



# A Case for Solar Power Generation & Storage

## Systems for Indian Railways

**Biprodas Dutta**

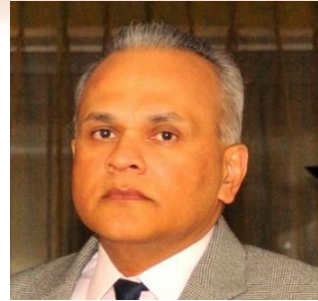
Professor of Physics, The Catholic University of America  
and

President, Vivaswan Technologies, Inc.  
Washington, DC, USA

**Professor Bipradas Dutta, President  
Vivaswan Technologies, Inc.**



**Mohan R. Krishnan, President &  
CEO, Encell Technology**



**Mr. Soumyo Sarkar, Senior Advisor,  
Vivaswan Technologies, Inc**



- Ph.D.: Vanderbilt University
- M.S.: Georgia Institute of Technology
- B. Tech: Indian Institute of Technology, BHU, Varanasi, India
- >80 refereed papers & 21 patents
- **PV Power Plant Engineering, Procurement and Commissioning (EPC) Services**
- Director, Nanotechnology Center, The Catholic University of America (CUA)
- Director, Materials Science & Engineering Program, CUA
- Professor of Physics, CUA

- M.S.: Massachusetts Institute of Technology
- B. Tech: Indian Institute of Technology, BHU, Varanasi, India
- COO & CEO, Global Business Development, **The JPM Group**, based in Delhi, India (2010-2013)
- Investment Portfolio Manager and Proprietary Trader, **Deutsche Bank AG** (1999 to 2010)
- Director, , NA Industrial/Marine Business Division , **Rolls Royce** (1993 to 1999)

- MBA: University of Iowa
- B. Tech: Indian Institute of Technology, BHU, Varanasi, India
- CEO, Portfolio Manager & Founder of **Sumit Capital LLC**, a New York based registered investment advisor.
- Managing Director, **Deutsche Bank & Founder, Deutsche Bank Matched Book Arbitrage Group** (1995-2010)
- Founder, Equitech Proprietary trading group, **Credit Suisse** from (1990-1995)



**Mr. Shyamal Mitra, Director of Business Development, VTI**

- Bachelor of Technology, Banaras Hindu University, India.
- Executive Director (retired), National Hydroelectric Power Corporation (NHPC) Limited – A Gov't of India Undertaking



**DR. N. DUTTA, Director & Vice-President, Engineering and QC**

- Expert in AC/DC systems designing, power evacuation, electrical layout, operational maintenance
- Pioneered nanofabrication techniques for module surface artifacts/coating which can improve light-trapping and efficiency
- Ph.D., University of Delaware, Newark, DE, USA
- B.S., The Catholic University of America, Washington, DC



**DR. D. DUTTA, Director & Vice-President, Foreign Operations**

- Ph.D., Arizona State University, Tempe, AZ, USA
- B.S., University of Maryland, College Park, MD, USA

- 2016-17: Highest-ever clean power additions in India:
  - **Wind + Biomass + small-scale hydro electricity = 4.5GW**
  - **Solar install target is 12GW**
    - **Solar generation + energy storage solutions** can be designed for a wide range of applications (i.e. electrification of rural villages)
- **IR's vision of clean energy**
  - IR consumed ~21.3 billion kWh in 2016
  - A total of about 14GW of renewable energy is required to meet today's electricity requirement
    - Possible to implement 1GW/yr
  - Project will self-finance from the 7<sup>th</sup> year from market value of power generated
  - Mitigate the release of 1.5 millions tons of carbon emissions/GW of RE installations
- **US solar tech is cost-competitive; we demonstrate**
  - **Export-import bank of USA financing** for 85% of project value
    - 15% margin requirement can be **acquired as a loan locally, or PPP**
  - Quality **American-made components** for **higher long-term returns**



Residential



Agricultural



Municipal



Commercial

## IR has an Immense Infrastructure

- **Traction needs of the second largest network in the world**
  - ~68,000 km of railway; of which, ~26,000 km (38%) is currently electrified
  - Electrified tracks carry ~63% freight traffic and ~50% passenger traffic
  - 22 million passengers/day
  - 1.1 billion tons of freight/year
- **Non-traction needs**
  - ~15% of IR's energy requirement
  - Powering >7200 stations, as well as factories/workshops, offices, etc.
- **IR consumed 2.6 billion liters of diesel in 2015**
  - 3.2% of India's total diesel consumption in the transport sector
- **IR is the single largest consumer of electricity in India**
  - IR consumed about 21.3 billion kWh in 2016
  - 2% of total India's total electricity generation

## IR's Robust Future Growth

Passenger demand = 8.9% annually  
 Freight demand = 9.7% annually

## Energy Costs Expected to Rise

Business-as-usual (BAU) for **traction electricity** will grow at an annual rate of >3.8% to be **7.93 – 11.50/kWh by 2030**

BAU costs for **non-traction electricity** will grow at an annual rate of >3.7% to be **INR 14.00 - 20.00/kWh by 2030**

## Warranty, Guarantee, Performance, Reliability & After-sales Support

- America has some of the **largest solar panel and inverter manufacturers**
- American products set the benchmark in warranty, performance, and reliability
  - SolarWorld provides up to a 30 year performance guarantee
- **Reliability: 20-25year warranty periods**
  - **Warranty periods indicate component longevity**
- **Established companies** with a history of **ethical business practices and customer support**

## Ensure Reliable, Long-term Returns on Investment

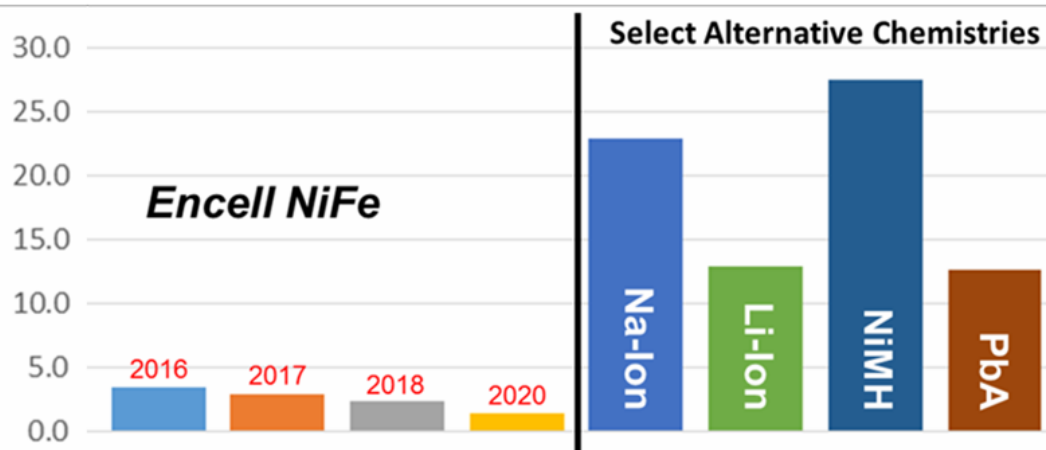
# Energy Storage Comparison: Novel storage system will deliver more stored power in the long-term for the lowest total cost

- Environmentally Friendly and Safe**
- No Climate Conditioning Required**
- No Capacity Fade for 1<sup>st</sup> 75% of Cycle Life**
- > 80% Wh Round Trip Efficiency**



**Industry Best LCOE <\$0.04 per delivered kWh**

**Comparison of Levelized Cost (¢/kWh per cycle)**

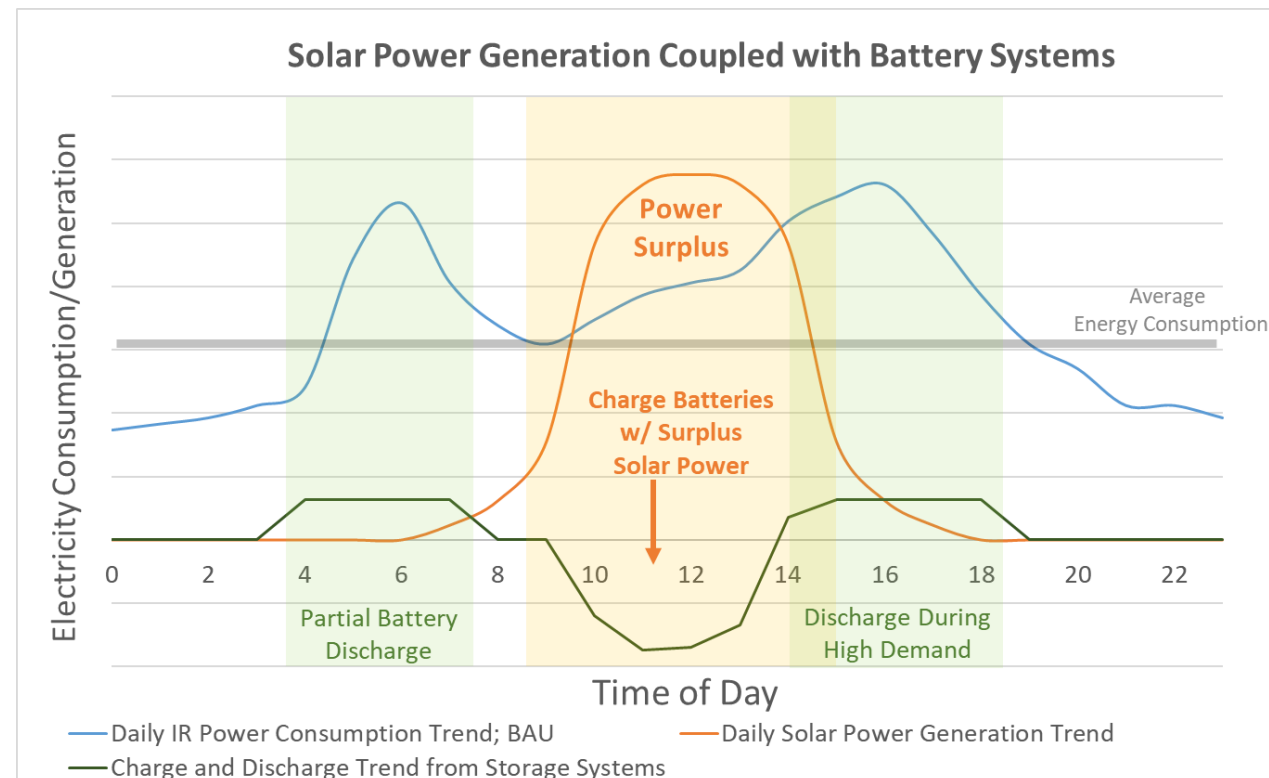
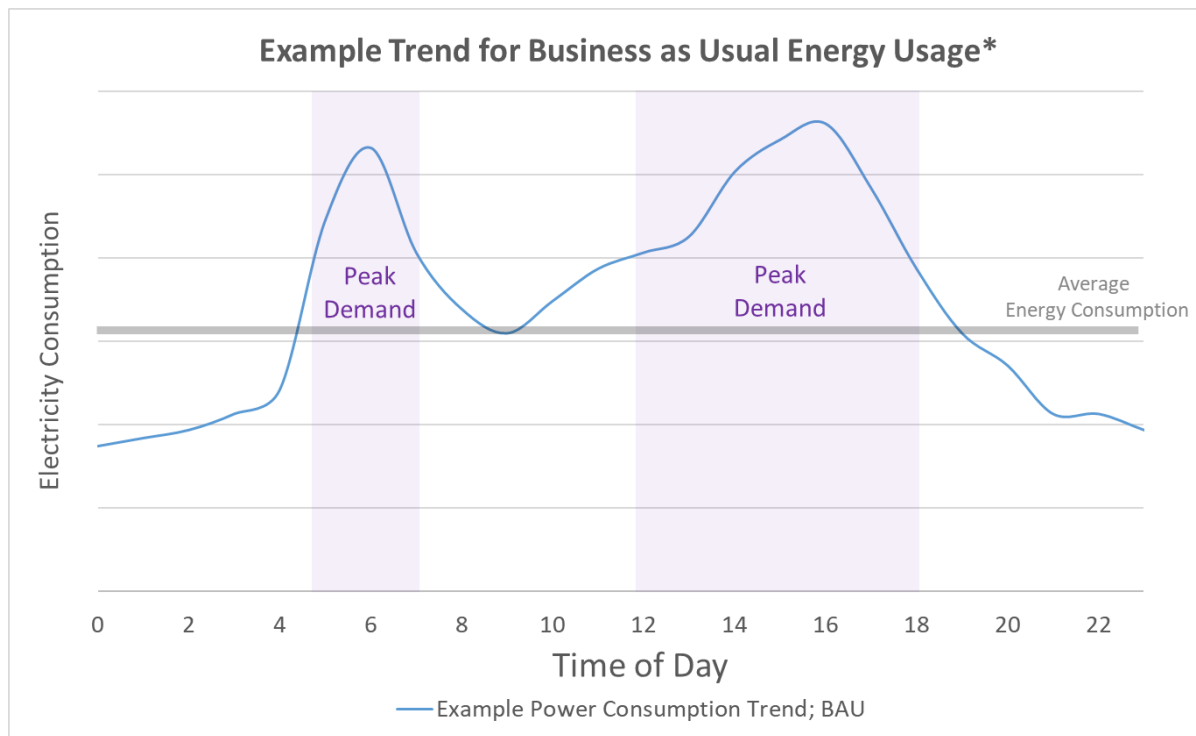


	Nickel Iron		Lead Acid Types		Lithium-Ion Types			
	Encell Fused Iron	Changhong Pocket	Flooded PbA	Sealed PbA	LCO and NCA	NMC	LiFePO <sub>4</sub> phosphate	Li-Titanate
Energy (Wh/kg)	35	25	40	30-40	175-240	150-220	90-130	70
Cycles at 25°C (80% DoD)	11000	1000	1000-1500	200-400	500-1000	500-1000	2000-3000	4000-5000
Wh Efficiency (%)	80	60	65	80	90	90	90	90
Low Charging Temperature (deg C)	-30	-20	-40	-40	0	0	0	0
High Charging Temperature (degC)	60	55	50	50	45	45	45	45
Charge Rate (C)	1	0.2	0.2	0.2	1	1-2	3	3
Peak Discharge Rate (C)	6	.2C	4	4	2-3	2-3	10	10
Flammable	No	No	No	No	Yes	Yes	Yes	Yes
Abuse Tolerance	H	H	M	M	Low	Low	Low	Low
Requires Climate Conditioning	No	No	Yes	Yes	Yes	Yes	Yes	Yes
Requires BMS	No	No	Yes	Yes	Yes	Yes	Yes	Yes
Capacity Fade	No	No	Yes	Yes	Yes	Yes	Yes	Yes

**Other Chemistries Need Expensive BMS and Cooling Systems – ENCELL DOES NOT**

Battery Chemistry	Over Charge	Over Discharge	Puncture	Environmental
Lead Acid	✓	DEAD	✓	☠
Lithium Ion	☠	☠	☠	☠
NiCd	✓	DEAD	✓	☠
Nickel Iron	✓	✓	✓	✓

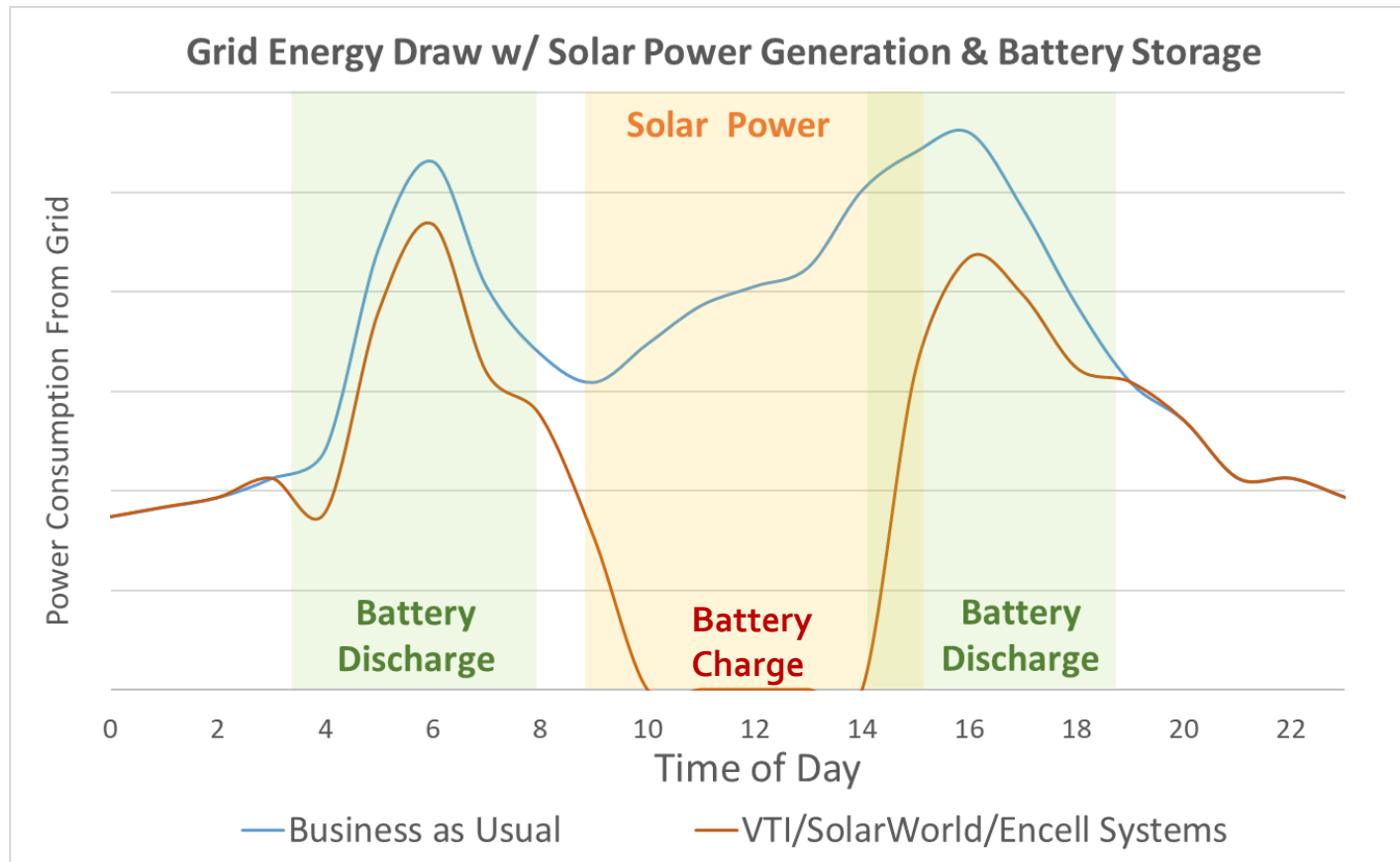
**Encell Is Safe, Environmentally Friendly, And Durable**



\* Business as usual trend is representative of typical real-world dynamic electricity demand

## Proposed system is flexible for IR's daily energy requirements

- **Mitigate energy demand during sun hours (8am – 4 pm)**
- Peak insolation between 9am and 3pm
  - Generation systems can be designed to satisfy 100% of the average local electricity demand during this time
- **Charge storage systems during sun-hours, especially if surplus power is available from PV systems**
- **Efficient, large-scale energy storage**
- **Stored energy can be used when necessary:**
  - Deploy energy to meet expected demand increases
  - Account for unexpected fluctuations in demand at anytime
  - **Flexible on a day-to-day basis**



- Significantly **reduce amount of energy drawn from the grid**
- **No need for complicated power purchase agreements (PPA) with DISCOMs**
  - IR uses all energy generated internally
  - Any energy surplus is stored for later use
- **Mitigate chances of incurring high fees due to higher than expected demand** at any time of the day/night
- Flexibility to use stored energy as IR deems prudent
  - Encell batteries can be discharged almost completely
  - Encell batteries can handle 1-2 duty cycles per day
- Battery system can also be charged from the grid in areas where grid electricity tariff is lower in the off-peak hours



Possible Low-Cost Financing by Ex-Im Bank, USA

For Example:



Financial and Power Generation Analysis:

Model Solar Power Plant with Integrated Storage

- **322.7 MW** Solar Power Generation
- **109,400 kWh** Delivered Energy Storage

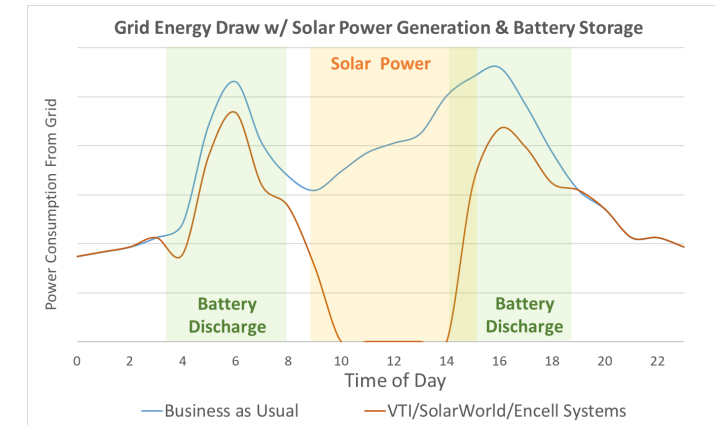
**\$400 million (Rs. ~2580 crores) towards Indian Railways project financing**

## Power Generation Assumptions:

- Total capacity: **322.7MW**
- **1500hours/year** of peak insolation
  - 5.0 hours/day, for 300 days/year
  - Generation = 1.5 million kWh/MW of installed capacity/year
- Surplus solar power diverted to storage systems to charge battery systems to full
- Assume 40% of complete system is operational through year 1
- **Insurance + operation + maintenance = 2.5%** of total project cost per year
  - Overall cost escalation of **2.5% per year**
- **Assume 0.6% loss in power generation efficiency** per year of total system
  - Select US panels guarantee as low as **0.35% loss in power generation efficiency/year\***
  - Ni-Fe batteries provide up to 20 year warranties on batteries\*

## Power Storage Assumptions:

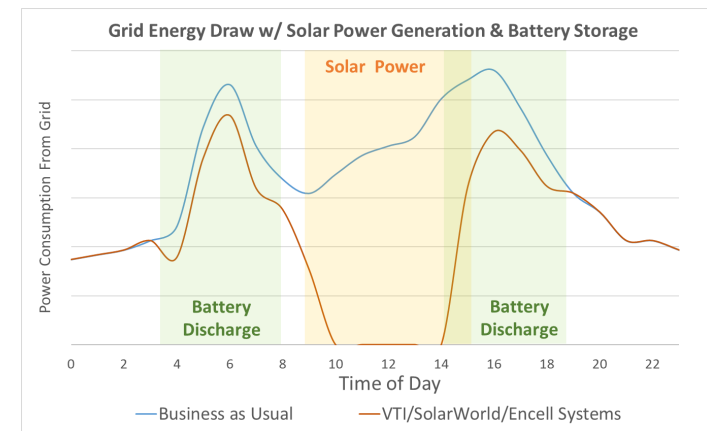
- Nickel-Iron preferred for most Indian applications
- Delivered capacity = 109,400 kWh
- Delivered capacity duty cycles = 1/day



## Loan Term Assumptions from the Ex-Im Bank of USA:

- 30% margin = **Rs. 774 crore (can be as low as 15%)**
  - Margin money maybe financed locally
- 70% loan principal: **Rs. 1807 crore**
- Interest rate = **3.6%** (lower rates possible)
- **15 year** amortization (range 7-15 years)
- Moratorium Period
  - First year for principal & interest
- Electricity costs offset = **Rs. 6.46 per kWh** (unit) generated using solar and distributed by storage systems
  - 2.5% year-over-year increase in electricity tariff
- Revenue stream from carbon credits assumed to be Rs. 250/ton of carbon emissions mitigated
  - Carbon emissions mitigated ~ 1.5 kg/kWh from coal-fired power plants in West Bengal

- **Total Project cost:** \$400 million (Rs. ~2581 Crores)
- **Total cost of Generation systems:**
  - 80% of total investment
  - Rs. ~2065 Cr (Rs. 6.40 crores/MW)
- **Total cost of Storage Systems:**
  - 20% of total investment
  - Rs. ~516 Crores



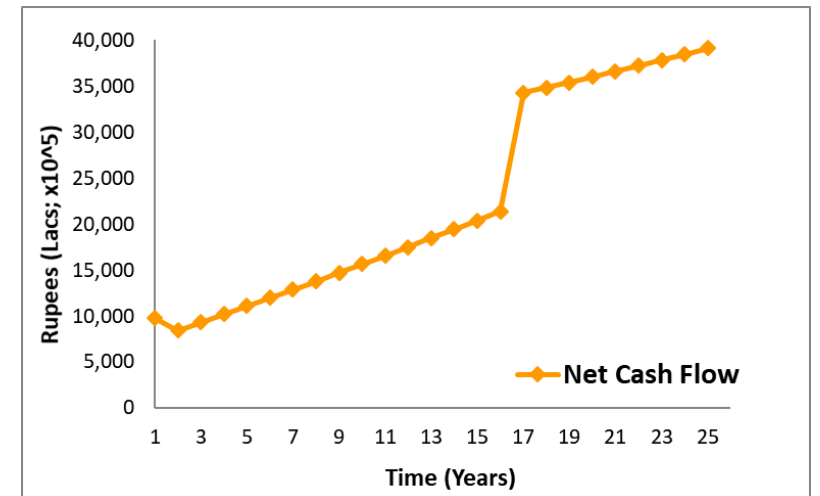
**Loan Terms are Indicative and can be Negotiated**

Cash Flow- All Currency Figures in Lacs (x10<sup>5</sup>)

YEAR	Installed Capacity (MW)	Units Offset from Storage/Generation Systems	Avg. Grid Traiff (Rs./kWhr)	Revenue Generated	Yearly Carbon Credits Revenue	Minimum Yearly Loan Service	Yearly Insurance + O&M	Net Cash Flow	Net Cumulative Cash Flow
1	126.88	1903.25	□ 6.46	□ 12,294.98	□ 714	□ 0.00	□ 3,227.00	□ 9,781.70	□ 9,781.70
2	322.70	4758.12	□ 6.62	□ 31,505.89	□ 1,784	□ 18,390.46	□ 6,454.00	□ 8,445.73	□ 18,227.43
3	322.70	4731.54	□ 6.79	□ 32,113.13	□ 1,774	□ 17,956.75	□ 6,615.35	□ 9,315.36	□ 27,542.79
4	322.70	4705.12	□ 6.96	□ 32,732.15	□ 1,764	□ 17,523.04	□ 6,780.73	□ 10,192.80	□ 37,735.59
5	322.70	4678.85	□ 7.13	□ 33,363.18	□ 1,755	□ 17,089.33	□ 6,950.25	□ 11,078.17	□ 48,813.76
6	322.70	4652.75	□ 7.31	□ 34,006.45	□ 1,745	□ 16,655.62	□ 7,124.01	□ 11,971.60	□ 60,785.36
7	322.70	4626.80	□ 7.49	□ 34,662.21	□ 1,735	□ 16,221.91	□ 7,302.11	□ 12,873.24	□ 73,658.60
8	322.70	4601.01	□ 7.68	□ 35,330.70	□ 1,725	□ 15,788.21	□ 7,484.66	□ 13,783.21	□ 87,441.82
9	322.70	4575.37	□ 7.87	□ 36,012.17	□ 1,716	□ 15,354.50	□ 7,671.78	□ 14,701.66	□ 102,143.48
10	322.70	4549.88	□ 8.07	□ 36,706.87	□ 1,706	□ 14,920.79	□ 7,863.57	□ 15,628.72	□ 117,772.19
11	322.70	4524.55	□ 8.27	□ 37,415.06	□ 1,697	□ 14,487.08	□ 8,060.16	□ 16,564.53	□ 134,336.72
12	322.70	4499.37	□ 8.48	□ 38,137.01	□ 1,687	□ 14,053.37	□ 8,261.67	□ 17,509.24	□ 151,845.96
13	322.70	4474.34	□ 8.69	□ 38,872.99	□ 1,678	□ 13,619.66	□ 8,468.21	□ 18,463.00	□ 170,308.96
14	322.70	4449.46	□ 8.91	□ 39,623.26	□ 1,669	□ 13,185.95	□ 8,679.91	□ 19,425.95	□ 189,734.91
15	322.70	4424.73	□ 9.13	□ 40,388.12	□ 1,659	□ 12,752.24	□ 8,896.91	□ 20,398.24	□ 210,133.14
16	322.70	4400.15	□ 9.36	□ 41,167.84	□ 1,650	□ 12,318.53	□ 9,119.33	□ 21,380.03	□ 231,513.17

## Overview:

- **Positive cash-flow every year of operation**
- Steady increase in net yearly costs offset with time
  - Cost offsets refers to savings generated by reducing the amount of energy purchased from the grid and operated by DISCOMs
- **Recover the initial margin investment (cumulative cash flow) before year 8**



\* Net Cash Flow and Net Cumulative Cash Flow refers to costs offset due to decreased energy draw from the grid

## IR: Electricity Purchased from DISCOMS

YEAR	Avg. Grid Traiff (Rs./kWhr)
1	□ 6.46
2	□ 6.62
3	□ 6.79
4	□ 6.96
5	□ 7.13
6	□ 7.31
7	□ 7.49
8	□ 7.68
9	□ 7.87
10	□ 8.07
11	□ 8.27
12	□ 8.48
13	□ 8.69
14	□ 8.91
15	□ 9.13
16	□ 9.36
17	□ 9.59
18	□ 9.83
19	□ 10.08
20	□ 10.33

### Estimated Tariff Schedule

- Assume a 2.5% increase in grid electricity tariff for IR across India
- Average electricity cost for every unit of energy drawn from grid = **Rs. 8.25/kWh averaged over the next 20 years**

## IR: VTI/Encell Solar Generation/Storage System

- Total system lifespan assumed = 20 years
- Total System Levelized Cost of Energy (LCOE) of VTI generation/storage systems:

$$LCOE_{20\text{ years}} = \left( \frac{\text{Total Capital Costs} + \text{Interest} + \text{Insurance} + \text{O\&M}}{\text{Total Units Offset}} \right)$$

- Total Capital investment + interest = Rs. 230,317 lacs
- Insurance + O&M over 20 yrs = Rs. 157,774 lacs
- Total Units offset over 20 yrs = 87,913 lacs
- **Combined system levelized cost over 20 years = Rs. 4.41/kWh**

**Levelized Cost Of Electricity Generated by Proposed System Is Rs. 3.84/kWh Lower Than The Grid Price**

- Reduce reliance on local DISCOMs
- Generate energy for IR's internal use
- Store surplus energy generated from PV system
- Reliably deploy stored energy in response to demand and local tariff schedules
  - Significantly reduce overall total energy drawn from grid
  - Minimize/eliminate demand and usage overage costs
- American manufactured products come with substantially lower interest rates
  - Interest rates have a significant effect on overall project cost and profitability
  - Acquire 3.6% (or lower) interest rate over an amortization period of up to 18 years

**High-Quality American-Made Systems & Engineering With  
Reliable Long-term Returns Are Now Possible in India**

# Societal Benefits of Solar Power Generation and Battery Storage Systems are Wide-Reaching

1. Job creation: VTI/Encell predicts formation of up to **5000 long-term jobs** for the described project alone
  - 15,000 temporary jobs created during construction and commissioning
2. Stimulate the **local economy**
  - Project requires substantial materials, expertise and labor from the local regions
3. Lower operational costs can be passed onto the passengers
  - Indian railways is the quintessential embodiment of **affordable transport for all**
4. Aid in India's effort for **electrification of all rural villages**
  - Combination of solar power generation & storage can be adapted for powering lights and small electronics in rural households
5. Mitigate release of over **700,000 tons of carbon emissions per/year**





Thank you



1. Charith Konda, Saurabh Trivedi and Gireesh Shrimali, Climate Policy Initiative, Decarbonization of Indian Railways (2016).
2. Indian Railways signs first bilateral PPA to cut energy costs | Business Standard News. Available at: [http://www.business-standard.com/article/economy-policy/indian-railways-inks-first-bilateral-ppa-to-cut-energy-costs-115020700481\\_1.html](http://www.business-standard.com/article/economy-policy/indian-railways-inks-first-bilateral-ppa-to-cut-energy-costs-115020700481_1.html).
3. Interesting facts about India Railways | Business Standard News | Business Standard News. Available at: [http://www.business-standard.com/article/beyond-business/18-interesting-facts-about-india-railways-business-standard-news-115021600404\\_1.html](http://www.business-standard.com/article/beyond-business/18-interesting-facts-about-india-railways-business-standard-news-115021600404_1.html).
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8. Mukherjee, S. & Ghosh, P. B. Estimation of carbon credit and direct carbon footprint by solar photovoltaic cells in West Bengal, India. *Int J Low-Carbon Tech* **9**, 52–55 (2014).
9. Solar tunnel powers part of Paris-Amsterdam train line. Available at: <https://phys.org/news/2011-06-solar-tunnel-powers-paris-amsterdam-line.html>.
10. Centra, M. Hourly electricity load forecasting: An empirical application to the Italian railways. *World Academy of Science, Engineering and Technology* **5**, 888–895 (2011).
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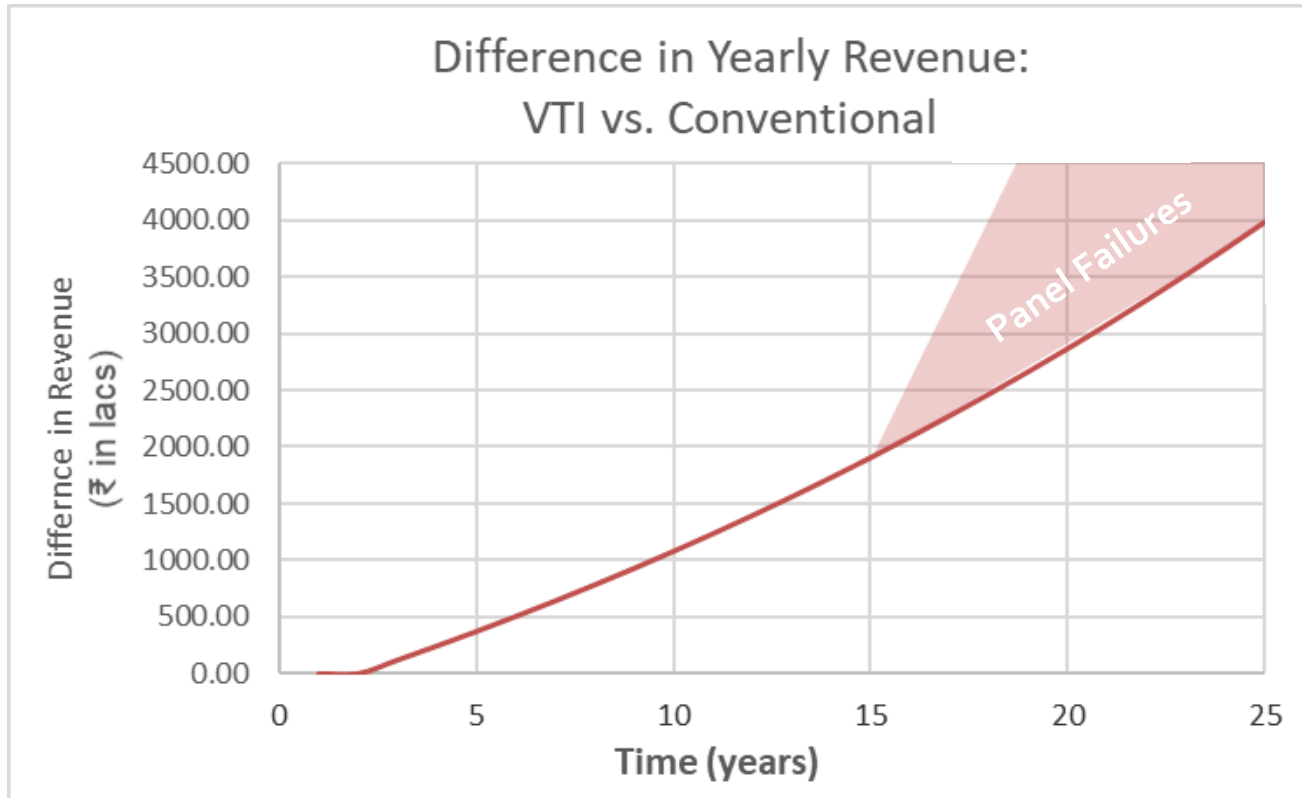
Year	Quarter I			Quarter II			Quarter III			Quarter IV			Total Interest	Total Principal	Total Annual
	Installment	Closing Balance	Interest	Installment	Closing Balance	Interest	Installment	Closing Balance	Interest	Installment	Closing Balance	Interest		Installments	Payment
1	0	180,712	0	0	180,712	0	0	180,712	0	0	180,712	0	0	0	0
2	3,012	177,700	1,626	3,012	174,688	1,599	3,012	171,676	1,572	3,012	168,665	1,545	6,343	12,047	18,390
3	3,012	165,653	1,518	3,012	162,641	1,491	3,012	159,629	1,464	3,012	156,617	1,437	5,909	12,047	17,957
4	3,012	153,605	1,410	3,012	150,593	1,382	3,012	147,581	1,355	3,012	144,570	1,328	5,476	12,047	17,523
5	3,012	141,558	1,301	3,012	138,546	1,274	3,012	135,534	1,247	3,012	132,522	1,220	5,042	12,047	17,089
6	3,012	129,510	1,193	3,012	126,498	1,166	3,012	123,487	1,138	3,012	120,475	1,111	4,608	12,047	16,656
7	3,012	117,463	1,084	3,012	114,451	1,057	3,012	111,439	1,030	3,012	108,427	1,003	4,174	12,047	16,222
8	3,012	105,415	976	3,012	102,403	949	3,012	99,392	922	3,012	96,380	895	3,741	12,047	15,788
9	3,012	93,368	867	3,012	90,356	840	3,012	87,344	813	3,012	84,332	786	3,307	12,047	15,354
10	3,012	81,320	759	3,012	78,309	732	3,012	75,297	705	3,012	72,285	678	2,873	12,047	14,921
11	3,012	69,273	651	3,012	66,261	623	3,012	63,249	596	3,012	60,237	569	2,440	12,047	14,487
12	3,012	57,225	542	3,012	54,214	515	3,012	51,202	488	3,012	48,190	461	2,006	12,047	14,053
13	3,012	45,178	434	3,012	42,166	407	3,012	39,154	379	3,012	36,142	352	1,572	12,047	13,620
14	3,012	33,131	325	3,012	30,119	298	3,012	27,107	271	3,012	24,095	244	1,138	12,047	13,186
15	3,012	21,083	217	3,012	18,071	190	3,012	15,059	163	3,012	12,047	136	705	12,047	12,752
16	3,012	9,036	108	3,012	6,024	81	3,012	3,012	54	3,012	0	27	271	12,047	12,319
All Currency Figures in Lacs (x10 <sup>5</sup> )													□ 49,605	□ 180,712	□ 230,317

## Overview:

- Total loan amount = **1807.1 Crores**
- Total Cumulative Annual Payments over 15 years = **Rs. 2303.2 Crores**
- Total Cumulative Interest Payments over 15 years = **Rs. 496.1 Crores**

**Loan Terms are Indicative and can be Negotiated**

# Power Generation Comparison: VTI power generation systems will generate more power in the long-term



The above assumes no degradation in performance in the first two years

- For the **VTI systems**, assume 0.6% loss in power generation efficiency per year
  - Panels available that guarantee as low as **0.35% loss in power generation efficiency/year\***
- 1.0% or more loss in power generation efficiency per year for industry-standard systems
  - **Indian/Chinese panels with industry-standard quality control** will have faster rate of efficiency degradation
- Differences in cumulative generation losses leads to significant decrease in profitability for industry-standard systems
  - **Rs. 40 crore/year** in decreased revenue at year 25
- Indian/Chinese panels have 10-year warranty periods that mean **higher long-term costs after warranty period** due to:
  - Panel failures
  - Panel replacement due to low output

## Expertise Provided

- Preparation of technical specifications and tie-up with utility for grid connectivity and power evacuation for railways
- Preparation of bankable detailed project report (DPR) and submissions to various authorities
- Achieving financial closure of projects
- Soil testing and topographic surveying
- Equipment finalization
- Selection of equipment vendors and procurement
- Implementation of project as EPC (Engineering, Procurement and Commissioning) contractors

Continuous R&D in  
PV & Battery  
technologies keeps  
us ahead of the  
competition

## Expertise Provided

- Negotiate full project financing packages from world-wide banks
  - United States
  - Asia
  - India
- Specialize with the Export-import (Ex-Im) bank of the US
  - Can negotiate financing from \$0.1 – 400+ million
  - Globally competitive interest rates and terms
- Take advantage of:
  - US-made quality, warranty, reliability and customer support
  - Financing options that negates having to compromise between PV component quality and upfront/monthly costs

## OM Services Include

- Asset management
- Personnel management
- Panel up-keeping
- Water management
- Inspection and monitoring
- Troubleshooting
- Plant output optimization
- Preparation and maintenance of data/data logging
- Site health and safety management - meeting all statutory requirements like factories act, environmental protection act etc.
- Monthly activity report

Our solar project implementation and operation experience means minimal operational disruptions

Robert Guyton, Jr., Founder, Chairman and Chief Business Officer



**Career Highlights:**

- M.B.A: Harvard University, MA
- B. S: Washington & Lee University, Business Administration
- Chairman and CEO of **Monarch Capital Partners**, Venture Capital Fund (1998 – 2005)
- Co-founder of **Inktomi Corporation**
- Vice President in the Corporate Finance Department, **The Robinson-Humphrey Company, Inc**
- Founder, **Convergent Resources, Inc. & Harbor Payments, Inc.**

Randy G. Ogg, Chief Technology Officer, Director of Research & Development



**Career Highlights:**

- B.S.: University of Florida at Gainesville, FL
- Chief Technology Officer for **Battery Park Industries Moltech Power Systems/HuaYi**, Shanghai, China & Gainesville
- Quality control and technical design capacities , **Energizer Power Systems**
- Process Development and Research Engineer, **Proctor & Gamble**
- Six Sigma Master Black Belt and ISO 9001-2000 Certified Lead Auditor certifications

**Mr. Shyamadas Banerji, M.S.: MIT  
Director, Vivaswan Technologies, Inc.**



**Career Highlights**

- World Bank, Washington DC,
- Lead Financial Officer/ Lead Private Sector Development Specialist (1976-2001)
- Economics and Project Finance Consultant (2001 - present)

**Professor Abhijit Sarkar, Ph.D., University  
of Illinois, USA. Director, Operations, VTI**



**Career Highlights:**

- Physicist, Professor of Physics, Catholic University, Washington DC,
- Photovoltaic research and implementation
- PV circuit designing
- Procurement and logistics

**Mr. Shyamal Mitra, Director of Business  
Development, VTI**



**Career Highlights:**

- Bachelor of Technology, Banaras Hindu University, India.
- Executive Director (retired), National Hydroelectric Power Corporation (NHPC) Limited – A Gov't of India Undertaking



**DR. R. BHATTA, Vice-President, Procurement & Logistics**

- Ph.D. Georgia State University, Atlanta, GA, U.S.A.
- M.S. Georgia State University, Atlanta, GA, U.S.A.
- 10 years experience in PV research and implementation
- Expert in PV circuit designing
- Procurement and logistics



**DR. N. DUTTA, Director & Vice-President, Engineering and QC**

- Expert in AC/DC systems designing, power evacuation, electrical layout, operational maintenance
- Pioneered nanofabrication techniques for module surface artifacts/coating which can improve light-trapping and efficiency
- Ph.D., University of Delaware, Newark, DE, USA
- B.S., The Catholic University of America, Washington, DC



**DR. D. DUTTA, Director & Vice-President, Foreign Operations**

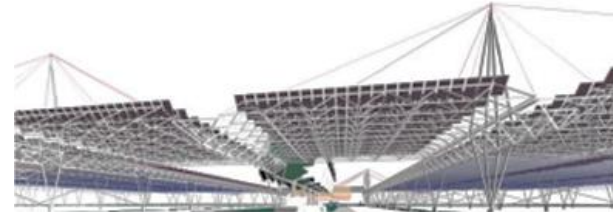
- Ph.D., Arizona State University, Tempe, AZ, USA
- B.S., University of Maryland, College Park, MD, USA

# Example US-based Projects

**Rooftop Systems in USA**  
**12kW Maryland, USA**



**400kW Solar Power Plant; Boron, California**



**800kW Parking Structure; Thousand Oaks, California**

# Example VTI Projects in Asia



**VTI Engineers on-site of a 5.5 MW Solar Power Plant at Bap, Rajasthan.**



**5.5 MW Solar Power Plant at Tinvari, Rajasthan**



**DPSC Ltd., 2MW Solar Power Plant Asansol, India**



**VTI Engineers at an Inverter room Tinvari, Rajasthan**