Off Grid Micro Grid Projects in South East Asia

September 2018

DLRE

LEADER IN MICRO GRIDS

January 2007: First in the World – Fully Automated High Penetration Renewable Energy Hybrid Power System (Diesel Generator + Wind + Solar + Energy Storage System)

March 2008: First MW Class Micro Grid with Wind + Solar + Battery + Energy Storage System

October 2011: Micro Grid Test Bed in Singapore with > 1 MWh of energy storage

March 2016: Deployment of Samsung SDI Lithium Energy Storage System to be integrated with GE/Alstom Micro Grid

March 2016: Installed over 74MWh of Energy Storage (Lead acid and lithium battery)

Ambassador Robert Blake and Daily Life Renewable Energy representative Markson Tang view the solar panels and wind turbines which power the new Hybrid Renewable Energy System on H.A. Uligam.

High penetration of renewable energy (>90% of total installed generating capacity) in 54 micro grids in Vietnam: Solar, wind, ESS and DG hybrid renewable energy systems

MICRO GRIDS IN THE MALDIVES

Wind + Solar + ESS + DG Hybrid Micro Grid

3 difficult to access island with challenging local environments were chosen in the northern, central and southern regions of the Maldives to implement the world's first AC coupled Micro Grid with multiple sources of generation such as a micro wind farm, PV, diesel generator and energy storage. Achieved KPI of reducing diesel consumption by > 30% and providing 80% of domestic energy needs with renewable energy

SRI LANKA UTILITY SCALE WIND FARM

Rs 2 billion windpower plant for Kalpitiya

HARSHINI PERERA

A windpower generation project designed for the North Western province will generate 25 gigawatt hours of energy per year to the national grid.

It is expected to start operations by the end of this year.

A Singaporean company, Daily Life Renewable Energy and several other Sri Lankan investors have shown interest in setting up this windpower generation plant in Kalpitiya supporting the national energy grid, Industrial Services Bureau (ISB) Technical Director Anura Vidanagamage told *Daily News Business.*

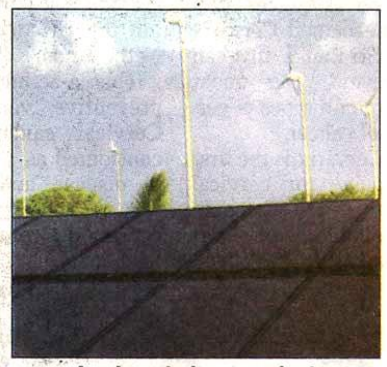
The investment of Rs two billion will be allocated for the thirteen turbine power plants. It has already received approval from the authorities. The ISB is currently engaged in land acquisition, soil testing and land surveying.

The Industrial Services Bureau in the North Western Province will support the project in consulting, managing the project and managing operations.

He said that ISB will support interested investors to set up windpower mini hydro projects.

The ISB is currently engaged in livelihood and micro enterprise development projects with the NGO Consortium in Ampara, Vavuniya and Jaffna.

Technical assistance will be given to micro enterprises in those areas by the ISB.



A solar, wind power plant

Utility Scale Connected Wind Farm

RENEWABLE ENERGY INTEGRATION DEMONSTRATOR SINGAPORE (REIDS)

Minister S. Iswaran, Prime Minister's Office and Second Minister for Home Affairs and Trade & Industry, unveiled the pledge of support for NTU's Renewable Energy Integration Demonstrator-Singapore (REIDS) initiative by EDB, NEA, Sustainable Energy Association of Singapore (SEAS) and ten leading clean-tech industry leaders such as GDF Suez and Vestas

REIDS has already brought together ***ten of the world's leading clean energy companies*** to develop and demonstrate a diverse range of clean energy technologies that will be integrated with the physical micro-grid.
These ten companies include:
1. Accenture – one of the world's leading organizations providing management consulting, technology and outsourcing services
2. GE – industry leader in electric power generation, electric grid equipment, and transport solutions
3. Class NK – not-for-profit society dedicated in providing classification and technical services to maritime and clean tech industries
4. DLRE – Singaporean company focusing on micro-grids, distributed generation, remote area power systems
5. ENGIE – world's largest independent electricity producer with activities in electricity generation and distribution, natural gas and renewable energy
6. Renewable Energy Corporation (REC) – top company that operates the world's largest integrated solar manufacturing complex outside of China in Singapore
7. Schneider Electric – global company specialising in electricity distribution, automation, and energy management
8. Trina Solar – pioneer of China's photovoltaic industry and global solar modules, and solutions provider
9. Varta AG – a leading global energy storage solutions provider
10. Vestas – world's largest manufacturer and installer of wind turbines

Source: https://www.edb.gov.sg/content/edb/en/news-and-events/news/2014-news/southeast-asias-first-and-largest-micro-grid-testbed-to-be-built-on-singapores-semakau-landfill.html

MICRO GRID ESS FOR REIDS

Solar + ESS + DG Hybrid Micro Grid

- 250kWh ESS
- Customised PCS
- Packaged in 20 ft cabins
- Integrated with GE (General Electric) Micro Grid Controllers

Energy Storage is Integral to Micro Grids

- Installed over 50MWh of ESS since 2006
  - International brands
  - Various storage technologies
- Mainly for off grid systems – nano grids and micro grids
  - Telecommunication towers
  - Remote area power systems
- 15kWh to 4.5MWh energy storage systems
- Complex warranty terms
- Specifications and performance disparity
- What to do at end of battery life?

Leading Battery Technology Today

- China is the world's leading manufacturer of Lithium batteries
- Rapidly decreasing price due to electric vehicles adoption and widespread renewable energy implementation
  - China has a large percentage of wind and solar capacities not connected to the grid
  - China needs to reduce emissions from vehicles to improve air quality in major cities
- Lithium battery has become a mainstream commodity
  - Power and energy density
  - Mature technology

Commercial Aspects

- Cost of materials for lithium battery has not fluctuated as much as the downward pressure in selling price
- Prices has decreased largely due to
  - Intense competition
  - Maturing technology
  - Lithium battery becoming a commodity
- Pursuit of lowest value added cost and highest energy density
- Consolidation of the industry will occur

Other Considerations

- No one size fits all solution
- Environmental consideration
  - Disposal is expensive
  - Methods to prolong useful life of the battery is welcomed
- Industry creation – 2nd and 3rd lease of life
  - Retired EV batteries can be re-conditioned for stationary energy storage
  - Retired stationary energy storage can be used for grid regulation
  - Value created in the entire value chain of collection, logistics and reconditioning

Pulau Ubin Test Bed

Challenges for Hybrid Energy Storage

PULAU UBIN MICRO GRID TEST BED

Clean and Renewable Energy for Pulau Ubin

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INTELLIGENT MICRO-GRID WITH RENEWABLE ENERGY TECHNOLOGIES FOR PULAU UBIN

EMA has embarked on a first-of-its-kind project in South-east Asia to develop an intelligent micro-grid infrastructure with clean and renewable energy technologies on Pulau Ubin, an island northeast of Singapore with a land area of about 10 square kilometres. The off-grid solution will displace the diesel generators currently being used by organizations, small businesses and individual homes on the island. The project will showcase how clean and renewable energy can be deployed in an environmentally, socially and economically sustainable manner for an off-grid community.

Pulau Ubin will host a number of plug and play facilities for test-bedding various close-to-market clean and renewable energy solutions. This will help elevate Singapore as a "living laboratory" to research, develop and showcase new energy technologies.

The first phase of studying the technical and commercial viability of the various clean and renewable energy options and assess their integration with an intelligent micro-grid infrastructure was completed.

EMA launched an Expression of Interest on 20 November 2009 to invite companies to express their interest to participate in a request for proposal for a developer cum operator to design, build, operate and maintain an intelligent micro-grid infrastructure with clean and renewable energy technologies on Pulau Ubin.

A total of 21 submissions were received when the Expression of Interest was closed on 18 December 2009. EMA had evaluated these submissions carefully based on the information provided. The following companies have been invited to submit detailed proposals by fourth quarter 2010 as part of a Request for Proposal for the intelligent micro-grid infrastructure:

- Daily Life Renewable Energy Pte Ltd and OKH Holdings Pte Ltd
- EADS Defence and Security Systems SAS
- GE Pacific Pte Ltd
- Lockheed Martin Missiles and Fire Control
- Patrick Energy Services Inc
- Sembcorp Utilities Pte Ltd
- Shimizu Corporation
- Singapore Technologies Kinetics Ltd
- Tuas Power Ltd

Companies interested to test-bed their close-to-market clean and renewable energy solutions in the micro-gird infrastructure will subsequently be invited to submit their proposals under another Request for Proposal process in second quarter 2011, after the completion of the detailed design of the intelligent micro-grid infrastructure.

ENERGY MARKET AUTHORITY

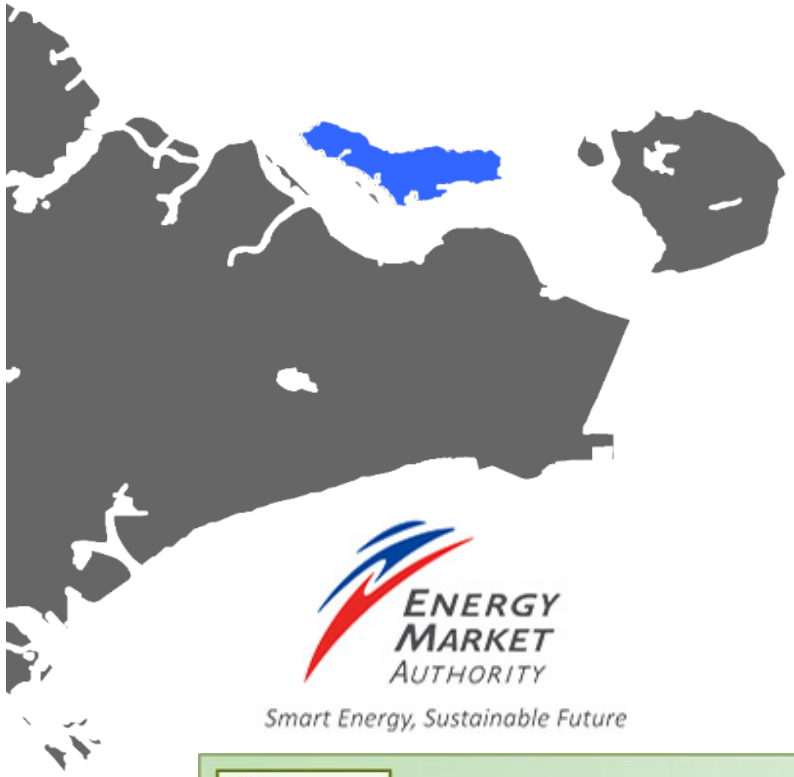
Smart Energy, Sustainable Future

Outbid Global Companies
Experience and Technology

Gazetted Utility Provider
Providing Public Service

Long Term Partner
Chosen to Provide
Infrastructure for Phase 2

PULAU UBIN MICRO GRID TEST BED



Pulau Ubin, an island north-east of mainland Singapore is where DLRE implemented a Micro-grid Test Bed for EMA (Energy Market Authority of Singapore). This micro-grid serves the island residents in the jetty area with high quality, high availability electricity that was previously generated from diesel generators.

The test bed consists of hybrid solution of diesel generators, solar panel and battery energy storage systems.

The test bed was also created for the government to analyze the impact of a high penetration of renewable energy on the grid stability.

8 Million USD
Cost of project implementation

99.99% Uptime
Availability of electricity to residents

60 kWp
Total installed solar panel capacity

310 kVA
Total installed generator capacity

1000 kWh
Total installed energy storage

41
Total consumers provided with electricity

KEY STATISTICS (PHASE 1)

End to End the grid cover a rectangular area of 1,200m x 200m

99.99%
Uptime since inauguration
The 10th Oct 2013

100%
Power Quality in adherence to mainland SG standards

25%
Penetration of Solar Energy
Space limitations for placement of solar panels

1MWh
Avg Daily Consumption

65kW
Maximum Load Demand

42
Customers (Government orginzations, Business Owners and Residents)

400VAC L-L
Grid Voltage

50Hz
Frequency

240kW
Maximum Generators Output
(6 x 40kW Variable Speed Generators)

1000kWh
Energy Storage Capacity
(

SingTel StarHub

Celestial Ubin Beach Resort CELESTIAL

SINGAPORE POLICE FORCE

NATIONAL PARKS

KEY STATISTICS (PHASE 2)

248kW
New Maximum Generators Output
(2 x 100kVA CAT + 1 x 110kVA Perkins generators)

7
Additional grid interactive inverters

96kWh
Additional Lithium Battery

190kW
Maximum output power from the new inverters

252kWh
Additional Zinc-Air Battery

5km²
Area covered by TVWS Communication

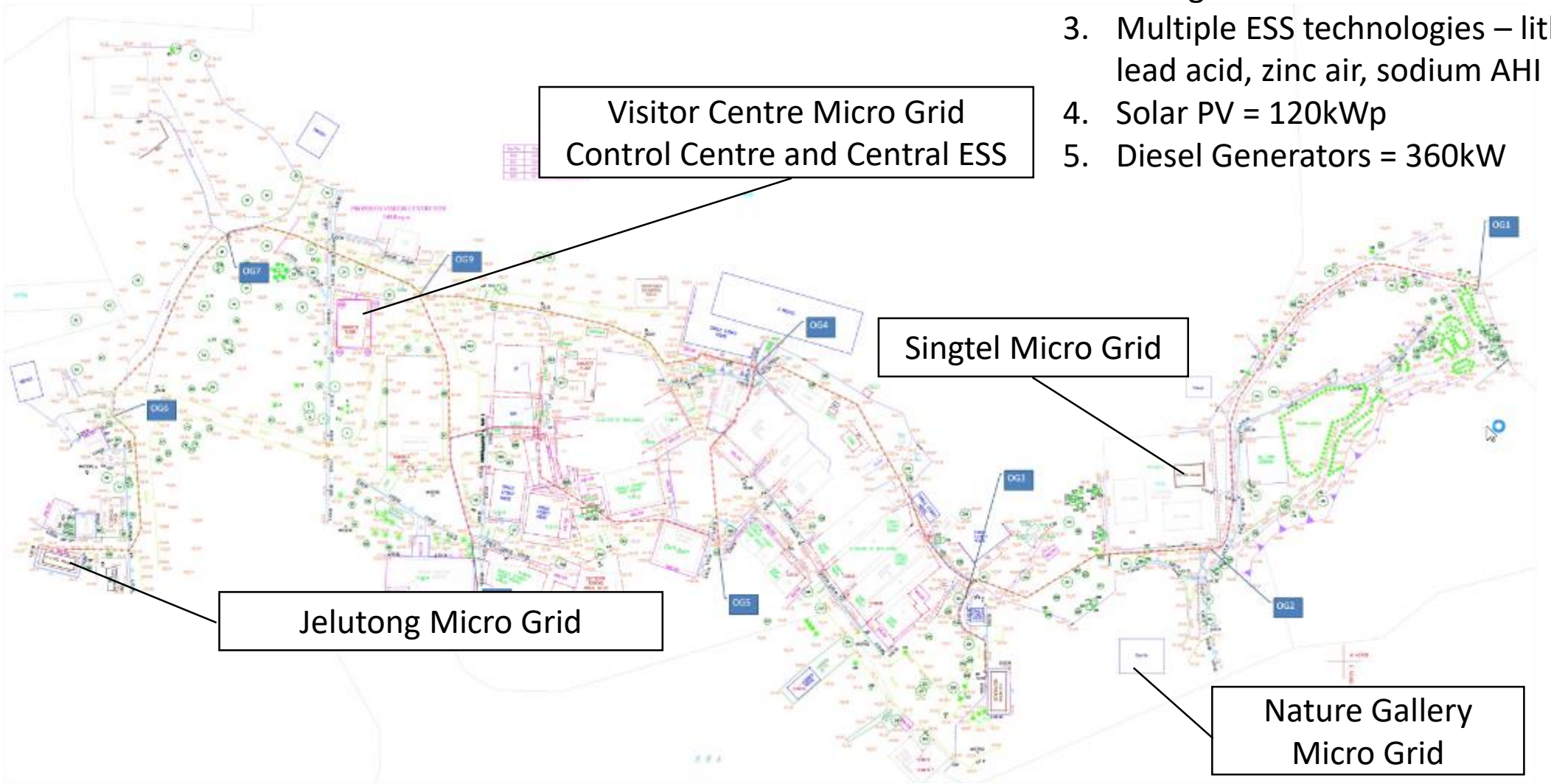
255kWh
Additional Aqueous Ion Battery (salt water battery)

8.7kWp
Additional PV installed

1. **Distributed Energy Storage System (ESS):**
    1. **The micro-grid is sub divided into 5 nano-grids**
    2. **Each nano-grid backed up by a dedicated ESS + Grid Interactive Controller**
    3. **Increase reliability of the micro-grid**
    4. **Reduce generator running hours**
2. **SCADA Control**
    1. **Smart control of the entire grid**
    2. **Infinite number of scenarios to automatically adjust the configuration to face every possible situation**
3. **Data Monitoring and Analysis**
    1. **Collection of key data to predict possible equipment failure**
4. **Network**
    1. **Implementation of wireless broadcast platform to collect data at every strategic location**
    2. **Wirelessly connected to mainland SG's Hi-speed optic fiber internet line at Changi Beach Club**

Micro Grid Layout

1. Connected or operate in standalone modes
2. Distributed generation and distributed storage
3. Multiple ESS technologies – lithium, lead acid, zinc air, sodium AHI
4. Solar PV = 120kWp
5. Diesel Generators = 360kW



ESS Installed on Pulau Ubin

Battery Type	Installed Capacity	Round-Trip Efficiency	Year Commissioned	Year Purchased	Cost per kWh (USD)
Lead Acid	1MWh	80%	2013	2011	$220
Zinc Air	250kWh	60%	2016	2015	$400
Aqueous hybrid ion	250kWh	80%	2016	2015	$400
Lithium	100kWh	90%	2016	2015	$450

Facts and Figures

	Pulau Ubin (USD)	Jan 2018 (USD)
Cost of Diesel Generation per kWh	$0.22	$0.20
Cost of Solar PV Generation per kWh	$0.18	$0.04
Cost of Energy (Solar PV + ESS) per kWh	$0.55	$0.26 (lithium with 85% DOD, 2000 cycles)
Cost of Solar PV modules	$0.78 per Wp (2011)	$0.35 per Wp (2018)
Cost of Lithium-ion Battery	$450 per kWh (2016)	$250 per kWh (2018)

TVWS – ENABLING WIRELESS DATA COMMUNICATIONS

Changi Beach Club (Mainland Singapore)



Assembly Area (Pulau Ubin)


TVWS – SMART METERS INSTALLED IN OG BOXES






TVWS – ENABLING SCADA & INTERNET ACCESS

South East Asia

Countries in Which We Operate

Latest Hot Spot for Large Scale Solar Project

- Pending PPA revision
- Improved bankability will attract investors for large scale solar projects
- FIT to be fixed at USD0.935 per kWh
- Although large areas of the country is on grid, power quality is an issue
- Many islands still depend on diesel generators for electricity generation
- Micro grids with high penetration of renewable energy will require ESS for load shifting and frequency/voltage reference

Observations

- Changing of lead acid batteries to lithium batteries for off grid power systems
  - Prolonging replacement from 2 years to 5 years
  - Significant reduction in total cost of ownership
- Increase in ESS and renewable energy implementation
  - Reduced cost of solar PV
  - Reduced cost of lithium battery
  - Expected 3GWh of ESS to be installed
- Advantage of increasing renewable energy implementation
  - Pronounced benefits only for off grid power systems
  - Reduce levelized cost of energy

A Stable Grid in a Developed Country

- High penetration of solar PV planned
- Initiatives for public housing and Government buildings to install Solar PV
- Peak load shaving and energy storage
- Credible and excellent platform for deployment of innovative energy storage solutions
- Aim to reduce use of fossil fuel
- Achieve lower levelized cost of energy

Critical Success Factors

- Engage in disruptive ESS technologies R&D
- Commercialization strategy – Focus on stationary energy storage applications
- Leverage on existing lithium battery manufacturers' facilities
- Cheaper and environmentally friendly materials
- License factories to manufacture
- Target to be 20% below cost of lithium batteries
  - < USD200 per kwh
  - Sodium-ion battery expected to debut at USD180 per kWh
- Similar charging and discharging characteristics
- Larger physical footprint and heavier in weight

Sodium Ion Batteries

MOTIVATION:

- Singapore targets higher deployment of renewable energy for climate change mitigation
- Renewable energy such as solar energy is intermittent
- Higher penetration of solar energy could be achieved through distributed generation and distributed storage system
- Develop innovative storage systems (100-1000 kWh) to address intermittency (frequency regulation of micro-grids).
- Prior to fabricating such medium sized battery packs to address micro-grid challenges, we propose in this programme to develop 36 kWh battery packs for telecommunication towers

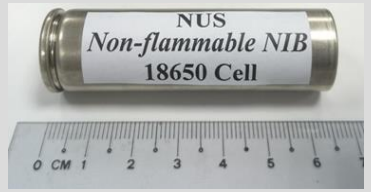
Proposed target for Telecommunication Towers:

- 36 kWh
- 4C (15 min. charge/discharge)
- 5000 (@ 1C) cycle life
- Safety
- Inexpensive

Eventual target for micro-grids:

- 100 – 1000 kWh
- 4C (15 min. charge/discharge)
- 5000 (@ 1C) cycle life
- Safety
- Inexpensive

State of the Art Non-Flammable Battery

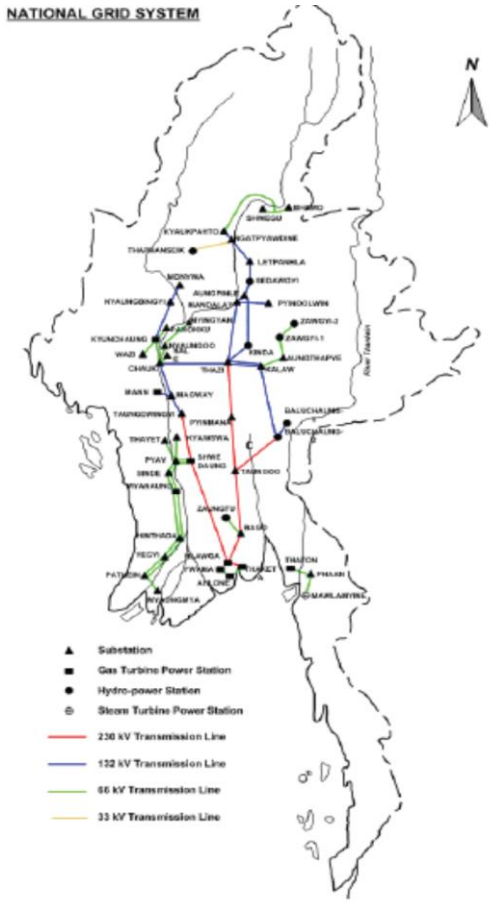
			
Institution	Kyoto University	Aquion Energy (funded by Bill Gates)	National University of Singapore
Country	Japan	USA	Singapore
Electrolyte used	Non-flammable; ionic liquid-based, expensive	Non-flammable; aqueous-based, inexpensive	Non-flammable; glyme-based, inexpensive
Energy density (Wh kg^{-1})	75 (60 in 18650 cell –3rd Na Battery Conf. Australia, 2016)	23	60 (in pouch cell, about 80-90)
Reference	Fukunaga, A *et al*., J Appl Electrochem, 46, p487 (2016)	J.F. Whitacre *et al*., J. Power Sources, 213, p255 (2012)	This work, unpublished

Last Frontier for Electrification in SEA

- 54m population but roughly 30% of the population has access to the National Grid
- Significant investment and time for power generation
- Power transmission and distribution infrastructure will take many years to complete
- Significant potential for deployment of Micro Grid
- Large scale renewable energy projects planned
- Requires large scale ESS for energy storage and grid regulation
- Replicate the Pulau Ubin Model

State of Myanmar National Grid

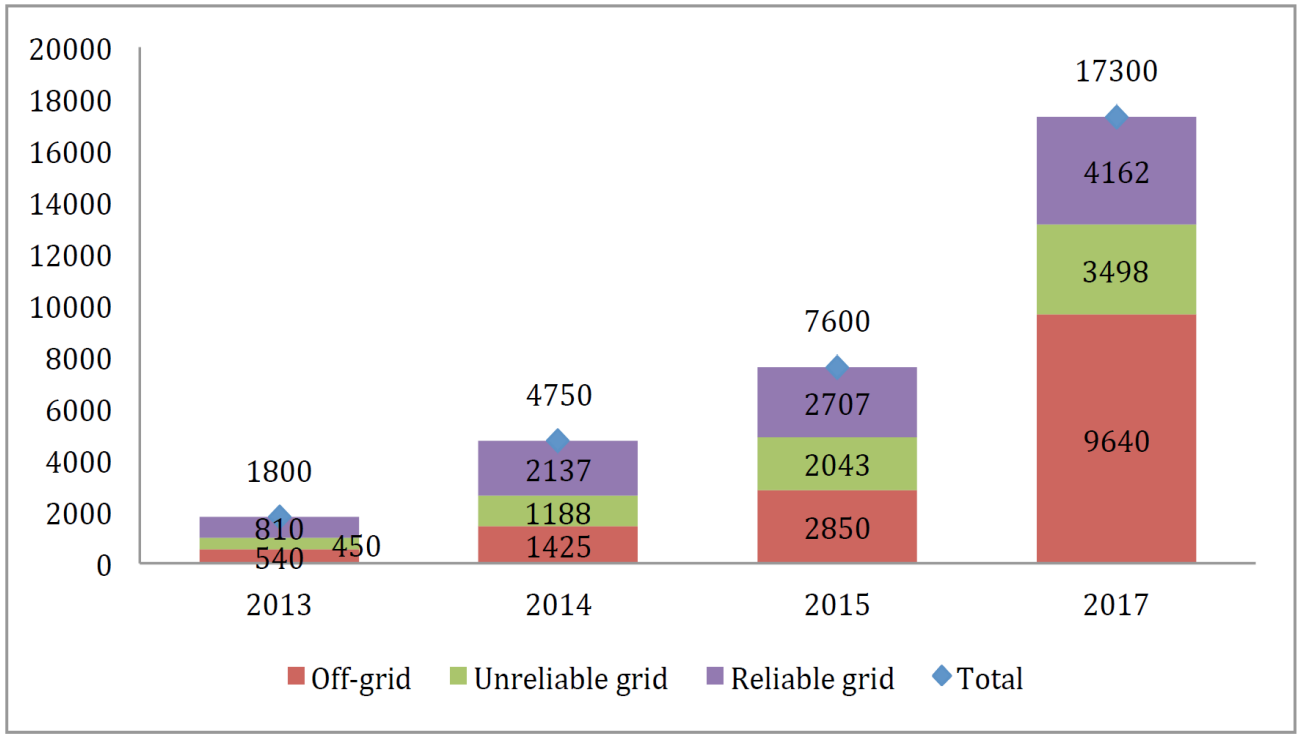
- ✓National Grid (Transmission and Distribution) is virtually non-existent in many parts of the country
- ✓Microgrid provides electrification quickly and provides stability for eventual national Grid Rollout
- ✓Renewable energy + energy storage with diesel back up for smaller power systems
- ✓Power quality issues needs to be addressed before large scale renewable energy projects (wind and solar) comes online
- ✓Different type of energy solutions required load shifting and grid (frequency and voltage) regulation



Distribution of Towers – Power Availability

- Energy needs expected to reach 455GWh in 2017
- Potential for Solar + ESS + DCDG systems
- 55% of all tower sites will be off grid
- Up to 70% of all sites will have a diesel genset

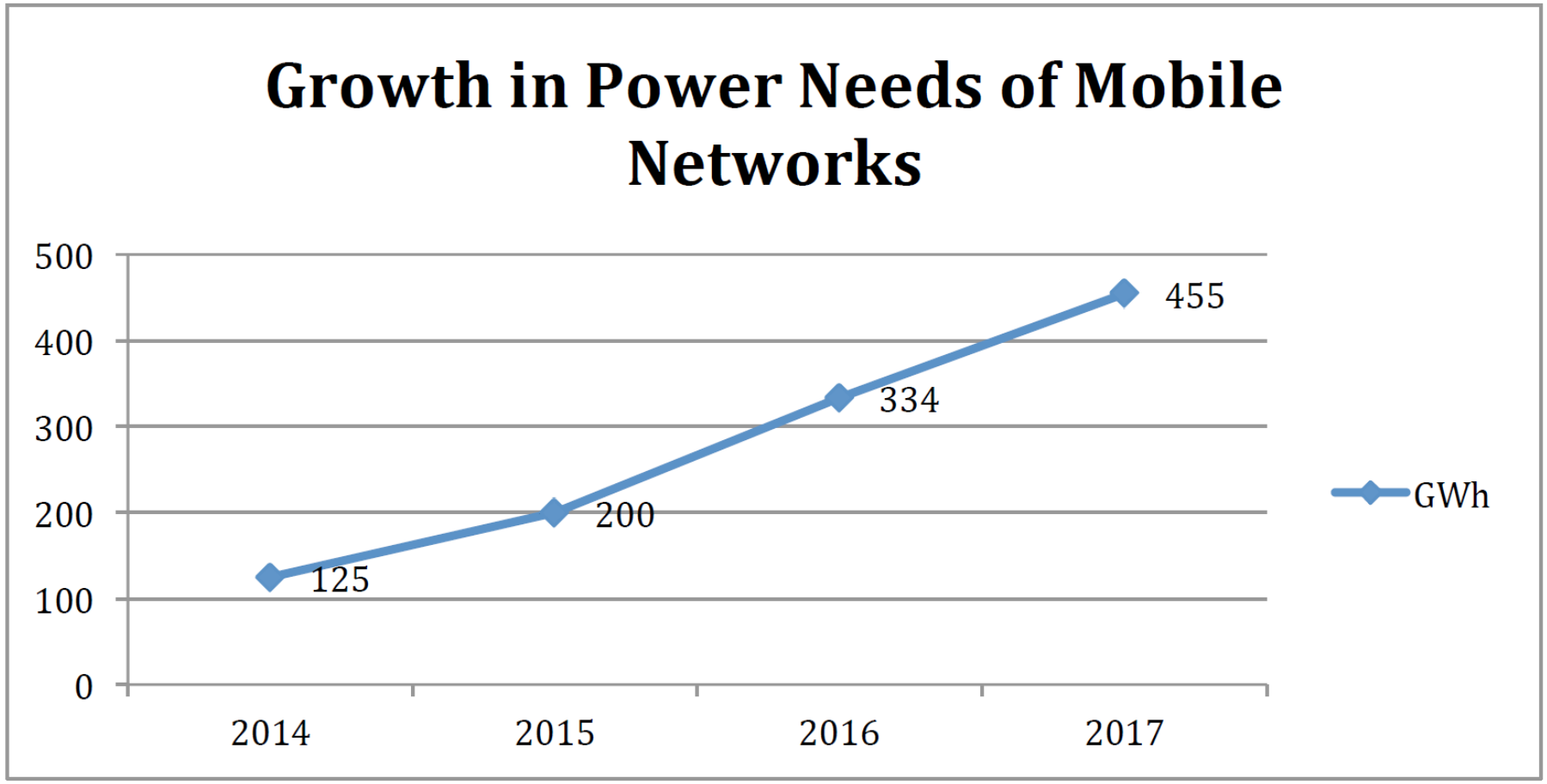
Figure 17: Size of the Network – Off-grid, Unreliable-grid, Reliable-grid (by 2017)



GPM estimates that, based on current powering approach, the MNOs or Tower Cos in Myanmar would require 25 million liters of diesel in 2014 and the diesel consumption would grow to 116 million liters by 2017.

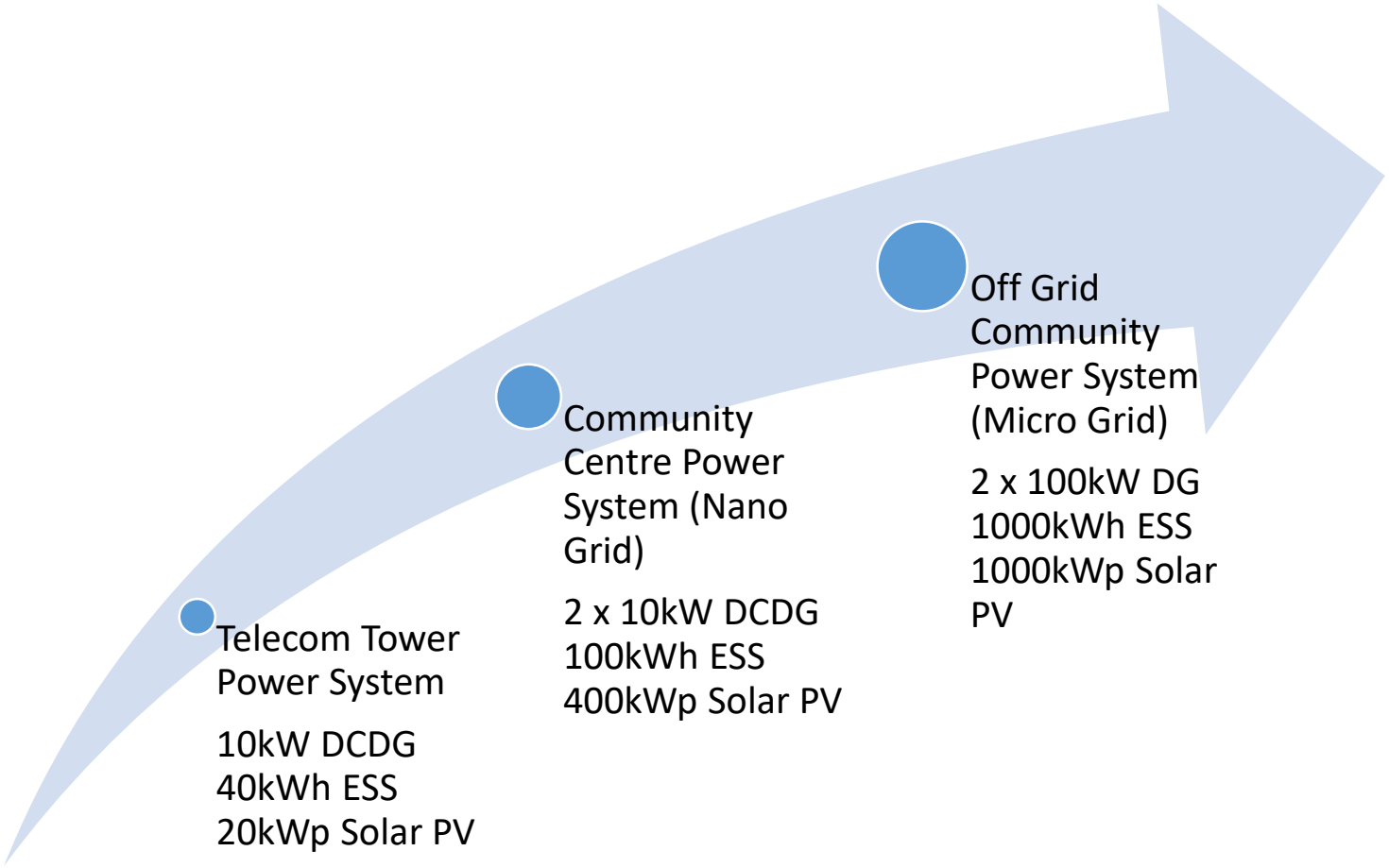
Source: IFC and GSMA

Energy Needs for BTS Towers in Myanmar



Source: IFC and GSMA

Progression from Nano Grid to Micro Grid

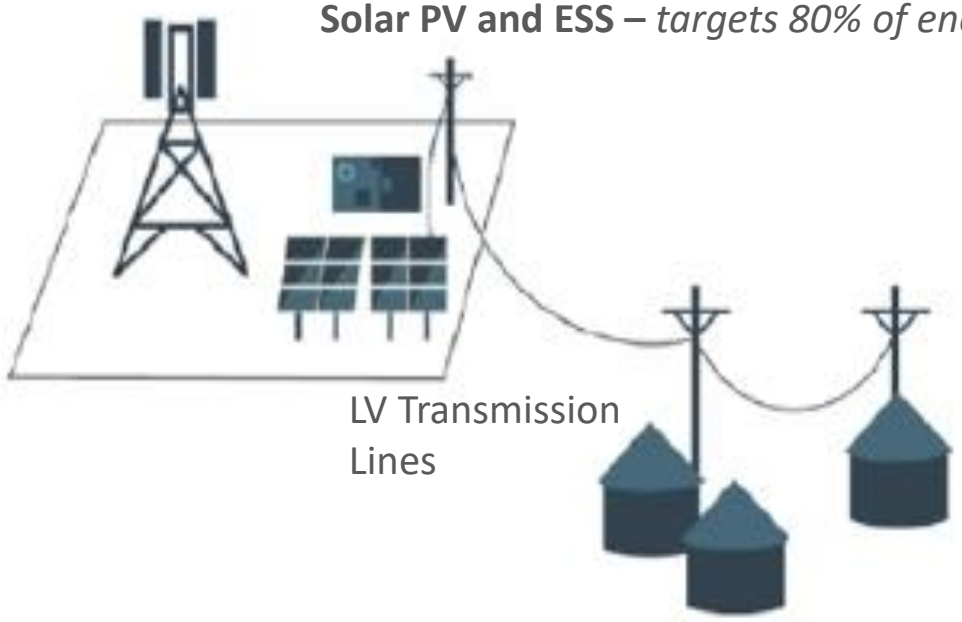


Evolution of Business Model

STAGE 1 – Mobile Network Operator(s): Fixed recurring income model

Diesel Generator

Solar PV and ESS – *targets 80% of energy generation from renewable sources*



STAGE 3 – Micro Grid for Residents and Small Businesses: *Houses, rice mills, oil mills, shops, brick factory, etc*.

STAGE 2 – Village Electrification Committees (VEC): Community Centre leased to VEC (Fixed recurring income with opportunity to expand energy generation and storage)

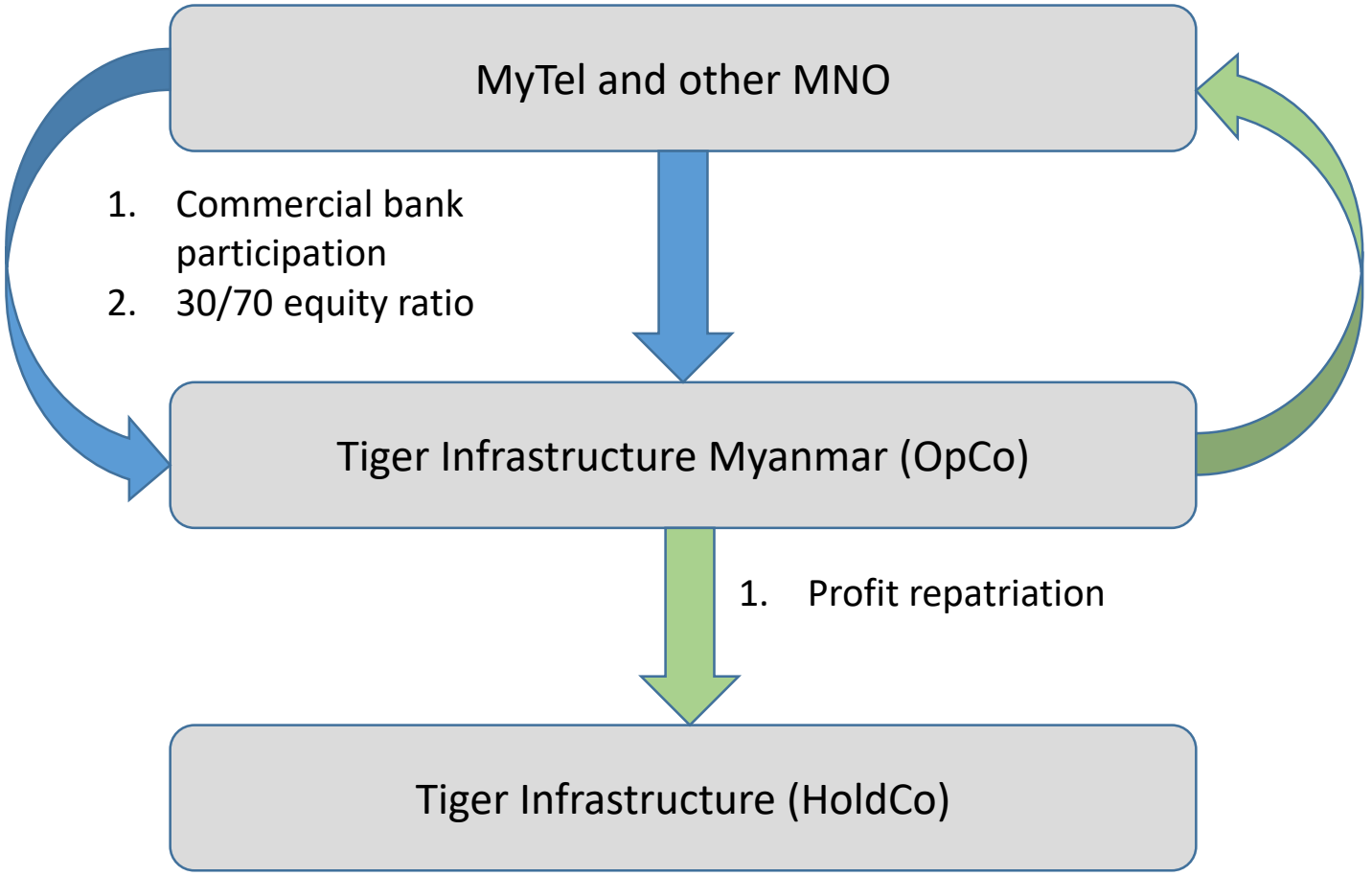
Phase 1

Strong recurring revenue with minimal operating expenses

Anchor Tenant (MyTel and other MNO)

Business Model for Tower Leasing

1. 2 Contracts：Master Lease Agreement (MLA) and Master Service Agreement (MSA)
2. Contract denominated in USD, payment by MyTel in MMK and converted by bank to USD
3. MAs signed between HoldCo and Mytel



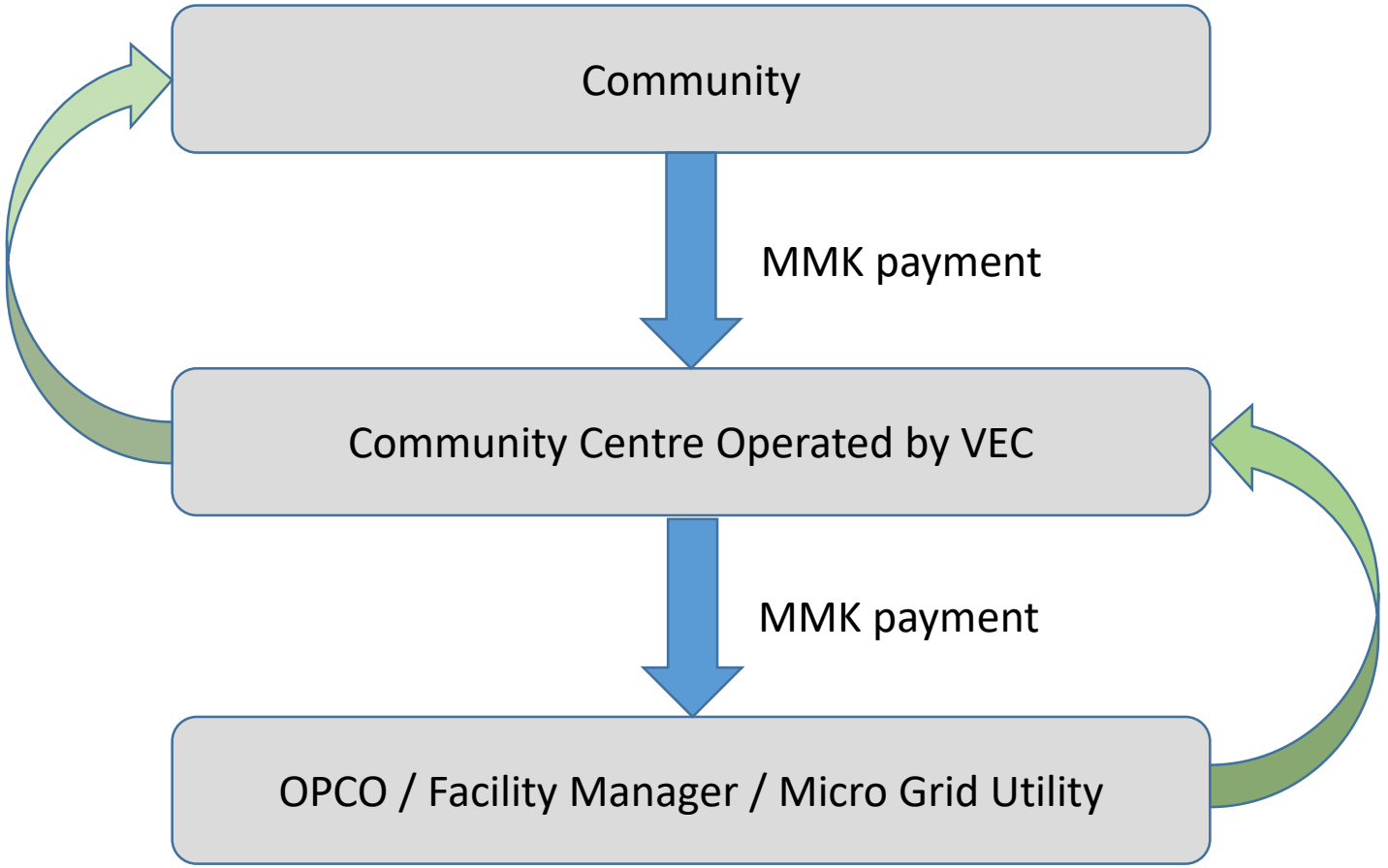
1. 15 years recurring revenue
2. “NFS “C” – operate as service provider for telco licensees
3. MIC approval – 5 years tax holiday and duty free import for the project

Phase 2

Community Centre Leasing + Energy Services for Village Electrification Committees (VEC)

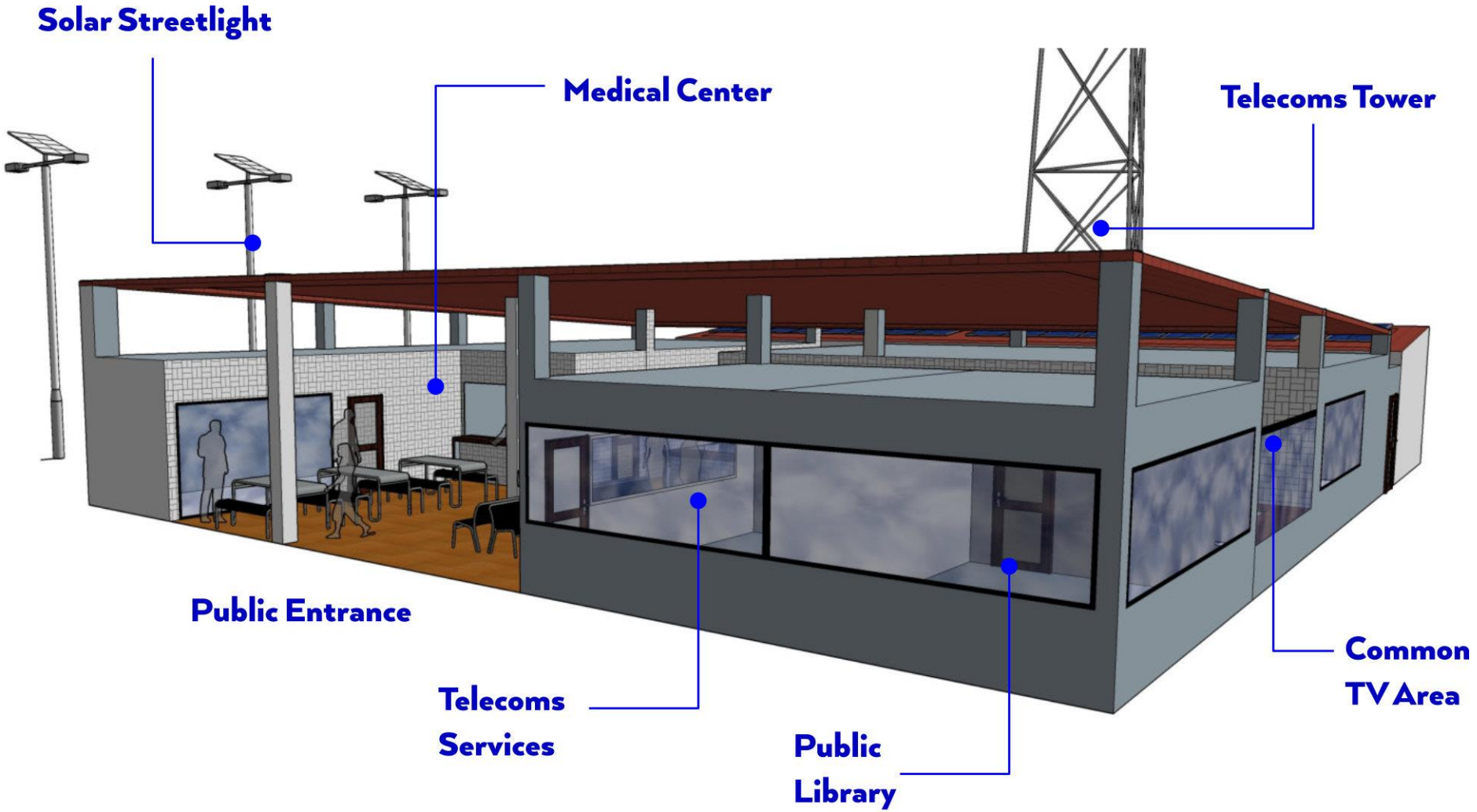
Business Model for Community Centre

1. Community centre to be operated by VEC to provide energy retail service to micro grid connected homes and businesses
2. VEC to be operated based on a cooperative principle with community ownership.
3. Services may include energy retail, micro financing, data services, other bill payments
4. Community amenities such as cinema, refrigerator, library and study room will be free of charge

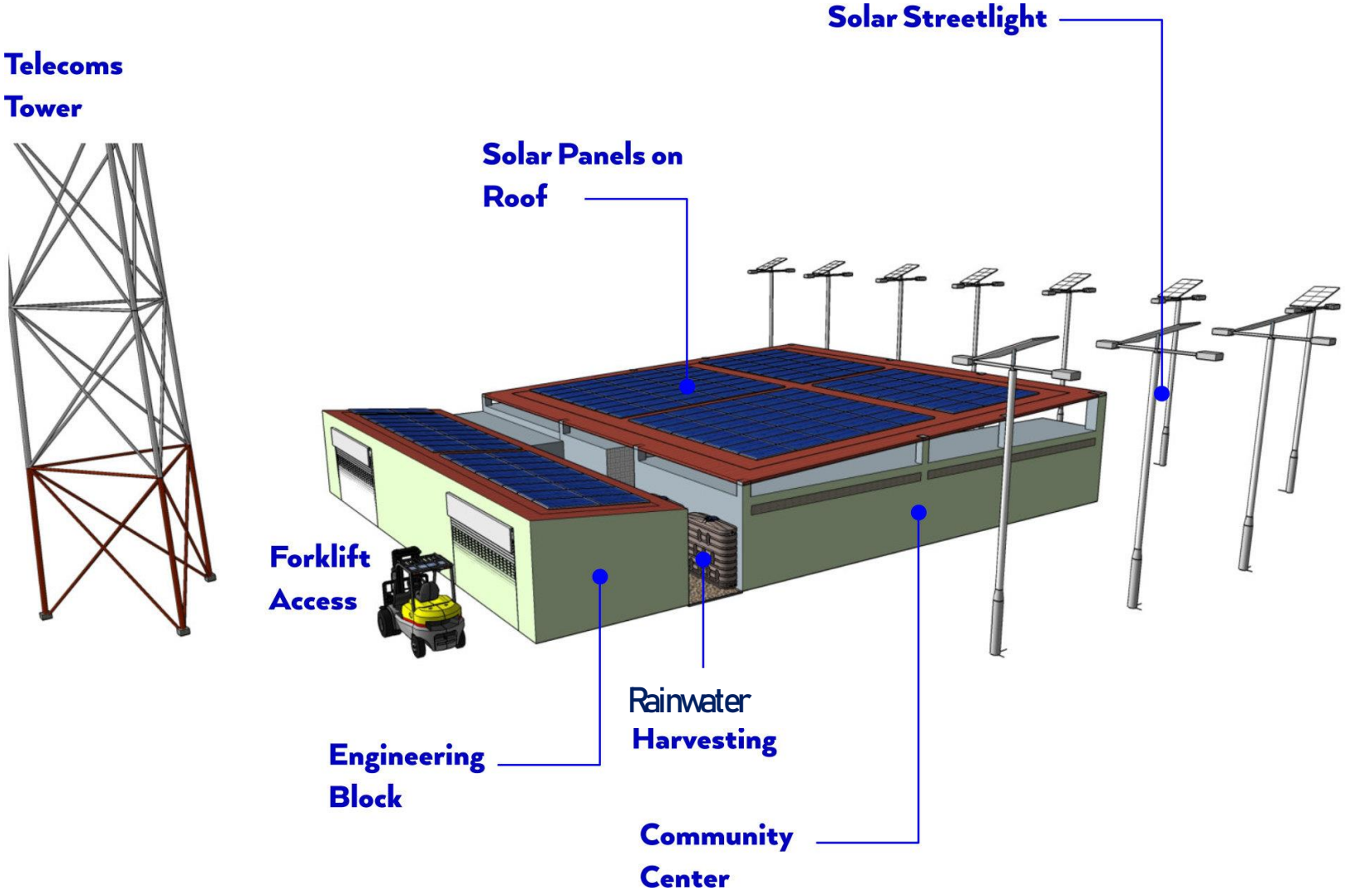


1. OPCO provides power at fixed cost to community centre
2. OPCO leases retail space at community centre to VEC
3. VEC to place 6 months rental deposit to mitigate default risk
4. VEC to deposit operating budget with OPCO for deduction of fees on a daily basis
5. VEC to collect revenue from community members and end users by cash or mobile payments

Proposed Community Centre



Proposed Community Centre



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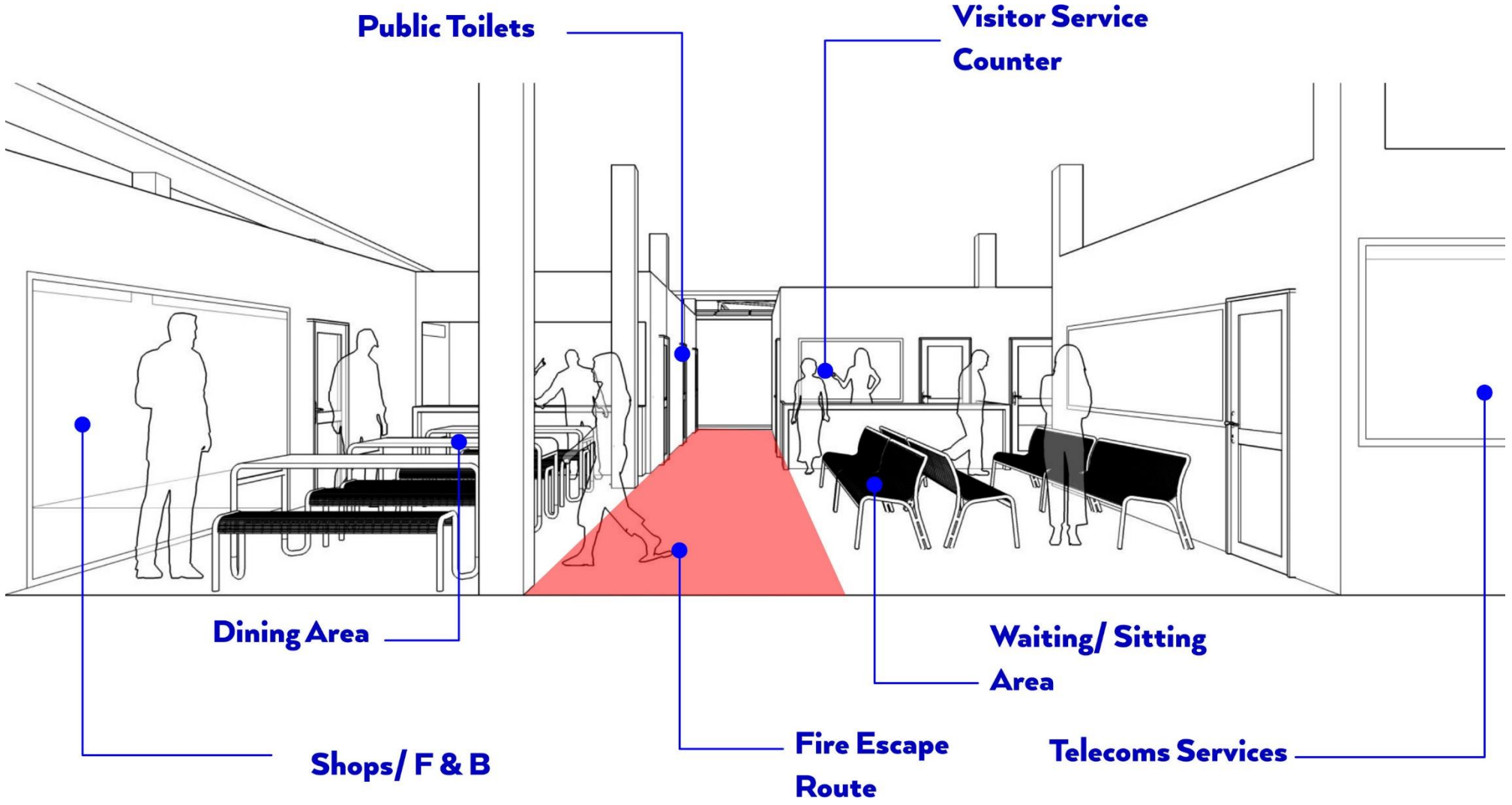
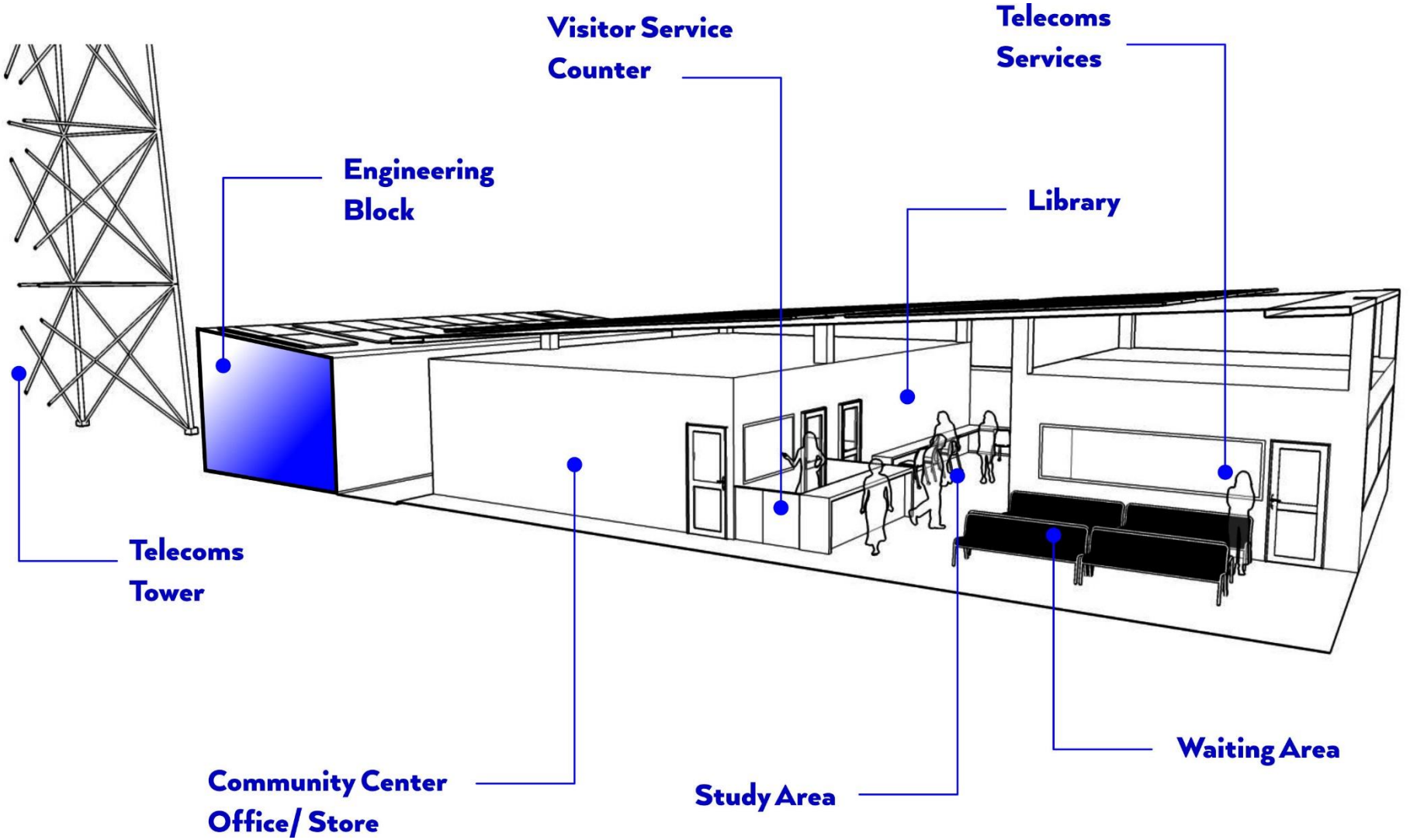


Proposed Community Centre



Phase 3

Off Grid Micro Grid

Energy Retailer, MV/LV Transmission & Distribution Infrastructure

Energy Generation

Fixed Income + Service Provider Hybrid Model

- To aggregate 5000 sites within 60 months through B2S and acquisitions
- Target to convert 1500 sites (30%) to micro grids
- Grow energy generation from 15kW to 500kW per site
- Expand embedded ESS from 40kWh to 1000kWh per site
- Potential annual revenue of USD164 mio* from electricity retail
- Reduce 10,000 tons of CO2 emissions annually
- Scaling up to be the largest micro grid utility provider in the world

*Assumptions

1. Average 1MWh energy consumption per micro grid per day (derived from Pulau Ubin with 42 end users)
2. Electricity tariff of USD0.30 per kWh and cost of diesel is USD0.60 per litre
3. Target up to 80% of energy generation from solar PV
4. Each tower can theoretically support up to 3000 users (potentially 500 households within 5km radius)

The End

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