energy of energy consumption on Kakorotan Island.

V. CONCLUSIONS

Based on the simulation result using HOMER software, the model of power plant system for island community's electric energy demand in Kakorotan Island can be obtained. The annual electricity production from the PV Diesel system for Kokorotan island is 312.595 kWh in which 80% electricity comes from renewable energy (PV and Wind energy) as well as 20% electricity comes from diesel. The cost of generating electrical energy in the term of cost of energy (COE) as 0.314 US$/kWh, Net Present Cost (NPC) as 725.086 US$ and operating cost as 37.973 US$. For future work, the model of power plant system for island community will be conduct for sensitivity analysis for fuel price change for the remote island.

ACKNOWLEDGMENTS

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