SUMMARY REPORT

IDB

Quadracci SUSTAINABLE ENGINEERING LAB.

CUTTING-EDGE WORKSHOP

HOW INFORMATION AND COMMUNICATIONS TECHNOLOGY (ICT) IS POISED TO TRANSFORM THE DELIVERY OF ENERGY SERVICES

AUGUST 30 AND 31, 2017 - HILTON HOTEL, WASHINGTON D.C.

Contents

Acknowledgements

This workshop was organized by IBD's Energy Division (ENE) in collaboration with Columbia University, and the IDB's Knowledge and Learning Division (KNL). Special thanks to Vijay Modi and team (Columbia University), the participating speakers, and Roberto G. Aiello (Task Team Leader, ENE) and Carolina Aclan (KNL) for their work on this event.

Ariel Yepez
Energy Division Chief
Inter-American Development Bank

Introduction

The goal of this workshop was to introduce new and innovative possibilities for the future grid to staff working in the energy sector within the IDB Group. Given recent developments in alternative energy sources and growth in the use of sensors, this workshop aimed to showcase the role which information and communication technology (ICT) could play in improving energy provision and services. The key themes presented in this workshop included the problems in developing grids, projections on how the grid will look in the future, and solutions to current problems to bring the grid into a favorable future.

The utility business was historically hardware driven, where utilities generated power and hoped it reached the customer. They meter the consumption at the home, and replace resources when failure is reported by the customer. Over the last decade a lot has changed, how measurements are made, what types of generation are widespread, and the price of monitoring equipment. Through digitization it is now possible to repair equipment before it breaks, utilize more renewable sources, and maintain large grid networks with fewer people.

Executive Summary

A. Current Insights on the State of the Grid.

1. *In many low and middle income settings the challenges of electricity provision are not technical alone, but also include ensuring reliable bottom up revenue flow from customers whose monthly payments are low.*

2. *Increasing electricity access for the last few percent of population can become rapidly more expensive.* Such customers are amenable to "grid-like" mini-grid systems which in spite of their somewhat higher cost are able to provide reliable and robust 24-7 pay as you go service, that is both more affordable and permits seamless growth of consumption. Digitization is a natural starting point for such systems.

3. *Growth of renewables has become an imperative both to meet INDC (Intended Nationally Determined Contribution) goals and increasingly for economic reasons.* Renewables such as solar and wind are essentially upfront cost propositions and hence financing is critical. To de-risk financial flows, one needs to prove through data the electricity generation. Given the decentralized nature of such systems it becomes increasingly important that developers have the means to monitor generation, detect anomalies and use analytics to automate such functions.

4. *Heating/cooling systems for thermal comfort become adopted with economic growth and can be directed to aid grid stabilization.* While countries are at early stage of adoption it is important to ensure that their role in flexibility is tied to early programs that can ensure that these systems are compatible with common communication protocols.

B. Projections for the Future of the Grid.

1. *Increasingly, utilities should be able to benefit from management of demand response and grid-interactive services, carried out internally or though contractors and subsidiaries.* There are several critical aspects of utility operation that will be impacted by the new technologies: demand projection, network planning, network expansion, equipment upgrade, fault detection and response, meeting remote area or last-mile access and/or CSR (Corporate Social Responsibility), commercial side operations such as meter reading, billing, and collection. The future utility needs to prepare for cost-effective and efficient operation of all above functions.

2. *The electric grid will be an enabler for reducing emissions.* It is changing from being a "one-way" provider of electricity to one that is more transactional and accommodating of prosumers and other measures of flexibility. A more interconnected grid that encourages distributed local generation through renewables will thereby lower emissions.

3. *Digitization is leading to the democratization of the grid and its resources,* where private sector players can increasingly provide generation and other services beneficial to the grid and get paid for it. Thereby creating viable investment and/or business opportunities that can support both the grid and the customer.

4. *Digitization of the utility will benefit almost all aspects of utility operation*: meeting voluntary INDC (Intended Nationally Determined Contribution) targets of individual countries, e.g. renewable integration, efficiency, and energy access, as well as maintaining the financial health of the utility.

5. *Countries where infrastructure growth is still occurring can be key beneficiaries of standardized ID protocols.* They ensure that appliances can be tagged to customer meters, customer meters to distribution lines and transformers, transformers to feeders, feeders to substations (MV to LV), and sub-stations to transmission lines. Additional geo-tagging tools have reduced in cost dramatically as well. This alone can pay off in conjunction with transformer level metering and feeder lever metering in ensuring both customer level and meter reader level loss detection and accounting.

6. *Deeper integration of renewables will be enabled through ensuring flexibility in the grid.* Such measures will be derived through a combination of hardware and software: operational rules, interaction agents, demand response, load shifting, and peak reduction measures. Increasing flexibility will be an earlier win compared to deep deployment of battery storage.

C. Practical Solutions: Possible Ways Forward for the Grid.

1. *Low-cost smart or prepaid metering can create a virtuous cycle of financial accountability,* allowing visibility into where the non-technical losses are and hence a means to stem

them. This can lead to improved financial health of the utility, a challenge in many low and middle income settings.

2. *To most efficiently modernize or expand utility operations, you must know the state of installed resources*. What is the current level of digitization in metering and what is the current level of variable renewables penetration. From these two factors you can determine what to prioritize first.

3. *Various enabling environments can support digitization of the traditional grid,* e.g. geospatial tools, legislature, software, data analysis platforms, cloud computing, cyber security, supercomputers, and a smarter world.

4. *Hydropower can be rethought as a grid resource to enable higher utilization of renewables, as the future primary energy supply might come from renewables.* This is especially important where hydropower is common in Central and South America. For example, adjustable speed turbines are more likely to adapt to rapid up/down ramping requirements.

5. *Developing appliance standards and standardization of protocols for interaction of the grid with appliances/aggregators will allow easier deployment.* Such deployment when carried out in conjunction with scheduling algorithms or demand response measures can expand flexibility beyond industrial and commercial customers to residential loads as well. Through development finance and other financing sources there is an opportunity for ensuring inter-operable systems and achieve cost reductions through scale.

6. *Electric vehicles offer particular opportunities in scheduled charging cycles that could ensure higher grid utilization without higher investment becoming a win-win for the consumer and the utility.* Latin American countries, perhaps led by Chile (with high Copper and Lithium reserves) can play an important role in becoming leaders in flexibility through electric vehicle charging.

7. *Scheduling pumping loads could be another low-cost source of flexibility.* In several middle-income countries irrigation pumps and other water infrastructure continue to be a significant portion of the load.

8. *In many low-income settings, the poor do not have credit history or any record of regular payments. Through ICT and communication one can ensure financial inclusion for the poorest.* Data from the field shows that the poor are actually creditworthy while frequently it is the service provider that is not. Hence data can enable financial inclusion for the poor as well as allow the utility to remove weak links in the accountability chain, thus proving its own credit.

Presenters' Take-Away Messages

Prerit Agarwal: *Real-time Renewable Monitoring Infrastructure*

- Real-time System Monitoring is valuable as it provides means to verify the value of one's investment in renewables, and provides confidence in its proper operations.

- Performance of solar panels should be evaluated by comparing the expected energy with generated energy. The expected energy, is obtained using sensors, pyranometer or reference solar cell, to estimate the amount of energy given the actual irradiation hitting the panel.

Shazim Chapra: *Small/Medium Scale Systems: Entrepreneur Perspective*

- Monitoring allows for real picture of site without being at the site itself, thus providing a clear picture of what is happening.
- Centralized solar in Pakistan has not taken off because of infrastructure problems. If the grid is unstable then it is a huge knock on possible financial generation of the country.
- It is difficult for the consumer to tell what is a quality solar product. IADB could help countries develop standardizations to show quality devices.

Ariel Nunez: *Geospatial Data - Best Practices & Data Infrastructure*

- Spatial data infrastructures or geospatial information must persist after a project is completed.
- Prioritize open source software and foster an ecosystem of local talent. Open by default, if you want to close access to something then a reason should be provided.

Balki Iyer: *Digitization of the Utility: Supporting Integrating Renewables into the Grid and Demand Side Management.*

- The top priorities for the utility are electric vehicles, constant transmission, distribution efficiency, renewables, and storage. None of these strategies can be fully implemented without a digital framework.
- With depleting fossil resources and the expected increase of atmospheric CO_2 over the next 20 years (400-440 ppm) decarbonization is imperative.
- Utilities need to embrace the cloud. Their security for non-cloud storage is less than that currently implemented on cloud systems.
- Digitization is going to be economically beneficial. Companies which will succeed have already embraced digitization while those that do not embrace it now, will be penalized later. Ignore exponential trends at your own peril.

Yashraj Khaitan: *Metering, Billing & Commercial Systems of the Utility to Support Diagnostics, Audit & Revenue Collection.*

- India's power sector loses 17 Billion USD on an annual basis. This is enough to provide power to Bangladesh for 5 years.
- Non-payment of bills causes a vicious cycle of bad debt and lack of trust in the utility. A very easy payment process is necessary to ensure good payment. There needs to be a timely way to generate the bill so customers get regular account status updates.
- Digitization and proper bill management can be very effective in increasing utility revenue and decreasing losses.

Dr. Matthias Preindl: *The Future of Electric Vehicles & the Grid*

- In addition to decentralized energy generation gaining traction, the numbers of Electric Vehicles (EVs), are also growing. Predictions tend to be around 50-60% of market being electric in the next 10 years, higher if an investment in charging infrastructure is made. By 2030, 24% of the vehicle market will be EVs and 5% of global energy consumption will be from EVs.
- With all these new EVs there is a potential to provide energy back to the grid. They could serve as an additional distributed resource for the grid. EVs can be used as backup batteries to stabilize the grid. With home charging controllers, EVs can provide energy to the home when the prices are high and charge when the prices are low. This could benefit the consumer's wallet as well as the utilities' if both embrace the technology.

Dr. Fred Jiang: *The Future of Sensors & Communications*

- Smaller granularity in sensor data increases the possibilities for analysis and data aggregation. If data is visualized it can help stem excess consumption.
- Mapping your energy footprint in real time can provide informative feedback that then impacts everyday interactions.

Jack Bott & Jia Ji: *Minigrid Experiences for Remote Regions - IoT without the Internet*

- The last mile customer can be exponentially expensive to connect to the grid. For these customers grid-like power from off grid systems can be more appropriate.
- Share generation to get higher utilization and payback from initial expenditure. Lower maintenance on central generation as well. For properly managed systems, digital management and minimizing the human from the loop can make the system work.
- Systems need to be sustainable, train locals, continually generate revenue or your system will fail.

Main Points

I. Democratize the Grid

Distributed resources should be embraced not shunned. More and more private individuals are investing in renewables and electric home appliances; heat pumps, solar hot water heaters, electric cars, and backup batteries. Through digitization these resources can be a boon for the grid instead of a hindrance. No longer will the grid be exclusively a "one way" provider of electricity. A more modern grid is more transactional and accommodating of prosumers.

If the traditional grid ignores the trend towards decentralized resources then consumers will find other means to profit from them without the grid benefiting. Con Ed customers in Brooklyn got together when the utility did not want to pay a feed-in tariff for solar generation into the grid. They used blockchain technology to create a network of generation and usage among themselves.[1] These multiple generation points could then also provide stability, during natural disasters or otherwise, making it much more difficult for everyone to lose power at once.

Islands like American Samoa are an example of how renewables can be managed properly to provide nearly 100% of power demand.[2] Solar provides 99% of the consumed energy on American Samoa. Wind power on other islands amounts for 30-40% of generation. With more digitization and sensor deployment everywhere else could follow suit. Improvements in weather forecasting and the presence of a digital utility can also enable demand side management.

In addition to decentralized energy generation gaining traction, the numbers of Electric Vehicles (EVs), are also growing. Predictions tend to be around 50-60% of market being electric in next 10 years, higher if an investment in charging infrastructure is made. By 2030, 24% of the vehicle market will be EVs and 5% of global energy consumption will be from EVs. With all these new EVs there is a potential to provide energy back to the grid. They could serve as an additional distributed resource for the grid. EVs can be used as backup batteries to stabilize the grid. With home charging controllers, EVs can provide energy to the home when the prices are high and charge when the prices are low. This could benefit the consumer's wallet as well as the utilities' if both embrace the technology.

With all these new developments in technology, utilities are shifting roles from traditional energy providers to managers of microgrids. Digitization is leading to the democratization of the grid and its resources. Private sector players can provide generation and other services beneficial to the grid and get paid for it, creating viable business models that can support both the grid and its customers.

II. Smart Metering

The utility business was historically hardware driven, where utilities generated power and hoped it reached the customer. In such traditional systems, inexpensive meters are used to measure the consumption at the home. However, many drawbacks are associated with these types of meters.

In the case of India, where the power sector loses $17 billion in revenue annually, traditional metering only contributes to electricity loss and by convention revenue loss. The lack of consistent and usable data from the existing meters results in inefficiencies in bill collection, little to no maintenance, and poor procurement of electricity infrastructure.

India operates on an L1 procurement strategy where the lowest bid gets chosen. Ten to twenty percent of all its existing meters are purchased on a yearly basis and of these procurements only 25-30% are for new connections, most are to replace faulty meters. Faults on static meters which are the majority of those installed, are undetectable unless seen in person; if the customer complains or a technician is present at the site. In addition, these meters are not geo-tagged, thus upwards of 40% of the customers in some regions of India are “ghost consumers” or non-paying consumers. Due to poor organization, customers may not get a bill for 6 months and when they do it is too high for them to pay. This leads to default in payments and mistrust between the utility and consumers. As a result, power theft becomes prominent, as potential customers are not willing to pay the utility for services given the lack of reliability in the metering and bill generation process. The situation is made worse by voltage spikes and dips, from 60 VAC to 1000 VAC in places where it should be a constant 240 VAC. Consequently, customers are being asked to pay for power that burns their appliances. This creates a vicious cycle between customers and their utility. This story is not unique to India, in fact many utilities in developing countries face the similar challenges when it comes to metering and monitoring their network.

Low-cost smart or prepaid metering can increase financial accountability, allowing visibility into where the non-technical and technical losses occur and hence a means to stem them. This can lead to improved financial health of the utility, a challenge in many low and middle income settings. Connected smart meters and sensors can find the loses on the grid. It then becomes more of an issue to deal with the person stealing power rather than detecting theft.

One company benefiting from digitized resources is Greenewable Solar, partnered with Locus Energy. Their business model is to lease rooftop solar systems. Their digital monitoring allows them to remotely track production at the site. As an example, they have had many issues with cleanliness of solar panels, an issue for any solar operator. The Locus monitoring tools allow them to know when panels are dirty. They found one customer needs to clean their panels 3 times a week because of fumes coming from their building. Without monitoring enabled by smart metering, the panels would have been maintained with conventional wisdom and would not have produced as expected.

The goal of smart metering is to reduce operation and maintenance expenses, to analyze sites for outlier performance and to reduce response times by sending the right teams to fix issues when they occur. Even in developed nations there must be a larger push for collecting and utilizing smart metering data from the grid.

Today there are 50 billion IOT sensors in the world. They are getting cheaper and can be put on anything. The cloud storage market is expected to grow from $18 billion to $112 billion in less than 3 years. Utilities need to embrace such technologies to collect and store data. The most progressive utilities use less than 10% of the data they collect. Utilities can't even tell customers if there is going to be an outage or that there is an outage, customers have to let the utility know. This needs to change as we move through the 21st century.

III. Challenges of Access & Reliability

Universal electricity access is a mandate that all countries strive to achieve. Electricity access typically begins in urban centers - as the demand for such services are usually by wealthier high consuming customers, and then spreads to the more remote areas.

Electricity access in remote areas is a challenge because grid connection becomes more expensive as customers become more remote. With more access comes a divergence between the increasing cost of connecting new customers and the low consumption of newly added customers. The consumption of new customers no longer covers the cost of providing the service.

Knowing where the customers are, their possible consumption, and the cost to connect them is relevant when planning for access in remote areas; how much wire is necessary, do they currently have an alternative source of power, and do they have a revenue stream that would allow them to pay for electricity. Knowledge of where customers are located enables service providers to plan how best to connect them. The per customer cost of connection wires is minimal when the customer is less than 200 meters from the grid. Beyond this threshold the cost of connection increases with wire distance. Finally, understanding the demand (kW) and the consumption (kWh) will influence the choice of technology suitable for the customers. For low consuming customers, grid-like services from distributed generation sources (e.g. solar systems, minigrids) might be more suitable in matching their consumption needs at a lower cost.

Distributed generation sources such as solar home systems have gained traction in recent years due to new service models like Pay As You Go (PAYG). This model has shown more potential for systems which cost between $300 - $400. Anything lower, the transaction cost is too high. In poor remote regions, solar home systems can provide about 3 kWh/month. Typical grid systems in remote areas can provide 50 - 70 kwh/month, while the monthly consumption ranges from 15 - 30 kWh. The consumption is higher than what a solar home system can provide but too low for the grid to be properly utilized. Thus there are opportunities for distributed systems, with and without batteries, within this range which could provide grid-like services. The price reduction in battery cells makes it of more interest for grid or stationary based applications.

Distributed systems with grid-like services should be designed such that they can be upgradeable should the demand grow. Systems requiring low capital should be implemented in demand clusters where growth in consumption can occur. The system should be inclusive to allow users with different resources and levels of education to access the technology. Digitization of distributed systems for metering, bill generation, payment and monitoring can reduce operation costs and increase system transparency. Considerations for data collection and security should be put in place prior to deploying such systems.

In urban areas, grid infrastructure is primarily plagued by a lack of reliability, in the form of electricity theft, outages etc. A proposed solution to improving reliability might be to increase generation by adding power plants to meet the load. If the grid infrastructure is very poor, then improving the data streams along the electricity network can be more effective in reducing losses and thereby improving reliability. Good data collection on the electricity network allow operators to know and detect problems, thereby allowing the operators to fix the problems.

IV. A More Effective Grid Plan | How to Digitize?

Nearly all goals of the utility and individual countries (e.g. renewable integration, efficiency, energy access and financial health of the utility) would benefit from digitization. It allows the utility to incorporate lower cost systems, energy accounting, demand side management and renewables. Various advancements and enabling systems (e.g. geospatial tools, legislature, software, data analysis platforms, cloud computing, and cyber security) can support digitization of the traditional grid in a cost effective manner.

Geospatial Tools

Geospatial tools allow the utility to know how its assets are spatially distributed. This includes knowing locations of transformers, poles, lines and customers relative to generation plants. However, maintaining geospatial data tends to be more important than creating the data. When considering appropriate geospatial tools, open source software and data sharing should be prioritized. Involving local teams and government will support sustainable data collection and management. Finally, user communities should be encouraged to develop and maintain usable tools which meet the needs of diverse users.

Software Platforms

Utilities are used to procuring hardware; wire, poles, generation plants, but when adding software there are many new challenges. Software platforms should support multiple manufacturers and should expose the data including metadata to the necessary party. They should also allow infrastructure to be managed remotely from a central location especially in cases where it is hard to access electricity assets.

Standards & Protocols

As utilities develop a digital strategy, it is equally important to develop software protocols and equipment standards that will allow for a more cohesive grid. The goal of these protocols and standard should be to facilitate procurement of equipment and enable easy repairs of infrastructure. The standards can help minimize equipment turnover from year to year.

New Business Models

In India, utilities incur $4-5 in transaction costs (software, administration etc.) to serve the consumer, after paying for power. Average revenue per user is $22 and 70% of that goes to purchasing power. In well run utility, transaction costs for the utility should be no more than 10% of the revenue. To reduce its per customer transaction cost, utilities could outsource digitization and system management to a company through a meter, billing, and collection (MBC) business model. This is similar to telecom companies who have employed long term technologies such as IBM/Ericsson. A meter, billing, and collection (MBC) Agency model can allow the utility to serve customers at $1- $2 per customer.

Business models which save costs, improve revenue collection efficiency, and decrease electricity losses should be adopted by the utility. The utility also benefits from having one service provider for all its digital needs where it can set clear performance metrics to ensure accountability. However, clear contract terms should be outlined for both the MBC Agency and the enrolled utility.

Performance Metrics

Relevant performance metrics are needed to ensure that the right digitization strategy is in place. In the case of monitoring outputs from renewables, comparing actual energy output to the expected or forecasted output, is one approach to ensuring that a solar system or project is performing as desired. Expected energy can be estimated from a reference cell given irradiation hitting the cell. Other metrics such as amount of loss reduced in the network or bill collection efficiency are more relevant when evaluating the value of deployed meters on the network. Proper determination of appropriate metrics should be done to ensure that the right digitization strategy is chosen and that its performance is sustained.

Agenda: *How ICT is Poised to Transform Delivery of Energy Services*

Day 1

8:45		Breakfast
		SESSION 1
9:15	IADB	Welcome
9:20	IADB	Introductions
9:30	Vijay Modi	Future of the Electric Utility: Digitization, Renewable Integration, Access & Last Mile
10:30		**Coffee Break**
11:00	Prerit Agarwal &	Real-time Renewable Monitoring Infrastructure
	Shazim Chapra	Small/Medium Scale Systems: Entrepreneur Perspective
12:15	Vijay Modi	Electricity Access & Choice of Technologies
13:00	Jack Bott & Jia Ji	Minigrid Field Experiences for Remote Regions - Internet of Things without the Internet
13:30		**Lunch**
		SESSION 2
14:30	Balki Iyer	Digitization of the Utility: Supporting Integrating Renewables into the Grid and Demand Side Management.
15:45		**Coffee Break**

16:15	Yashraj Khaitan	Metering, Billing & Commercial Systems of the Utility to Support Diagnostics, Audit & Revenue Collection.
17:30		Wrap-up

Day 2

		SESSION 3
8:45		Breakfast
9:15	Dr. Matthias Preindl	The Future of Electric Vehicles & the Grid
10:30		**Coffee Break**
11:00	Dr. Fred Jiang	The Future of Sensors & Communications
12:15	Ariel Nunes	Geospatial Data - Best Practices & Data Infrastructure
13:00	Vijay Modi	Wrap-up Discussions

Speaker list

Prerit Agarwal

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Prerit heads the solutions and delivery team for commercial, industrial, and utility projects at Locus Energy along with International Business Development. He has over nine years of experience in the solar and renewable industry. He overlooks Locus business for International markets with a focus in India, APAC, MENA, and Africa. He also previously worked at Ausnenco, Amonix and United Technologies in automation and controls. Prerit holds a Master's Degree in Computer Science from the University of Southern California, and earned his Bachelor's Degree in Computer Engineering in India."

Jack Bott

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Jack works as a Mechatronics Engineer at the Quadracci Sustainable Engineering Lab, New York, NY, where he is focused on solar mini-grids for irrigation and household electricity. He is pursuing an MS in Electrical Engineering at Columbia University, has a BS in Mechanical Engineering from Columbia University, and a BA in Physics from Bard College. Jack has field experience deploying control systems across Africa.

Shazim Chhapra

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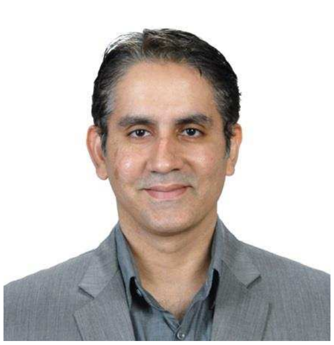

Shazim is a business professional with over 15 years of experience running his family industrial holdings in Pakistan and South Africa. He is currently the CEO of Greenewable Solar, a renewable energy company developing solar PV solutions for the commercial, industrial, agricultural and residential segments in Pakistan. He also is a principal at MI Ventures, a New York based early stage fund that makes investments in seed stage technology companies. He is credited with turning around two businesses during his time in South Africa. He holds a Bachelor's degree in Mechanical Engineering from Columbia University and an MBA from NYU's Stern School of Business.

Balakrishnan G. Iyer (Balki)

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Balakrishnan G. Iyer (Balki) is Co-founder and Chief Growth Officer of Utopus Insights, responsible for all sales, marketing and business development activities for the company. He is a senior Management Professional in the Energy & Utilities sector who served as Chief Operating Officer (COO) of Enel Green Power India. Enel established its presence by acquiring a platform where Balki was part of the Key Management responsible for growth of the company through BD, develop projects by managing Engineering & Construction and the Operations of all the Renewable Power Projects in India. Balki has also co-founded a data analytics/technology company in the E&U space that developed new products including predictive analytics. Balki also built and ran the offshore Operations team in India for the Customers.

Ji Jia

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Ji Jia is a candidate in the Computer Engineering Program at Columbia University. Currently he is doing IoT research with Prof. Xiaofan Jiang (EE) in the Columbia Intelligent and Connected Systems Lab. He is also working with Prof. Vijay Modi (ME) on the SharedSolar project as part of QSEL. Mr. Jia graduated from B.Sc.(2011) in Hefei, China. Mr. Jia has broad experience in both research labs and industry, as he has taken part in software systems development, and has led research projects as well as four manufacturing projects in the last few years. His specialty is filling the gap from research to product.

Xiaofan (Fred) Jiang

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Xiaofan (Fred) Jiang is an Assistant Professor in the Electrical Engineering Department at Columbia University and a member of the Data Science Institute. Fred received his B.Sc. (2004) and M.Sc. (2007) in Electrical Engineering and Computer Science, and his Ph.D. (2010) in Computer Science, all from UC Berkeley. Before joining SEAS, he was Senior Staff Researcher and Director of Analytics and IoT Research at Intel Labs China. Fred's research interests include cyber physical systems and data analytics, smart and sustainable buildings, mobile and wearable systems, environmental monitoring and control, and connected health & fitness.

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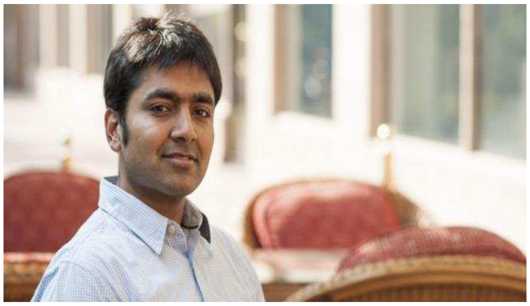

Yashraj Khaitan is the Founder and CEO of Gram Power, which is an energy technology company founded out of UC-Berkeley. Gram Power provides the industry's lowest cost and most integrated smart metering solution and works with Power Utilities as their technology backbone to help them radically reduce distribution losses. Yashraj graduated from UC-Berkeley with an undergraduate degree in Electrical Engineering and Computer Science in 2011 and opted out of his post grad program to launch Gram Power in India. After building the core team and technology, he currently heads business strategy, partnerships and technology vision for the company.

Vijay Modi

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Vijay Modi is a Professor and past-Chair of Mechanical Engineering in the School of Engineering and Applied Science and a faculty member at the Earth Institute, Columbia University. Between October 2011 and 2012, he was a member of the U.N. Secretary General's high-level task force on "Sustainable Energy for All" and he currently leads the U.N. Sustainable Development Solutions Network working group on Energy Access for All. He received his Ph.D. from Cornell University in 1984 and worked as a post-doc at MIT from 1984 to 1986 before joining the faculty at Columbia University. Prof. Modi's areas of expertise are energy resources and energy conversion technologies. His laboratory, the Quadracci Sustainable Engineering Lab (QSEL), has been responsible for technologies such as "SharedSolar" and widely used tools such as "Network Planner" and a free open-source app called FormHub, used over a million times.

Ariel Núñez
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Ariel Núñez is an Electronic Engineer with Masters studies on Computer Vision and Machine Learning. He worked for the World Bank for more than 6 years advising on Open Data and Open Source Software for Disaster Risk Reduction and Climate Change projects and at the World Food Program on the development of Geospatial Systems for Field Security. He now heads an engineering consulting firm based in Colombia working for Universities, Governments and International Organizations on Geospatial Data and Robotics using Open Source Software.

Matthias Preindl
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Matthias Preindl received the B.Sc. degree in electrical engineering (summa cum laude) from the University of Padua, Padua, Italy, the M.Sc. degree in electrical engineering and information technology from ETH Zurich, Zurich, Switzerland, and the Ph.D. degree in energy engineering from the University of Padua, in 2008, 2010, and 2014, respectively. He was an R\&D Engineer of Power Electronics and Drives at Leitwind AG, Sterzing, Italy (2010-2012), a Post-Doctoral Research Associate with the McMaster Institute for Automotive Research and Technology, McMaster University, Hamilton, ON, Canada (2014-2015), and a Sessional Professor in the Department of Electrical and Computer Engineering, McMaster University (2015). He is currently an Assistant Professor in the Department of Electrical Engineering, Columbia University in the City of New York, NY, USA. He received the Career Award of the Futura Foundation in South Tyrol, Italy and the CAREER Award of the US National Science Foundation (NSF) in 2016 and 2017, respectively.

Agenda

- Small Systems - Residential Monitoring
- Mid Size Systems - C&I Monitoring
- Large Systems - Utility SCADA
- Real Time Monitoring Software
- Performance Analytics
- Forecasting & Behind the meter production
- About Locus

Types of Solar Installations:

		Typical Size	Description
1 Utility-scale		10+ MW	Large-scale plants that supply into the wholesale electric power markets
2 Commercial		100 KW to 2 MW	Mid-sized installations that compete at the commercial price level
3 Residential		2-10 KW	Smaller-scale installations competing with retail power rates

Commercial and residential solar installations are typically considered to be "distributed solar" installations

The defining element is that there are a large number of smaller solar power plants

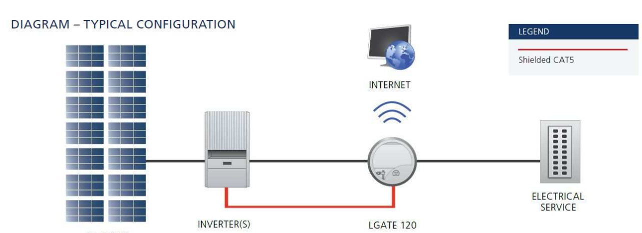
Residential System - Why monitor ?

End-Users: Homeowners,Project Owners

Transparency – verify value for investment (and assist in recommendations to other potential customers)

Peace-of-mind/confidence that installer is supporting a complex/expensive system

Basic Configuration - Revenue Metering Meter - Logger - Internet



Sample view of Solar Software

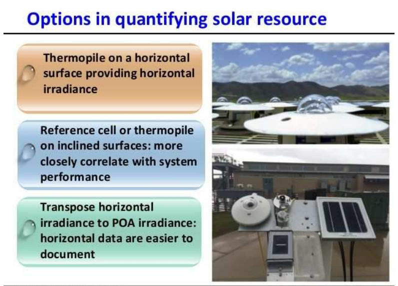
Residential System

- Installers
  - Performance verification – how do you efficiently maintain an expensive asset that makes no noise and has no moving parts?
  - Increased operational efficiency
    - Expanded geographical reach
    - Fewer truck rolls
  - Compliance

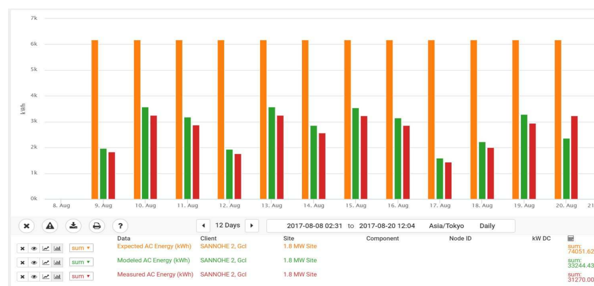
What needs to be monitored for Performance?

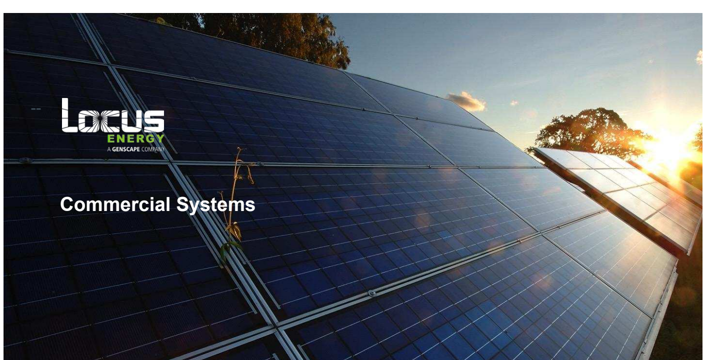
Solar Radiation - W/m2

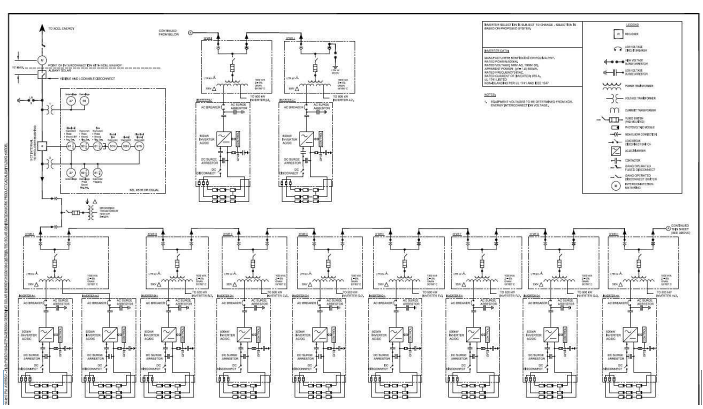
This is done via Sensor - Reference Cell or Pyranometer



Measured vs Modeled vs Expected







LGate 360

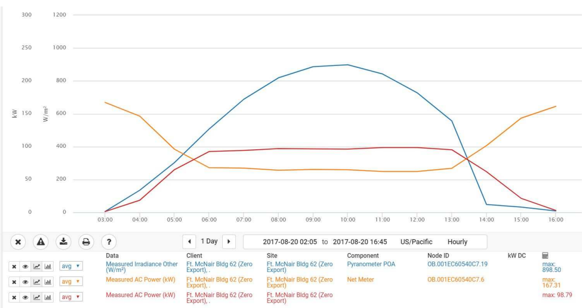
C&I DAS solution

- **Veris E51C2 meter**
  - ANSI C12.20 (0.2% Accuracy)
  - 120 – 480 VAC inputs
  - Polyphase
  - Solid-core and Split-core CT options
- **Obvius datalogger**
  - ARM9 embedded CPU
  - 5 minute logging interval
  - 2 months of on board storage
  - LCD display
- **Configuration options**
  - Broad inverter direct communications support
  - Multiple met stations options
  - Combiner/recombiner monitoring
  - SCADA options
  - Cellular modem
  - -20 to 70 C, 95% RH, non-condensing

MGM Case Study – ZeroBack Feed

Owner: NRG Renew
Client: MGM Mandalay Bay Resort
Installer: Sunora Energy
Location: Las Vegas, NV
Size: 6.4 MWdc, Rooftop
Inverters: 203 SMA string inverters
Solution:
- Zero export curtailment control via SEL3505
- Controller dynamically manages real power of inverters, meter points provided by owner SEL734
- Design & project management services
- Onsite commissioning

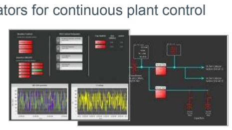
Zero Export



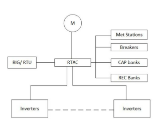
PV SCADA

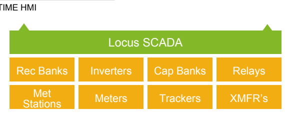
- SCADA is built using industry-recognized hardware and plant control algorithms to manage the real and reactive output of the plant
- Provides the interface to the operators for continuous plant control

Control capacities include:
- Active power management
  - Curtailment
  - Frequency control
  - Zero backfeed
- Reactive power management
  - Voltage control
  - Power factor control
  - Constant VAR support
- Tracker Control
- Real Time HMI



REAL TIME HMI



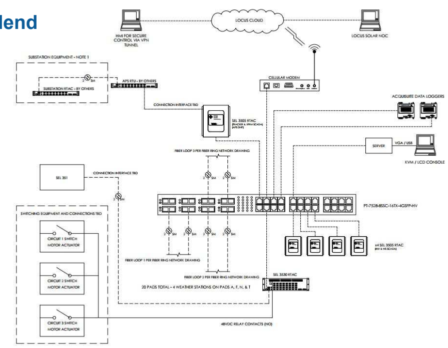


PLANT FIELD DEVICES

SCADA Case Study: APS Redrock 40MW

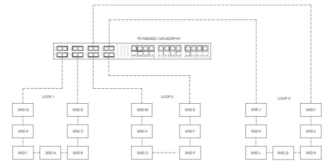
Owner: Arizona Public Service
Client: McCarthy
Location: Eden, North Carolina
Size: 40.0 MWdc, Groundmount
Inverters: 20 PE-HEC-US 2MW
Solution:
- Inverter Remote Control via HMI
- VAR/AVR/PF Control Modes
- Design & project management services
- Onsite commissioning

SCADA Headend



Site Layout

- Inverters – Twenty (20) Power Electronics FS2110CH (each with 10 inverter modules)
- Trackers – Forty (40) NexTracker NCU (each with ~60 SPC Trackers)
- Transformers – Twenty (20) CG Power Systems 2330 kVA
- Met stations – Four (4) Sets of 2 BOM, 2 CMP11, & 1 Lufft (UT-10 Tower TBD)



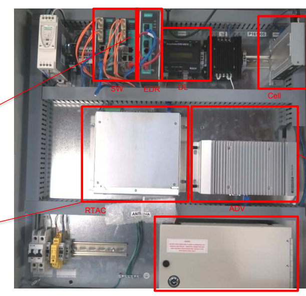
SCADA Rack

- Custom solution using standard components
- Building/Shelter Alarm Monitoring
- Local HMI Access

Equipment in SCADA Panel

Highlights

- End-to-end SCADA
- 76 cm x 76 cm
- NEMA 4X Rated
- UL508A



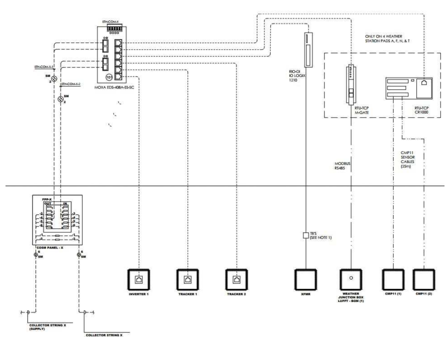
Digi WR21
- 4G LTE
- International Carriers
- Pre-fab antenna assembly

Moxa EDR-G903
- Fully Configurable VPN

Advantech ARK
- Embedded Computer
- Server run vendor applications

SEL RTAC 3530-4
- SCADA RTU/Realtime HMI
- Modbus/SEL/DNP 3.0 Support
- 10,000 Tags

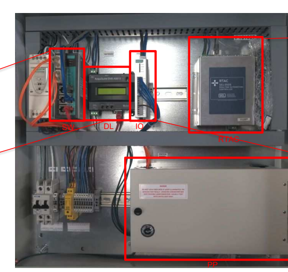
SCADA InField (Connect)



LGate Connect

Highlights

- Configurable Infield Comms
- 61 cm x 61 cm
- NEMA 4X Rated
- UL508A



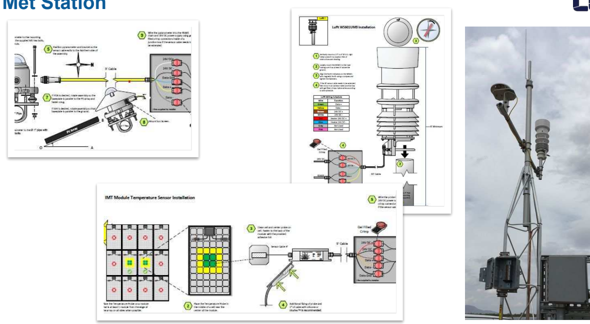
RTAC 3505
- Stackable Automated Controller
- Full Serial, TCP and IO Options
- 5,000 Tags

Moxa EDS-4XX-T
- Wide Temp Range
- Managed Switch
- SM/MM Support

AcquiSuite A8810
- 80 Modbus Clients (TCP/RTU)
- Local Display
- HTTP/HTTPS Upload
- Expandable Memory

Moxa ioLogik E1210 - T
- Remote IO
- 16 Digital Input

Met Station

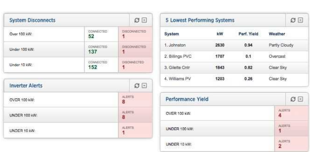


Software Overview

Fleet Management - SolarNOC

Configurable Fleet Overview

- Advanced dashboard with configurable modules to help visualize KPIs
- Each user has a unique view based on responsibilities or territory



Targeted Alerting Interface

- Advanced alerting (e.g., alarm logic for any data parameter)
- Capture a broader range of events by group or system

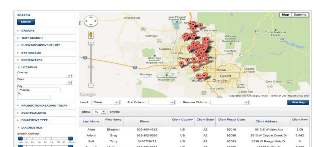
Fleet Management - SolarNOC

Custom Reports

- Premium reports engine with flexible configuration options for project-specific data analysis

Intelligent Search and Grouping

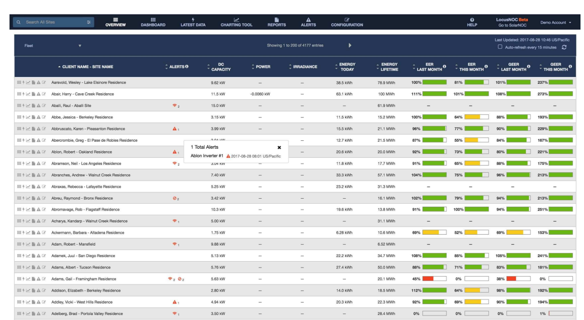
- New searching interface with geographic search, performance thresholds, fund relationships, and savable groups
- User-definable group builder allows users to set relevant parameters on dynamic or static basis



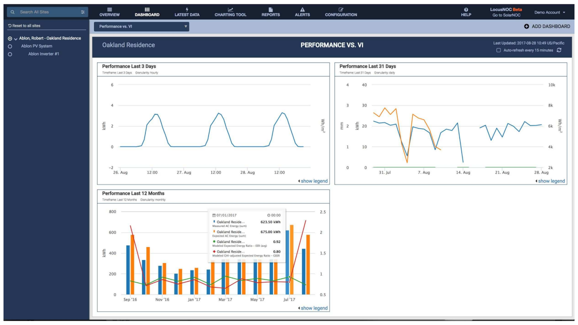
Data Visualization – Charting Tool

Powerful Charting Tool for data visualization and analysis.

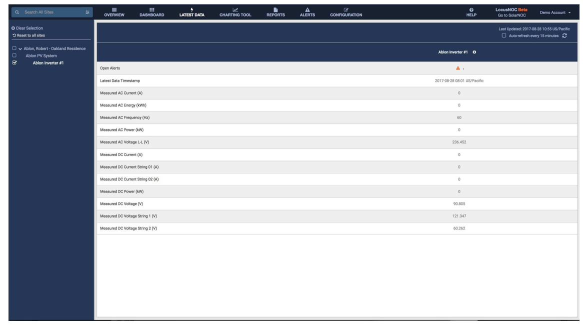
- Chart granular data for sites or devices.
- Visualize alerts
- Visualize performance
- Save charts
- Export data to a file
- Visualize and compare string data on a combiner box.



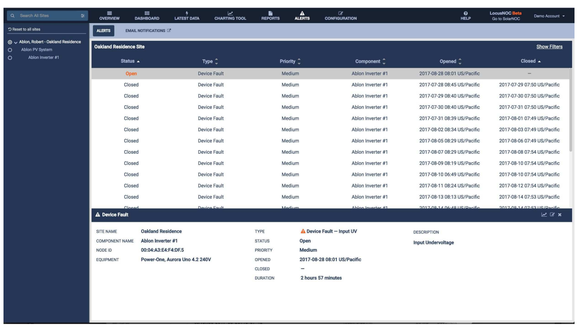
Overview



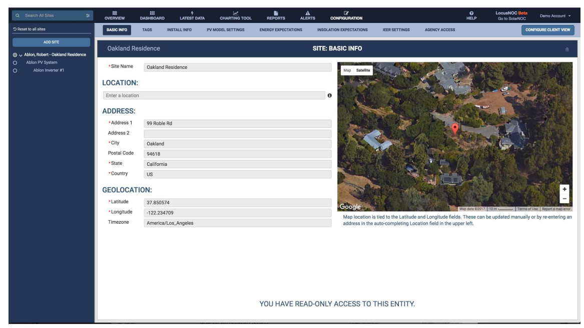
Dashboard



Latest Data



Alerts



Configuration

Locus analytics help reduce O&M Cost

Swinerton O&M maintains +750 MW of Solar Assets with Locus Platform.

O&M Expense

Reduced by 33 %

"We dispatch less and are more productive when we do. We save additional time and money by using analytics to help us determine the tech with the right level of experience to send out."

Reporting Expense

Reduced by 40 %

"PVIQ provides us with a near limitless analytical ability, enabling our analytics team to quickly develop detailed custom reports on a wide range of operating factors,"

Production

Increased by 2.5 %

"The savings created through the integration of SOLV™ with PVIQ allows Swinerton to offer reduced long-term rates for solar O&M to its customers. "

Fleet optimization is a key part of an effective fleet management process

At Locus, we see the Fleet Management function as breaking down into three distinct categories:

Fleet Management

Operations
- Encompasses routine 'under the hood' business processes
- System registration, billing, SREC management, etc.

Case Management
- React to identified problems & resolve system-specific issues
- Includes both short-term and long-term problems

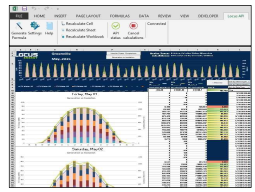
Optimization & Analytics
- Proactive identification of issues and areas for improvement, creating an overall healthier fleet
- Identify fleet-level trends and performance drivers, with tools like benchmarking or portfolio analysis

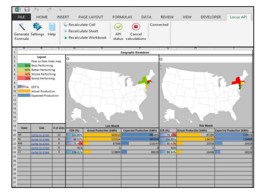
Locus Energy's tools can help support key optimization process – a fleet outlier performance review process

Excel Datalink Application

- Provides direct access to the Solar-OS database via MS Excel
- Available package of pre-built reports for detailed fleet and site analysis
- On-demand custom reports

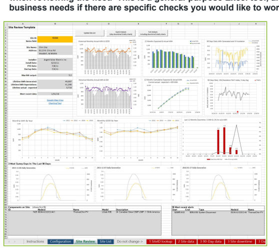
Powered by Locus External APIs





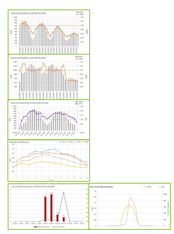
ANALYZING SITES FOR Outlier PERFORMANCE REVIEW: EXCEL DATALINK & SITE REVIEW TOOL

The VI-Based Site Review Tool is an Excel Datalink-based tool designed to help you quickly identify site issues when reviewing the fleet. This is a general-purpose Excel tool, and you can customize it with your specific business needs if there are specific checks you would like to work into the review process.



The standard tool can quickly highlight a range of issues:

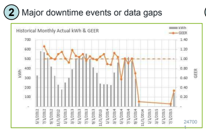
- Gradually accumulated performance issues
- Partial equipment failures (not fully down)
- Energy expectations not set properly
- Year-over-year performance changes
- Downtime or interval data gaps
- Shading
- … and many others



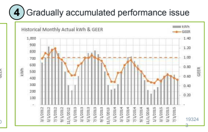
Underperforming site examples – Typical issues

1 Communication issues (no data)

2 Major downtime events or data gaps



4 Gradually accumulated performance issue



3 Partial equipment failures (not fully down)

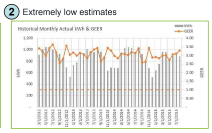
5 Seasonal issue or incorrect expectations data

Issue types 3-5 may not be caught quickly without a periodic review of all under-performing sites

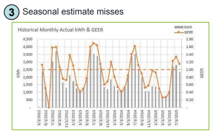
Over-performing site examples – Typical issue

1 Conservative estimates

2 Extremely low estimates



3 Seasonal estimate misses

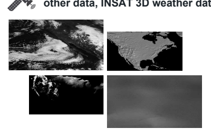


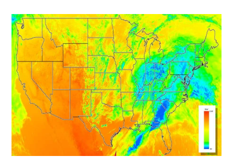
Some findings from monthly reviews of the over-performing sites might go back to the design team, rather than case management

Virtual Irradiance*

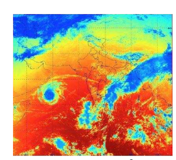
- Virtual Irradiance provides highly accurate, real-time solar resource estimates across geographical spread without having to deploy costly meteorological sensors
- Users leverage this data and the Locus analytics tools to gain valuable insight into the performance of their fleet of assets

NASA satellite imagery, NOAA weather and other data, INSAT 3D weather data





15 minute interval, 1 km^2 resolution irradiance estimates



15 minute interval, 3 km^2 resolution irradiance estimates

* Product currently offered in US, Indian subcontinent and parts of Asia only.

Virtual Irradiance*

Commercial-Grade Physical Sensor Accuracy

Monthly Error	=	Measurement error[1]	+	Soiling error	+	Downtime losses
5-15%+	=	~5%	+	0-10%+	+	0%+

5-15%+ monthly error, depending on intensity of sensor maintenance

Virtual Irradiance Accuracy[2]

Monthly Error	=	Error at optimal sites	+	Higher error in snow or dense cloud cover
1-6%	=	~1%	+	0-5%

1-6% monthly error, depending on duration of snow cover or dense cloud cover

Median monthly error of 2.6%
Median annual error of 2.1%

Virtual Irradiance is comparable in quality to a commercial-grade physical sensor for monthly sunlight estimates. VI often out-performs a physical sensor in practice due to maintenance issues.

* Product currently offered in US, Indian subcontinent and parts of Asia only.

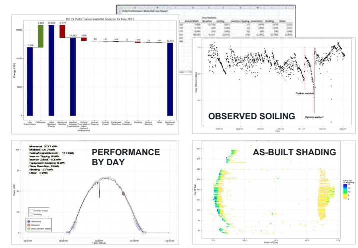
1. Note that higher-end thermopile pyrheliometer sensors can have lower measurement error of around 3% (http://www.nrel.gov/docs/fy11osti/52194.pdf)
2. For a more complete discussion of Virtual Irradiance error please see the "Near Real-Time Satellite-Derived Irradiance Modeling" paper on our website at http://locusenergy.com/wp-content/uploads/2014/07/ASES_VI.pdf

Waterfall Report

Supporting technology

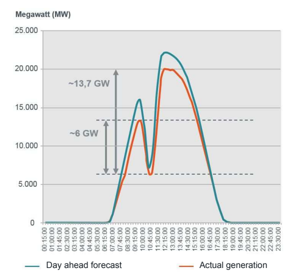
- ✓ Data acquisition
- ✓ Portfolio definition tools (site groupings)
- ✓ Full-coverage irradiance data
- ✓ Performance models
- ✓ Reverse-simulation data analysis engine

- Performance breakdown for site or portfolio into kWh lost to weather, soiling, shading, downtime, inverter clipping, etc.
- Visualizations of overall loss buckets, soiling trends, as-built shading observations, and performance by day

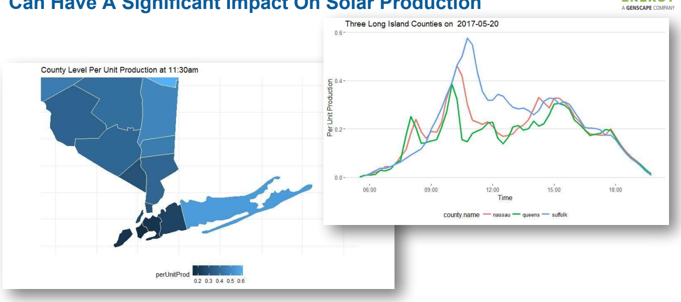


Crystal ball gazing – Forecasting the Renewable Future

- Share of RE in power-mix increasing
- Unlike conventional fossil fuel power, which can be generated as per load with greater predictability, RE production largely depends on the weather conditions.

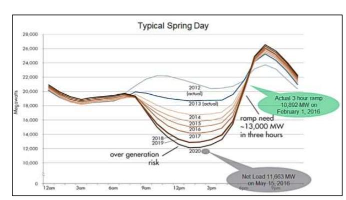


Short-Term Regional Variability From Weather Movements Can Have A Significant Impact On Solar Production



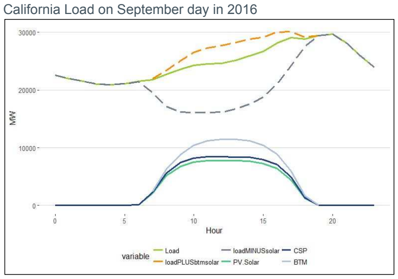
Behind-the-Meter Solar Production Is Affecting Forecast Error, And Estimation Methods Are Insufficient

1. Solar installations are rapidly increasing
2. The impact on net system load and power prices/congestion is increasing (example: duck curve)
3. Limited visibility into the production from behind-the-meter solar generation, and its subsequent impact on net system demand
4. Current methods of estimating production from distributed solar generation fail to incorporate many factors that may impact performance such as soiling, snow cover, shading and system degradation
5. Current ISO and utility demand forecasting methodologies don't independently model behind-the-meter solar generation, leading to higher error (MAPEs) during "solar hours"



The Impact of BTM Solar on Load Is Becoming Very Significant In Some Areas

California Load on September day in 2016

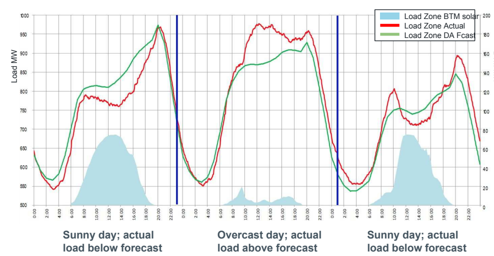


- Behind-the-Meter solar production drives down mid-day demand
- The magnitude of behind-the-meter solar is similar to that of utility scale solar in California

Without Solar Data, Forecasts Tend To Underestimate Load On Cloudy Days, And Overestimate On Sunny Days

Actual & Forecast Load With Behind-The-Meter Solar Over 3 Consecutive Days

Actual load and solar data, scaled to 1000 MW load, 200 MW solar

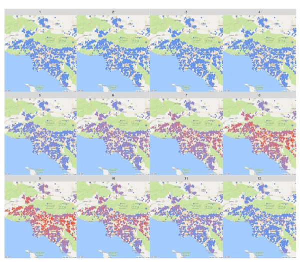


Most deviation between forecast and actual can be explained by solar.

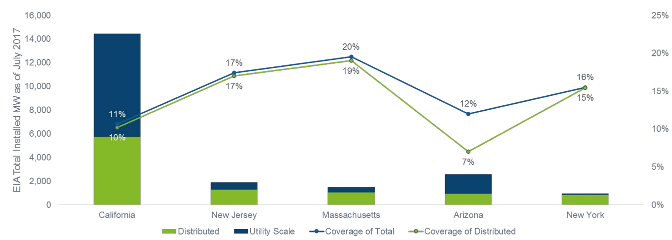
This case example with real data shows how without solar data, a forecast will likely split the difference between sunny and overcast days

Measured Solar Production Is Significantly More Accurate Than Modeled Data

- Modeled Solar Production will always have errors!
- Some of the challenges include:
  - Shading
  - Soiling
  - Dust/smog
  - Localised snowfall
  - Intermittent cloud cover
- The chart to the right, for example, shows the heavy impact of soiling in Southern California
- Actual production data will capture all of these effects



Coverage of Solar PV Capacity in Key Solar States

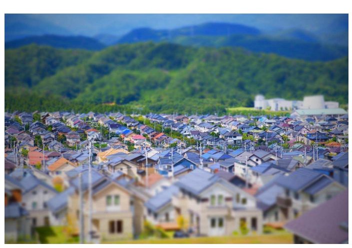


Notes:
1. Solar PV Installed Capacity based on estimates from the EIA Electric Power Monthly. Given the fast-moving and distributed nature of PV solar, there is a wide range in estimates on total installed solar capacity by state
2. The majority of sites (by count) that Locus monitors are considered distributed; however, Locus does monitor some sites that are considered utility scale. Locus Coverage of Total = Total Locus / Total State. Locus Coverage of Distributed = Total Locus / State Distributed.
3. These numbers do not include Genscape monitored solar installations.

Behind-The-Meter API Provides Measured Solar Production Data In Near Real Time

- Behind-the-Meter Production API aggregates and compiles near-real time distributed solar production data
- We can offer frequencies of monthly down to 15 minute intervals
- Data is available at zip code, county, load zone, and the state level

$$perUnitProd_{region,\ timestamp} = \frac{(total\ kW\ output\ from\ sites)}{(total\ kW\ capacity\ of\ sites)}$$



Product Sample: Data Is Provided Via A RESTful API

ZIP Code	Time Stamp	PerUnitProd	currVI
10312	6/24/2016 18:15	0.33	450
10312	6/24/2016 18:00	0.4	480
10312	6/24/2016 17:45	0.28	490
10312	6/24/2016 17:30	0.32	490
10312	6/24/2016 17:15	0.29	530
10312	6/24/2016 17:00	0.35	550
10312	6/24/2016 16:45	0.39	620
10312	6/24/2016 16:30	0.51	740

Querying a specific state would return all zip codes in that state; enables customers to aggregate to any larger geographic region (e.g. load zone)

= (solar kW output / kW capacity) for Locus monitored sites in the zip code and may be used as a performance factor for all sites in a given zip code

Optional: Satellite derived irradiance measurement to determine how much solar resource (i.e. sunlight) was measured during a given interval

Potential Behind-The-Meter Solar Data Use Cases by Customer Type

Balancing Authority
- Gain visibility into behind-the-meter solar production based on measured actuals
- Create more accurate day ahead and real time load forecasts to enable more efficient generation dispatch
- Understand the impact of distributed solar generation on system operations and stability

Energy Trader
- Associate variances between load forecasts and actual load that can be attributed to distributed solar generation
- Identify upside/downside risks to demand forecasts based on solar production and subsequently identify trading opportunities (e.g. DA/RT spreads)
- More accurately forecast demand and power prices (esp. for quantitative traders)

System Integrator
- Develop more accurate load forecasting models and situational awareness
- Develop more accurate solar forecasting models by training models with actuals

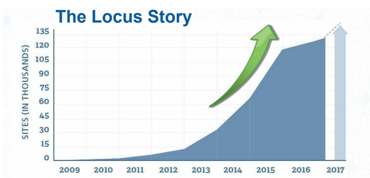
Solar Asset Manager
- Gain early insight into SREC production by modelling total regional solar production
- Benchmark fleet performance against regional averages

About Locus Energy

Company: Founded in 2007; operating in utility, commercial, industrial & residential PV markets.
Acquired by Genscape in 2015.

Capabilities:
- PV monitoring & Analytics
- Engineering & Development
- Managed services.

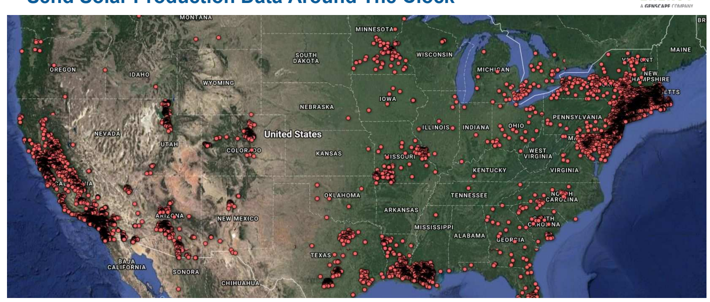
Presence:
- USA | APAC | Middle East



- *130,000+ Sites*
- *5GW*
- *80+ Billion Data Points Collected*

Offices: Hoboken, NJ | San Francisco, CA | Louisville, KY | Delhi, India

Locus Monitors A Broad Base Of Over 130,000 Sites That Send Solar Production Data Around The Clock



Business Overview

State of the art	Driven by Client Success	Global footprint
Core monitoring and Asset Management platform	Key focus on Data Analytics & Intelligence	Four offices – Hoboken, San Francisco, Louisville, Gurgaon
Cloud based, open architecture and highly scalable application	Full stack software & hardware solutions - Metering & Control	24 hour service support
Strong intellectual property portfolio – 7 patents granted, 14 in process.	Customizable as per user requirement	>5GW, >1,30,000 sites monitored

greentechsolar:
"Number 1 independent monitoring provider for the U.S. PV market" (by site count)

Ownership Structure : *From a line of Energy & Information Experts*

DMGT → dmg::information → GENSCAPE → Locus Energy

A **$2.6 bn** (FY16) publicly traded media conglomerate in UK

An information and intelligence powerhouse

A Global, diversified portfolio of commodity and energy intelligence companies in **Power, Oil, Natural Gas, Petrochemical, Agriculture, Biofuels, and Maritime Freight markets**

Locus Energy was acquired by Genscape in September 2015 for **expertise in the Solar monitoring and analytics market**

Locus Business Model

1. Core Monitoring

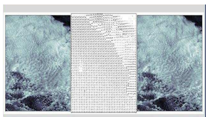
- Single-phase (residential)
- 3-phase (commercial)

2. Enterprise Data Services

- Role-based views in SolarNOC
- Data aggregation
- Fleet view diagnostics

3. Performance Analytics

- Integrated performance modeling
- Satellite irradiance
- Prescriptive analysis on production impacts



Select Locus Clients by Channel

Leasing Companies

Sungevity, Clean Power Finance, nrg, OneRoof Energy, Sunrun, SunEdison, Astrum Solar, PosiGen Solar Solutions

EPC / Developers: 300+ Clients

PsomasFMG, Standard Solar, 1st Light Energy, Washington Gas, Blue Oak Energy, nrg, Swinerton Renewable Energy, REC Solar, Safari Energy, entersolar, Conergy

OEMs, Enterprise & Agencies

Eaton, Clean Energy Finance and Investment Authority, Powerhouse Solar, KACO new energy, ExtraSpace Storage, Tigo energy

Contact Us:

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402-409, 4th floor, square one
Saket District Centre,
New Delhi -110017
Main: +91 011 43088800

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Main: +1 877 562 8736

TECHNOLOGY HEADQUARTERS

Locus Energy
657 Mission Street, Suite 304
San Francisco, CA 94105
Main: +1 877 562 8736

General Inquiries: info@locusenergy.com

Sales Inquiries : sales@locusenergy.com

Support Inquiries : support@locusenergy.com
+1 877 562 8736 X 2

IADB ICT Workshop

STRICTLY PRIVATE & CONFIDENTIAL

Distributed Solar – Entrepreneur Perspective

8/30/2017

www.gsolar.pk

Greenewable Solar (GS) - Overview

- Pakistan with a population of over 200 million is one of the world's fastest growing economies. Unfortunately, a crippling power deficit despite the government's best efforts to solve it, has held back the country's true economic potential. Solar is fast becoming a vital part of the energy mix.
- GS was established in the summer of 2015 as a solar EPC to capitalize on this opportunity. Since then we have successfully managed to leverage the deep relationships of our principals to win a diverse book of "blue chip corporate" clients. Our initial targets were urban commercial and industrial clients but since we have expanded into agrarian and rural economic sectors.
- Additionally, we are in project development phase for a 50MW Solar Utility plant.
- Our business model is predicated on collaboration with key strategic partners who can help accelerate our growth. Our services include:
  - Design / Engineering
  - Robust Distribution Network for Rural Electrification
  - Power Purchase Agreements to Corporates ("Yield Co") funded by Local Banks
  - Solar Analytics powered by Locus Energy
  - Solar batteries manufactured locally by Atlas Batteries

Solar Analytics Impact

- **Business**
  - Solar PV EPC business is fast becoming commoditized: a race to the bottom
  - A robust solar PV analytics platform enables:
    - Project Developers / EPCs to differentiate themselves in the marketplace
    - A reduction in O&M costs by helping maintain and manage DERs especially rural installations
    - Accurate location specific data that allows companies to create opportunities by offering new business models i.e. "Infrastructure as a Service" (Yield Co)
- **Operations**
  - Solar analytics allows businesses to be full-stack (fully integrated) solutions providers by:
    - Having accurate snapshots in real-time of individual and aggregate site performance
    - Eliminating / Reducing false positives
    - Saving time during on-site fault finding

On the Horizon

- **AI / Machine Learning**
  - Vast quantity of data requires predictive algorithms to aid in analysis, troubleshooting and preventative maintenance
  - Be able to predict future component failure with a high degree of precision
  - Reduce inventory overheads
  - Further reduce O&M and Support costs
- **Storage**
  - As batteries continue to proliferate and address the intermittency of Solar, analytics platforms have to be able to monitor and analyze this resource as well

EXECUTIVE TEAM

MUSHTAQ CHHAPRA , CHAIRMAN

Mr. Chhapra is an industrialist with diversified business interests in Pakistan and South Africa. He is recognized internationally for his philanthropic work as Founder and Chairman of The Citizen's Foundation and also runs The Patient Aid Foundation, a private-public partnership at Jinnah Hospital. In addition, he is a recipient of the Sitara-e-Imtiaz, Pakistan's highest civilian honor.

SHAZIM CHHAPRA , CEO, DIRECTOR

Shazim is a business professional with over 15 years of experience running his family industrial holdings in Pakistan and South Africa. He is credited in turning around two of the businesses. He holds a Bachelor's degree in Mechanical Engineering from Columbia University and an MBA from NYU's Stern School of Business.

AAMER ABDULLAH, DIRECTOR

Aamer is a business professional with over 20 years experience of financial markets. He currently is a partner at MI Ventures, a New York based early stage fund that makes investments in seed stage technology companies. Previously, he was a Managing Director & Portfolio Manager at a hedge fund and prior to that held senior roles at Deutsche Bank and Credit Suisse in New York City. He holds a Bachelor's degree in Electrical Engineering and Economics from Yale University and an MBA from Columbia University's Graduate School of Business.

ZAIN ABDULLAH, DIRECTOR

Zain is a seasoned finance executive with over 25 years of experience. Till most recently, he was the Senior Executive Officer of National Bank of Abu Dhabi Investment Management. Prior to NBAD he was Managing Director at the global investment bank Calyon in New York. He spent the earlier part of his career at Credit Suisse and JPMorgan. He holds a Bachelor's degree in Electrical Engineering from Massachusetts Institute of Technology and an MBA from Columbia University's Graduate Business School.

TEAM

PIENSA

TERRANODO

SPATIAL DATA INFRASTRUCTURES

Ariel Núñez
Geospatial Consultant
ariel@terranodo.io
ariel@piensa.co

SPATIAL DATA INFRASTRUCTURE

technology, policies, standards, human resources, and related activities necessary to acquire, process, distribute, use, maintain, and preserve spatial data

SPATIAL DATA INFRASTRUCTURE

technology, policies, standards, human resources, and related activities necessary to acquire, process, distribute, use, maintain, and preserve spatial data

TECHNOLOGY

- Software Client
- Catalogue Service
- Spatial Data Service
- Processing Services
- Spatial data repository
- GIS Software

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- **Software Client**
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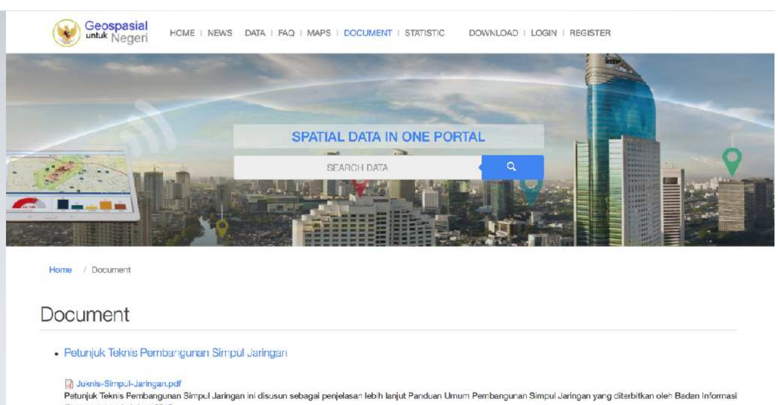
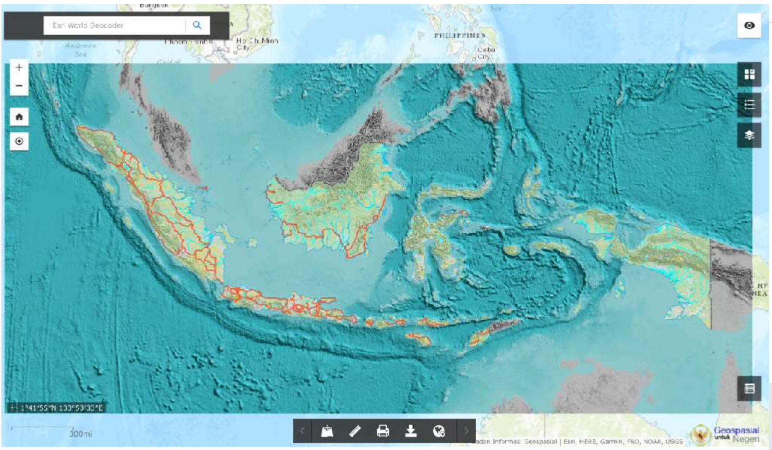
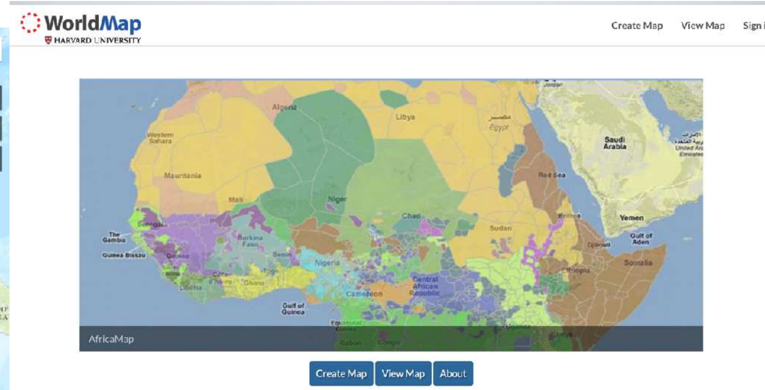


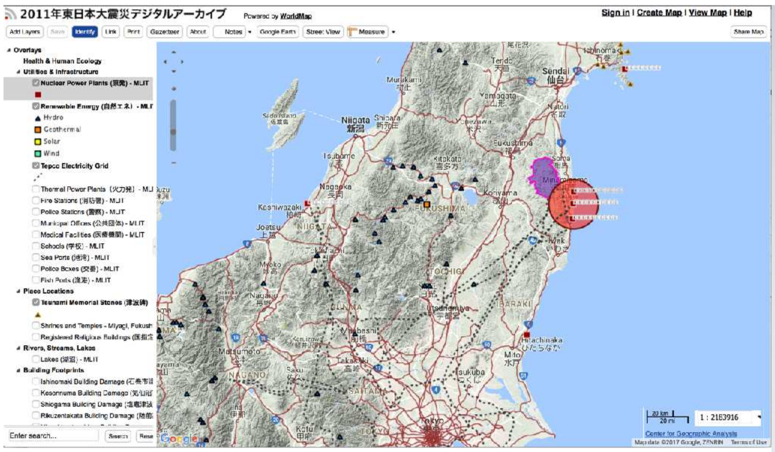
INDONESIA



Built with ESRI tools



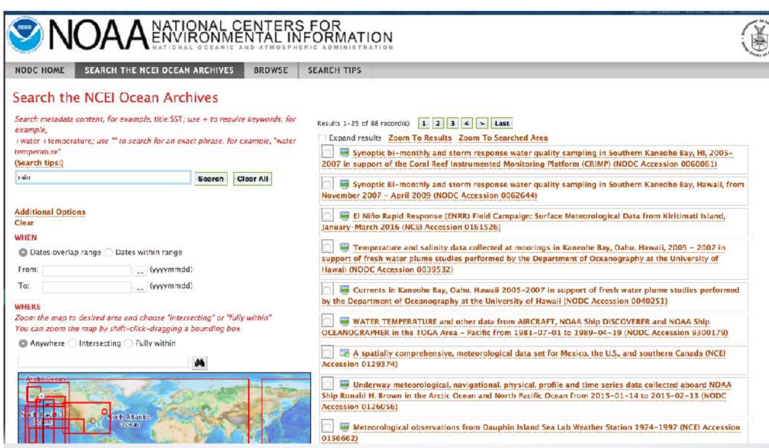
HARVARD WORLDMAP



Built with GeoNode, an open source tool

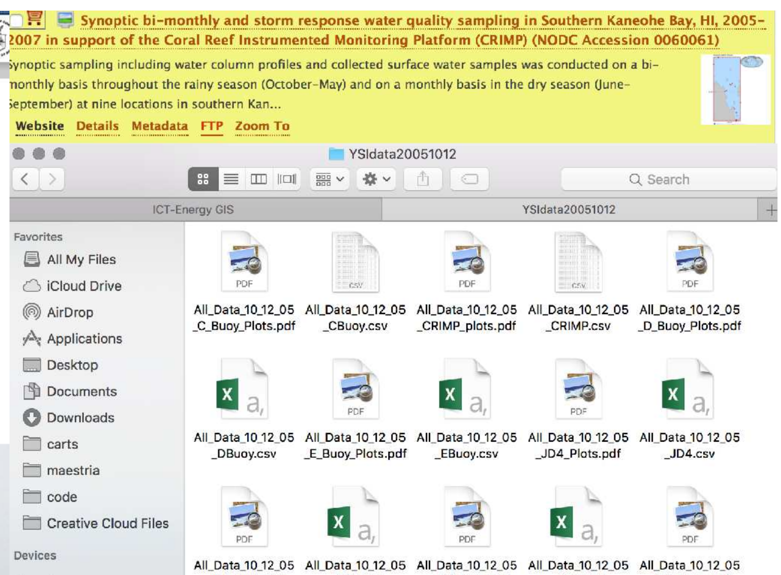
TECHNOLOGY

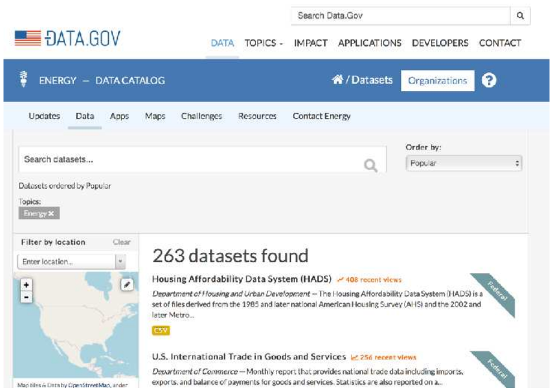
- Software Client
- **Catalogue Service**
- Spatial Data Service
- Processing Services
- Spatial data repository
- GIS Software



NOAA DATA PORTAL

Built with ESRI Geoportal





DATA.GOV

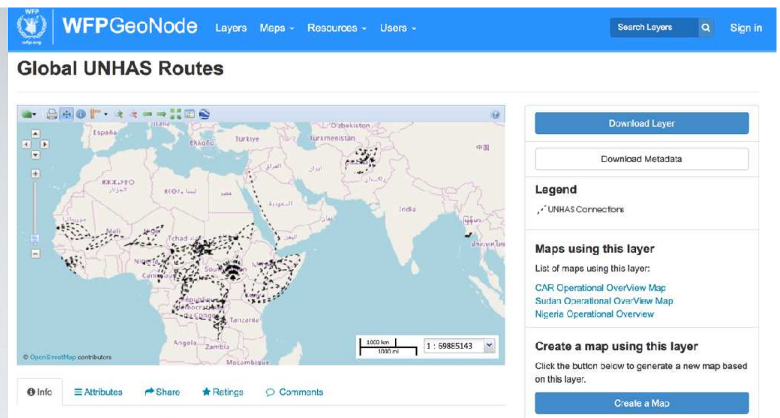
United States Open Data Portal

DATA.GOV

Uses pycsw, an open source software tool

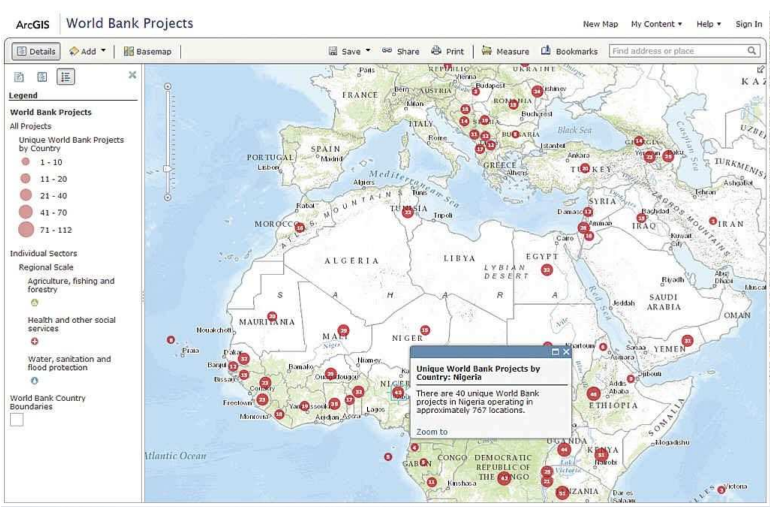
TECHNOLOGY

- Software Client
- Catalogue Service
- **Spatial Data Service**
- Processing Services
- Spatial data repository
- GIS Software



GEOSERVER

World Food Programme



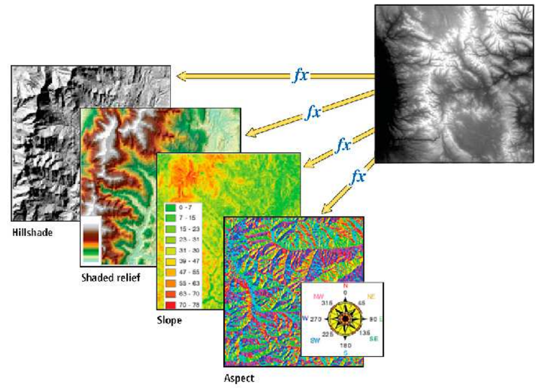
ESRI ARCGIS SERVER

MAPBOX VECTOR TILES

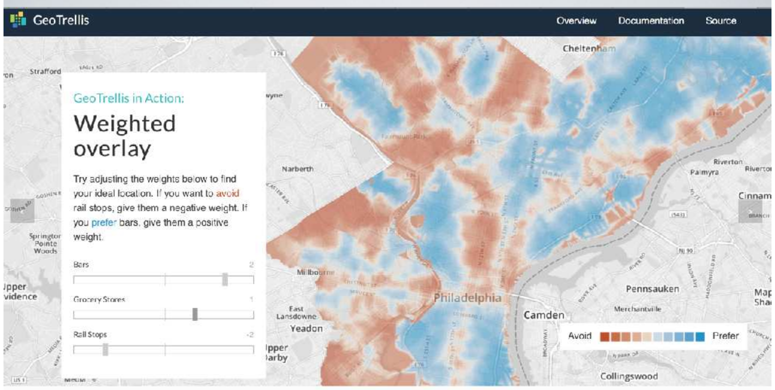
Similar to Apple Maps and Google Vector Maps

TECHNOLOGY

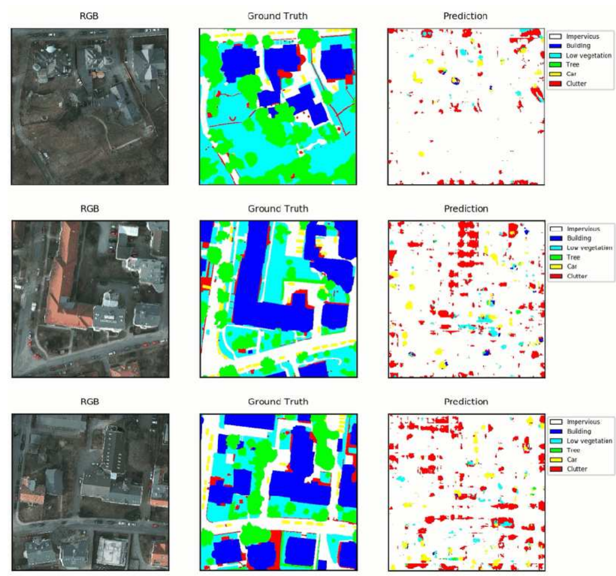
- Software Client
- Catalogue Service
- Spatial Data Service
- **Processing Services**
- Spatial data repository
- GIS Software



ESRI ARCGIS

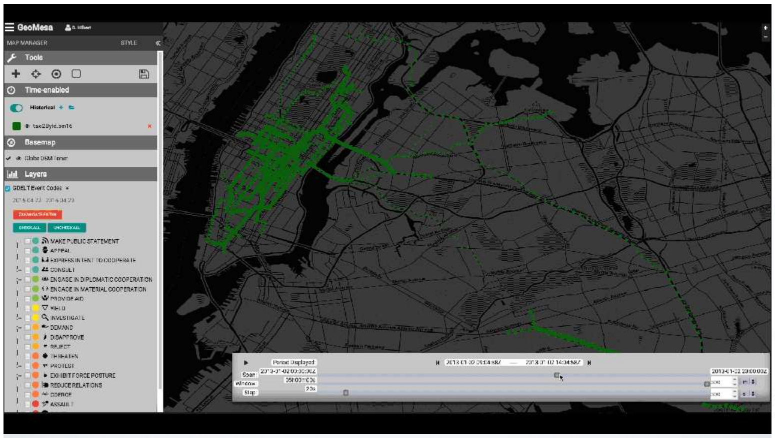


GEOTRELLIS



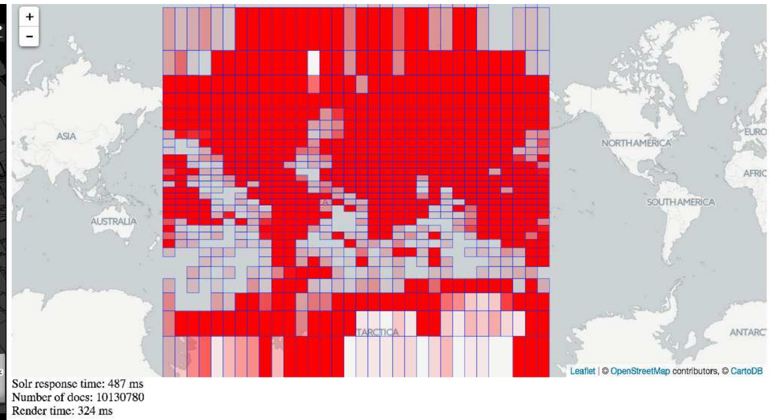
TECHNOLOGY

- Software Client
- Catalogue Service
- Spatial Data Service
- Processing Services
- **Spatial data repository**
- GIS Software



GEOMESA

BigTable style spatio temporal database

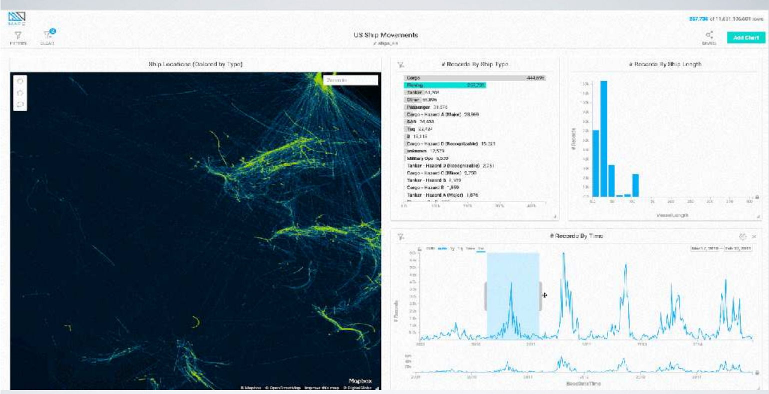


LUCENE

Solr / ElasticSearch

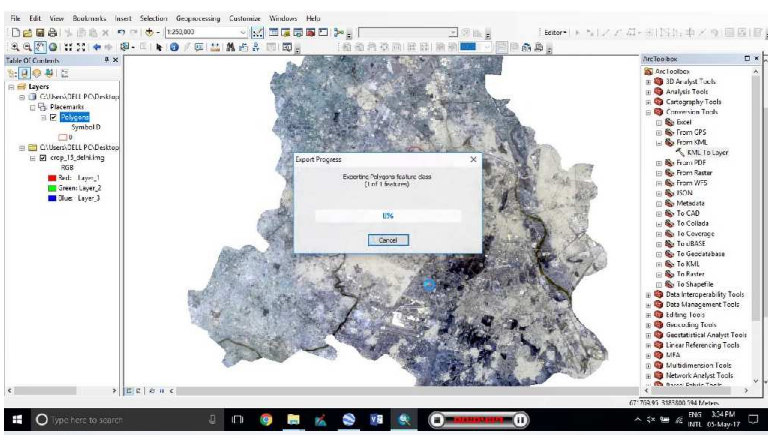
TECHNOLOGY

- Software Client
- Catalogue Service
- Spatial Data Service
- Processing Services
- Spatial data repository
- **GIS Software**

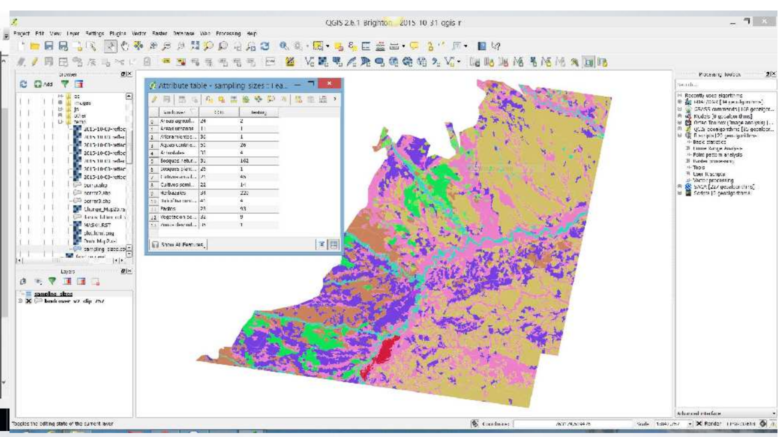


MAPD

GPU powered analytics - Example with US ship movements



ESRI ARCGIS



QGIS

Free and Open Source GIS solution

SPATIAL DATA INFRASTRUCTURE

technology, **policies**, standards, human resources,
and related activities necessary to
acquire, process, distribute, use, maintain, and preserve spatial data

POLICIES

ACCESSIBLE, LICENSED AND DOCUMENTED

POLICIES

PRIORITIZE OPEN SOURCE

POLICIES

OPEN BY DEFAULT

SET CLEAR LONG TERM GOALS

SPATIAL DATA INFRASTRUCTURE

technology, policies, **standards**, human resources,
and related activities necessary to
acquire, process, distribute, use, maintain, and preserve spatial data

STANDARDS

The Open Geospatial Consortium defines the standards for interoperability

STANDARDS
DATA TRANSPORT

- WMS
- WCS
- WFS
- TMS
- Vector Tiles

STANDARDS
DATA FORMATS

- CSV
- GML
- ESRI Shapefile
- GeoJSON
- Protobuff
- MbTiles
- Geopackage
- Geotiff

SPATIAL DATA INFRASTRUCTURE

technology, policies, standards, **human resources**,
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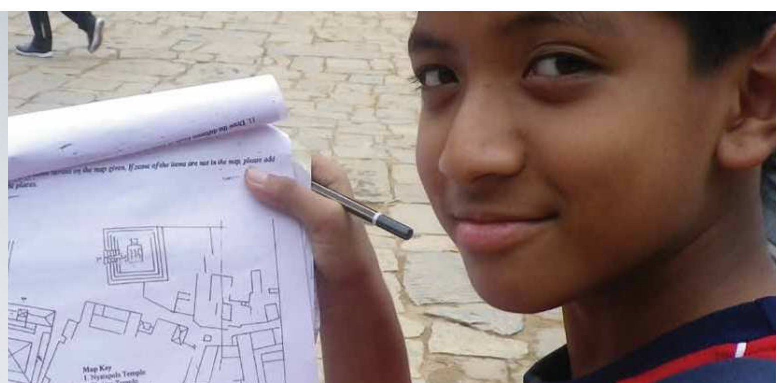
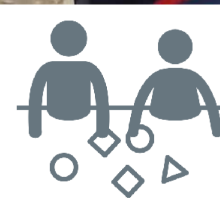
HUMAN RESOURCES OR: HOW DO I KEEP IT UPDATED?



CO-CREATED DATA



DATA OWNED BY LOCAL AGENCIES OR WORKING GROUPS

ENGAGE USER COMMUNITIES

DEVELOP STRONG INSTITUTIONAL PARTNERS

USABLE TOOLS

Data should be communicated in ways that meet the needs of diverse users

UTOPUS INSIGHTS

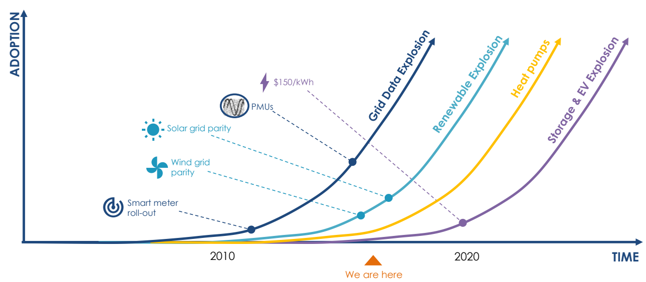
IADB ICT Conference
Balki G Iyer
Co-Founder & CGO
Utopus Insights, Inc.

Digitizing the Green Grid Revolution !

August 30, 2017

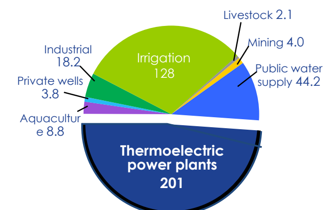
The World of Energy is Disrupting

Disruptive Energy… Mega Trends



Reason 1 for March to Clean: Power/Water Nex

Total water withdrawals today
Billion gallons per day (BGD)
410 BGD



50% water usage due to power plants

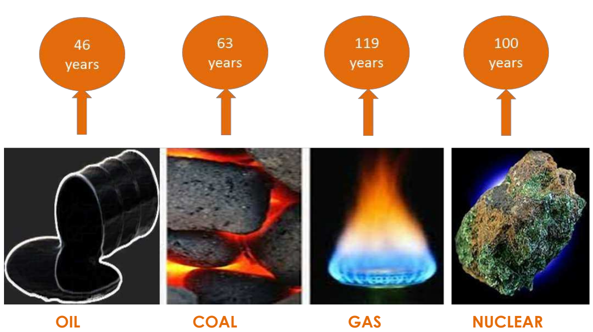
30% worlds population water constrained today … **60%** by 2025

Power **1st** to be curtailed in a water scarce world

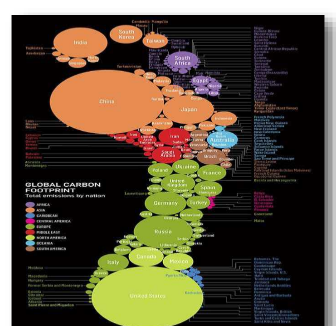
Carbon emissions and water scarcity challenges interlinked

Source: The 2030 Water Resources Group, Centre for Environmental Systems Research, University of Kassel

Reason 2 for March to Clean: Depleting Resources



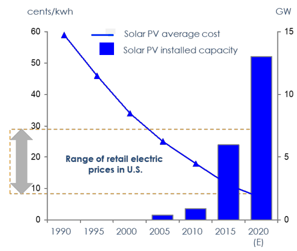
Reason 3 for March to Clean: 1.6 Earths



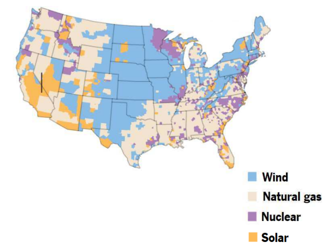
Grid Getting Greener

Renewable on the Grid – Parity NOW!

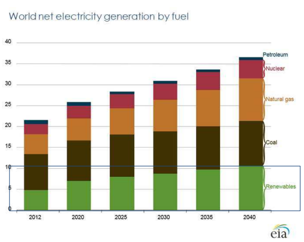
Solar PV costs on pace to reach "grid parity" for most consumers

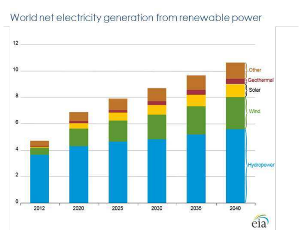


Majority of new U.S. capacity expected to be renewables



However it's a mix…and complex

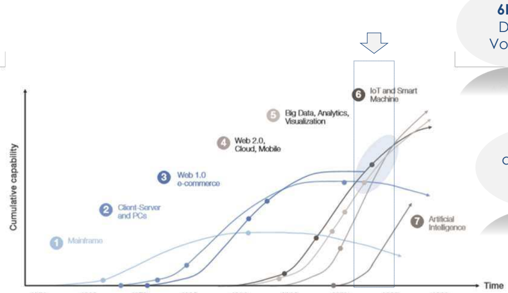




- Revolutionary transition towards more renewable energy and diversified supplies
- Distributed generation growing at a fast pace worldwide and its installed capacity expected to more than double in the next decade

Digitization Making Strides Elsewhere

The Digital Revolution



6B Pb Data Volume

50 Billion IoT Sensors by 2020

36% of all data will be stored in cloud

200 Billion Things on Internet by 2030

Digital Trends

- Cloud Adoption… SaaS to PaaS to IAAS (Insights as a Service)
  - So Lo Mo.. On the go
    - Partnership Collaboration ecosystem
      - Big Data & Real-time Analytics… Volume, Velocity, Variety

UBER

Wikipedia The Free Encyclopedia

Green Grid meets Digital !

Paradigm Shift.. Addressed by Digital Transformation

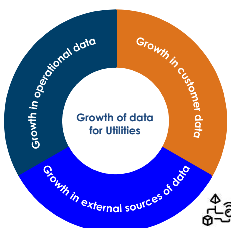
Status Quo	Today's Paradigm Shift	Challenges	Need for analytics
Conventional energy sources (e.g. coal, gas): predictable, reliable	**Renewable** energy sources (wind, solar): variable, dependent on weather	**Distributed** generation fleet, usually in remote locations **Uncertainty** in renewable generation making demand-supply balance challenging	**Centralized visibility** and analysis of asset performance **Forecast** wind/solar generation to mitigate uncertainty
Centralized energy resources: large plants far from customers	**Distributed** resources: solar panels, batteries, demand response, IoT	**Complexity** of designing and operating a distributed grid	**Plan and orchestrate** distributed and centralized energy systems
Limited focus on efficiency: demand growth and lenient regulation drive healthy returns	**Efficiency and reliability** are critical as demand plateaus and regulators require lower costs and high reliability	**Difficulty** of reducing cost while improving reliability	**Optimize** capital and maintenance plans to maximize reliability
Limited data available on the asset and customer	**Data explosion** due to implementation of IoT, sensors, SCADA, AMI, smart meters, etc.	**Heterogeneity** and quality of data coming from multiple silo-ed systems	**Integrate, curate and refine** data to create insights
Customer is a **ratepayer** and cannot choose its supplier	**Customers can choose** their own electricity provider, and also generate their own power	**Risk** of retaining and targeting attractive customers	**Identify**, manage and retain most attractive customers

Data, data everywhere and every kind…

Growth of data is a structural trend for utilities to capture new operational and customer insights

Growth in operational data

- **Renewable production**: IEA projects share of renewable energy in global power generation will rise from 22% in 2013 to **26% by 2020**
- **Increased deployment of telemetry and sensors**: Example: global synchrophaser market to grow at **27.4% CAGR** from 2014-2019
- **AMI Penetration**: Smart meter penetration of all electric meters expected to grow from 30% in 2015 to nearly **60% by 2020**



Growth in customer data

- **Social media insights**: 2.2B active users of social media. **Facebook** at 1.55B users and **Twitter** at 307M users in 2015
- **Call center conversations:** Increase in ability to extract consumer information from call center conversations

Growth in external sources of data

- **Internet-of-Things**: # of connected devices expected to increase from 2B in 2015 to 30.6B in 2025
- **Weather: Big data enabling hyper-local weather forecasting**

WW smart meter data generated estimated to grow from 115 Pb in 2015 to 160 Pb in 2020 thus driving the value of advanced analytics

What do these changes mean for the grid?

TODAY'S GRID	TOMORROW'S GRID
Centralized, 1-way	Distributed, bidirectional
Small-scale uncertainty	Large-scale uncertainty
Rate payers	Engaged "prosumers"
Volumetric sales	New business models
Generation follows load	Load follows generation
Static planning	**Digitization with predictive real-time optimization**

About Utopus Insights

An advantaged start-up… spun out of IBM !

World Class Team

- Headquartered in NY, offices in BLR
- Team with deep expertise in renewable energy
- Deep analytics, data science, energy experience , digital transformation in EU space

Validated IP & Products

- 15 years of research with leading utilities & renewable generators
- 26 patents, numerous more pending patent applications
- Analytics platform, asset analytics, DER integration

Active Clients

- Commercial contracts
- Joint Development Agreements/SERI to develop cutting-edge tools
- Global Pilots with promising results(in US & Asia)

Strategic Partner

vermont electric power company VELCO

Industry Credentials

- GWAC founding member
- Core CIM group membership
- EEI Finalist 2016
- Vermont REV award

Investors

IBM BCG VELCO

Best in Class team with deep digital transformation experience in E&U space globally

The Digital Revolution

From Reactive to….. | **Proactive…** | **…to Predictive**

- Manual/ adhoc reporting
- Unplanned / adhoc maintenance
- No database or data foundry

- Transparent reporting.. Portfolio wide, role based
- Real time alert notifications
- Centralized Asset management

- Analytics for predictive maintenance
- Operational forecasting for planned maintenance
- Complete Regulatory compliance

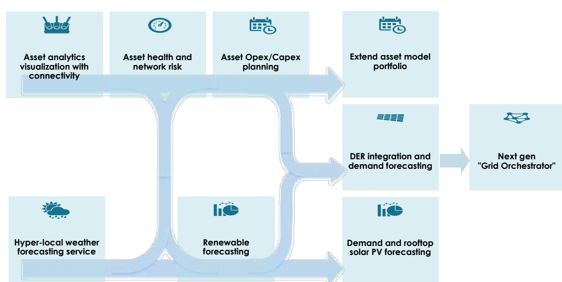
Creating a world class digital platform for proactive asset management

In short… we need a grand orchestration

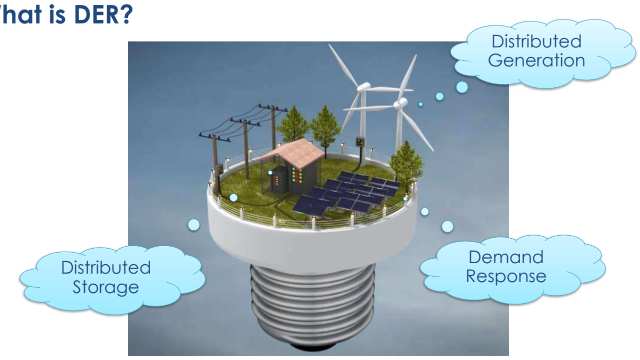
	Constrained/Scarce Energy	Abundant/Plentiful Energy
	"Later"	"Run the dishwasher"
	Discharge	Charge the battery
	Delay or vehicle-to-grid	Charge the EV
	Turn on expensive power	Curtail expensive power
	Post-heat, post-cool	Pre-heat, pre-cool

DER = "Distributed Energy Resources" or "Digital Energy Revolution?"

Our Roadmap: leading the industry to tomorrow's grid

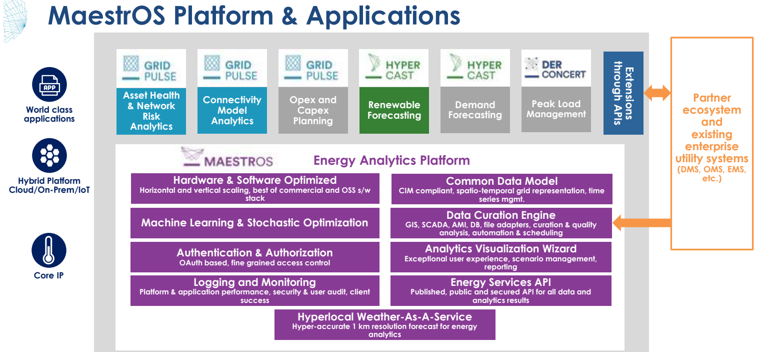


What is DER?



The Digital Energy Revolution will help transform "fickle" to "reliable!"

MaestrOS Platform & Applications



Descriptive to Predictive to Prescriptive !

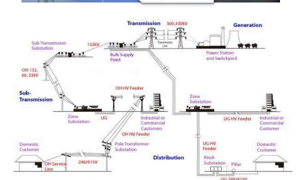
Optimized Risk Based Maintenance and Investment Planning for Assets

Business Considerations:

- Deliver reliable transmission services at lowest cost
- Wide geographic distribution of assets
- Long life assets impacted by load and the environment
- Diverse and aging infrastructure
- Data quality gaps & multiple systems
- Limited resources

Why an Analytics driven approach?

- Can true failure history and root cause be determined?
- What is the remaining service life of an asset?
- Can we assess system risk to account for connectivity?
- What is the optimal maintenance plan given the criticality and condition of an asset?
- What does an optimal investment plan look like?
- Can we prioritize across asset classes?
- Can we prevent the next grid failure?



GridPulse: innovative and intuitive user experience

Precise, holistic visualization of assets and connectivity

- Drill down through hierarchical layers of insights (system, substation, circuit, zones, assets)
- View asset / network risk and trace connectivity of all assets in one place
- Highlighted assets in need of immediate care (high failure risk / connectivity errors)
- Perform connectivity analysis to analyze impact

Understand network impact from a single asset, feeder, substation and system

- View asset health and connectivity errors details at each layer (Substation, circuit, zone, assets)
- Detailed reports to help asset managers assess the condition of assets and errors in connectivity
- Identify hotspots in the circuits having high failure risk and / or connectivity errors

User driven configuration of scenarios and visualization

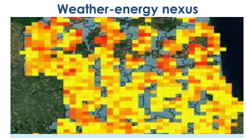
- User level dashboard configuration for scenario selection, color range setting, metric selection
- Managing and configuring scenarios per user's business needs
- Sharing dashboard with other users to enable joint collaboration and problem resolution

Nostradamus: Weather analytics center of competency for Energy applications

Deep weather expertise

- Hyper-local weather forecasting with up to 1 sq.km spatial granularity
- *16 day forecast with granularity of:
  - 10 min: from 0 – 3 days
  - 1 hr.: from 3 days - 5 days
  - 3 hr.: from 6 days - 10 days
  - 12 hr.: from 11 days – 16 days
- Observation and radar weather service
- Vegetation Management

Weather-energy nexus



- Energy consumption / production forecast for:
  - Outage propensity and impact
  - Substations, Meters
  - PV
  - Wind Turbines
  - Solar Farms
- Hyper-local outage forecasts with details on:
  - Perception, Temperature, Wind Gust, Icing, soil temperature

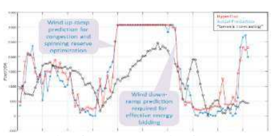
Intuitive weather and grid insights

- Operations dashboard for weather analysis
- Wind Gusts, temperature, precipitation forecasts
- Asset overlay and real time feeds for impact assessment
- Outage prediction, substation demand forecasting, peak load forecasting and management, reactive vs. active power forecasting

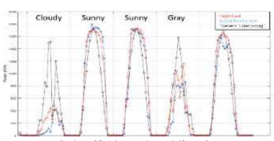
HYPERCAST

Renewable Forecasting

HYPER CAST



Wind (24 hour lead time)



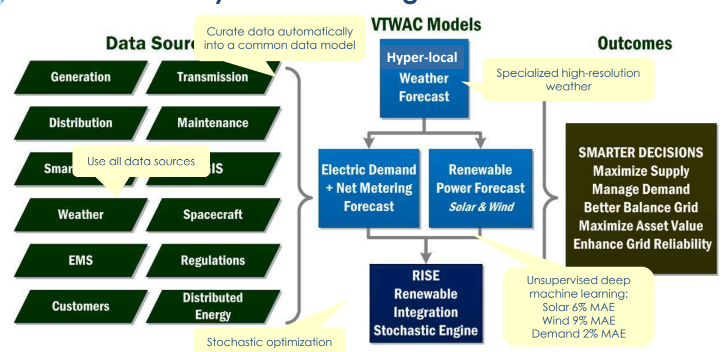
Solar (24 hour lead time)

- **Accuracy Breakthrough**
  - MAE as low as 7-8% for renewable assets (Industry benchmark/Regulatory limit)
  - Confidence limits as per regulatory needs
  - Up to 72 hours of lead time available
  - NowCasting with 10 minute forecast refresh
- **Robust Backend Engine**
  - Self learning capability … discovers the idiosyncrasies of your system
  - Hyper local coupled modelling approach
  - Drill down… pooling station to turbine level
- **Security**
  - Secure cloud based data storage & computation
  - Role based access… accessible anytime anywhere
- **Speed**
  - Easy to get started (1 week)
  - Flexible engagement

Specialized hyper-local weather forecasting combined with proprietary deep machine-learning

Need of the day: "a new intelligence"

Vermont Electric Power Company VELCO



Conclusions

- Energy is at the intersection of multiple disruptive trends… **solar, wind**, heat pumps, EVs, storage, instrumentation, **digitization**!
- This needs a new "**operating system**" to plan and orchestrate the grid
- Massive need for:
  - An **energy analytics** platform
  - A **suite of energy applications**
- Need for a new approach
  - Hybrid cloud/on-premises
  - Deep predictive and prescriptive analytics
  - Hyper-local weather
  - Common data model
  - Open APIs
- We must break down silos to **integrate disparate data sources**
- We must respectfully **curate data**
- **Machine learning** and **stochastic optimization** are key enabling technologies
- **Data intensive** industry…Be ready or be left behind!

Thank you !

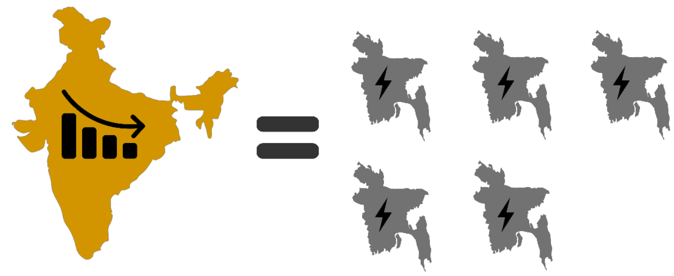
GRAMPOWER

MORE POWER TO YOU

Yashraj Khaitan | Founder & CEO
yashraj@grampower.com | +91-809-432-9978

Power sector in India LOSES ~$17B in revenues per year

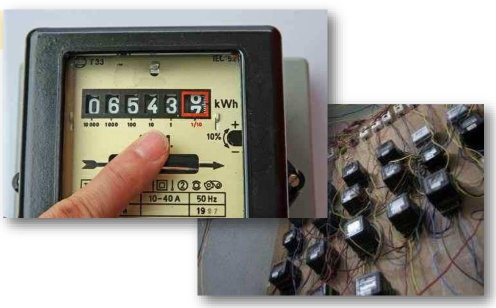
enough to provide free power to Bangladesh for 5+ years!



Current state of affairs

explains quite aptly why such losses exist

1. Faulty Meters
2. No Tagging
3. Table Billing
4. Non Payment of Bills
5. Dilapidated Infra
6. Manual MIS
7. Theft



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Utility Revenue Manager (URM)
Yashraj Khaitan (YK)

YK: How many consumer's do you have in this Utility?

URM: Anywhere between 150K – 300K

YK:

YK: Why a 100% error margin

URM: Well we have 40% 'Ghost Consumers'

Current state of affairs

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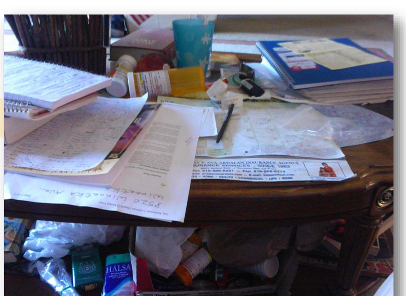

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We carried out a consumer survey in one of our Utility projects and got the following results:

- 1.66% of the sample size believed that consumers should pay full price for power
- 75% of the consumers didn't even know that they had a private distribution company distributing them power
- 43% either never received a bill or got it at irregular billing cycles
- 90.5% claimed that they have problems in paying their bills – distance or incorrect billing
- 37% of consumers had concerns about the bills they received

It would be surprising if bills were being paid in the above scenario

Current state of affairs
explains quite aptly why such losses exist

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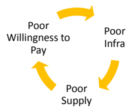
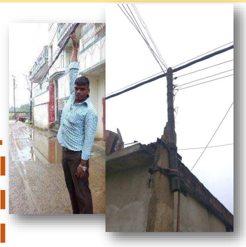


- Voltage levels as low as 60VAC
- Height of man = Height of wire
- Electricity poles are part of the consumer's home!
- Extremely low power factors
- Frequent breakdowns leading to low availability



Current state of affairs
explains quite aptly why such losses exist

1. Faulty Meters
2. No Tagging
3. Table Billing
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6. Manual MIS
7. Theft

- Delayed
- Limited
- Erroneous

Current state of affairs
explains quite aptly why such losses exist

1. Faulty Meters
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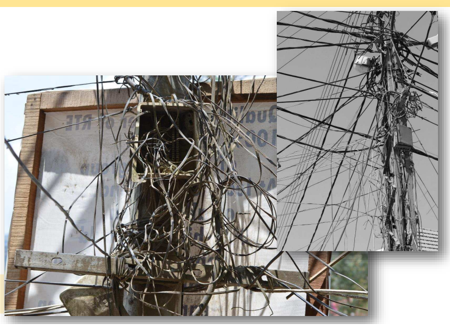
7. Theft



Solution to all this
lays in digitizing Utilities

1. ~~Faulty Meters~~
2. ~~No Tagging~~
3. ~~Table Billing~~
4. ~~Non Payment of Bills~~
5. ~~Dilapidated Infra~~
6. ~~Manual MIS~~
7. ~~Theft~~

SOLUTION → DIGITIZATION OF UTILITIES

All existing and new smart meter projects in India are hung
strongly indicating a change of approach is needed

1. CESC, Mysore – Poor implementation
2. HPSEB – Integration with DISCOM IT system a bottleneck
3. APDCL – Insufficient supply
4. PSPCL – Meters still not approved
5. WBSEDCL – Stuck in type test and meter approval
6. Tripura – Insufficient meter supply
7. TSSPDCL – Meter test reports pending
8. PED – Testing/Certification of meters pending

HUNG/DELAYED

1. UGVCL
2. APEPDCL – 16444 confusion
3. CED – Inadequate technical specification
4. MSEDCLS – Extremely ambitious technical requirements
5. KESCO – Unviable business model design

EXTENDED

1. Jharkhand – Poor technical specification and business model design
2. BESCOM – Low competition, DISCOM uncertain of long term performance

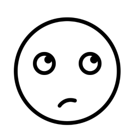
CANCELLED

- Projects for a total of 16,00,000 smart meters have been announced over the past 5 years
- Only ~30,000 meters have been supplied
- An estimated only 15,000-18,000 meters are functioning

There are several challenges for mass adoption
which are preventing the sector from taking off

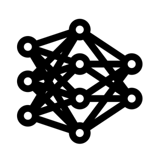
EXPENSIVE

The capex involved in smart metering is quite high, which financially strained DISCOMs can't afford



NOT PROVEN

Only small pilots have been executed till date, making it a tough choice for DISCOMs to invest large amounts



COMPLEX SYSTEM & INTEROPERABILITY

Communication technology today is not interoperable, and the necessary IT infrastructure or human resources don't exist with the DISCOM

Comparison of this approach
with existing approaches of the DISCOM

	Capex	Fixed Monthly Charge	Gram Power MBC Model
Low Financial Risk	×	✓	✓
High Accountability	×	✓	✓
Constant Technology Upgrade	×	×	✓
Technical SLA ⇔ Commercial SLA	×	×	✓
Low Technology Risk	×	×	✓
Low Monopolization	×	×	✓
Interoperability	×	×	✓
Low dependency on DISCOM HR and IT	×	✓	✓

DISCOMs are in the business of buying and selling power
just like telcos are concerned only with selling talktime

DISCOMs need a long term technology partner, instead of meter vendors

Current costs incurred by DISCOM
for metering, billing, collection and associated customer services

Item	Cost (INR/meter/month)	Note
Meter capex	15.9	Assuming 10 year lifetime
Replacement & Meter Addition costs YoY	23.8	15% new meter procurement each year based on DISCOM data in India
Digital Meter Reading	50.0	
Bill Generation & Distribution	6.0	
Payment Collection	5.0	Based on costs incurred by private Utilities
Software Licenses	35.0	Based on industry data
DISCOM Employee Costs	167.8	Based on several DISCOM's Annual Report Data
Interest Cost	10.5	12% interest for capex with 5 year term
Repairs & Maintenance	31.3	Based on several DISCOM's Annual Report Data
Admin & General Expenses	22.5	Based on several DISCOM's Annual Report Data
Total	**367.8 (USD 5.66)**	

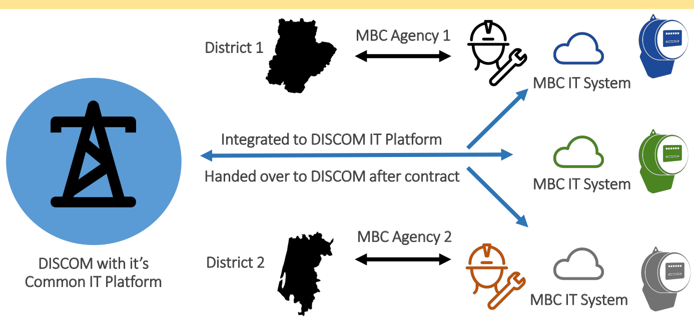
Meter-To-Cash Outsourcing
Smart meters can be provided in BOOT mode for less than current cost

0% CAPEX
100% capex in smart meters and complete infrastructure to provide metering, billing, collection (MBC) and customer service invested by private developer

LOW OPEX
In this model, the recurring cost of smart meters can be <u>LESS THAN</u> the cost currently incurred by DISCOMs with regular meters

PERFORMANCE GUARANTEE
Since 100% capex and 10 year maintenance contract is with private developer, performance and constant technology upgrade are GUARANTEED

Model architecture
To ensure scalability



How this model ensures scalability
While ensuring competition and quality delivery

1. <u>Common IT Platform</u>
   The DISCOM can mandate in tenders for all MBC providers to provide all the data and reports in a common format to their servers similar to how rural feeder monitoring is being implemented at a national scale
2. <u>Interoperability</u>
   Interoperability now becomes the responsibility of the MBC Agency and integration with the DISCOM's common IT platform ensures that the DISCOM does not get affected. Moreover, meters are generally replaced once in 10 years, which will also be the duration for MBC contracts so there is no risk of DISCOM getting stuck with NPAs as the next MBC Agency will also change the meters
3. <u>Competition</u>
   Different vendors can easily be chosen for different districts, thereby ensuring that there will be no monopolization of meters or communication technology or MBC Agencies

How this model ensures scalability
While ensuring competition and quality delivery

4 Protection against price and technology fluctuation
Under this model, the DISCOM is protected against price changes of the meter or obsolescence of the technology since technology selection and maintenance is done by the MBC Agency

5 Performance guarantee
Since the MBC Agency puts in 100% of the capex and is paid only upon performance and meeting the SLAs, there is complete performance guarantee ensured for the DISCOM

6 Zero financial risk
The DISCOM ends up improving operational efficiency, power quality, customer experience, and upgrading the infrastructure without any capex investment and technology risk, thereby making a strong value proposition for them

GRAMPOWER

PROPOSED TENDERING STRUTURE

Scope of services – MBC Agency

1. Supply and installation of smart meters of appropriate technology, and doing constant upgrades wherever necessary during complete contract period
2. Monthly DIGITAL meter reading, bill generation, distribution, and payment collection
3. 24x7 customer care center – all customer complains EXCEPT No Current Complains
4. Vigilance and analytics for loss reduction
5. Connection/Disconnection services
6. Recurring consumer indexing, addition of new customers, maintenance of LT network

Scope of services – Utility

1. Maintenance of HT network
2. Investment in all hardware except metering – transformers, LT/AB cabling, fuses, switchgears, etc.
3. Issuing necessary orders for vigilance
4. Making timely payments to MBC Agency
5. Providing necessary support to MBC Agency for installation, and other activities
6. Monitor the activities and performance of MBC Agency

Tendering structure
To ensure that the DISCOM gets performance

1. Revenue Structure
Monthly fixed charge with 5-7% annual increment to account for new consumers and inflation
2. Contract Period
10 years during which cost of meters for all new connections must be borne by MBC Agency itself in addition to cost for all contracted services
3. Incentive
AT&C target for new year ($AT\&C_{target}$) = Max ($AT\&C_{previous\ year}$, $AT\&C_{current\ year}$)
$AT\&C_{achieved}$ = AT&C achieved at the end of the year
Incentive = ($AT\&C_{achieved}$/ $AT\&C_{target}$) x Annual MBC Revenue
4. Penalty
Applicable when $AT\&C_{target} > AT\&C_{achieved}$
Penalty = ($AT\&C_{target}$/ $AT\&C_{achieved}$) x Annual MBC Revenue

Suggested Qualifying Criteria
To ensure that the most equipped organizations do the job at the lowest cost

1. Technical Eligibility Criteria – Past demonstrated experience of any of the following:
   - Must be a distribution licencee OR
   - Must be a distribution franchisee serving a minimum 30% of MBC consumer base
   - Must be an existing MBC service provider providing services to minimum 100% of the MBC consumer base
2. Financial Eligibility Criteria
   - MAAT for 3 years = 3 months of collection revenue from MBC area
   - No negative cash flows in past 3 years
3. Consortium
   - Up to 3 member consortium since in such a contract you must have a finance partner, technology partner, and human resource partner
   - The consortium together should be able to meet the technical and financial criteria
4. Performance Guarantee
   - One month of cash revenue collection from MBC service area

Guarantees needed from DISCOMs
To ensure that the investment is secure

1 **Guarantee of Timely Payments**
Since these projects will largely be debt funded, it is important to ensure timely payments from DISCOMs. To do this, an **ESCROW** must be setup between DISCOM and MBC Agency. From the monthly collections, only an amount equivalent to monthly MBC service charges would enter the ESCROW and remaining revenue would directly go to the DISCOM. The ESCROW amount will then be given to the MBC Agency

2 **Guarantee Against Termination**
The MBC Agency's capex investment in the project must be secured from a premature termination of the contract. Even today, when DISCOMs purchase meters or any other equipment, only 10% of the contract value is kept as performance guarantee and 100% of the cost is released. Hence in the event of a premature termination, the DISCOM must at least ensure payment of the **depreciated value of the asset**, calculation for which is explained on the next page

Guarantees needed from DISCOMs
To ensure that the investment is secure

Depreciated Value Calculation
- The total lifetime revenue/consumer (A) = MBC Service Charge/month x 120 months
- It can be assumed that 70% of this cost will be towards capex
- Revenue disbursed (B) = Total revenue disbursed till termination
- Depreciation rate = 5%/year
- Depreciated value at the time of termination = 70% x ($A_{depreciated}$ – B)

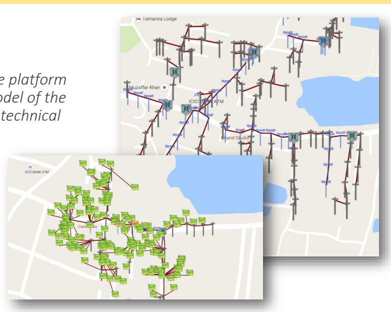
Tender Awarding

Awardee = L1 of monthly service charge for MBC

GRAMPOWER
OUR TECHNOLOGY

Mapping the Grid Online
To digitize, we must first map

1 **Asset Mapping and Consumer Indexing**
Gram Power uses our proprietary mobile platform to create a digital and mathematical model of the grid with accurate GPS coordinates and technical details of 100% of DISCOM assets



Smart Metering
The lowest cost, most advanced and most integrated smart metering platform

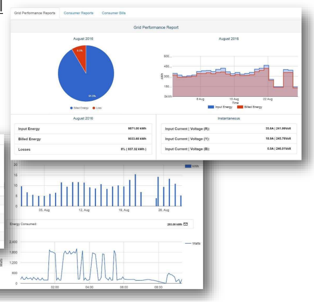
2 **Smart Metering for reducing losses**
Internationally patented, lowest cost, lowest power and most advanced Smart Meter for single phase, three phase, distribution transformers and all other input and load points of the Utility. ***The meters are 100% configurable and upgradable, come with net-metering, prepaid and postpaid facility, thereby making the solution future proof***

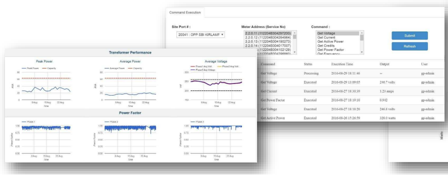
All MBC services controlled and managed online
to bring in high levels of operational efficiency and radically reduce losses

All MBC operational activities are managed on our online portal

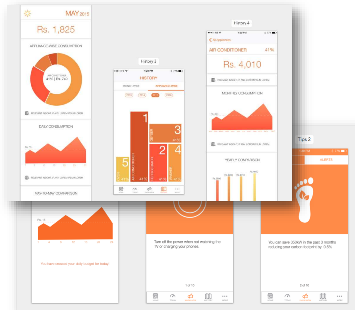
3

- THEFT AND FAULT DETECTION
- COMMAND EXECUTION
- BILLING & DISTRIBUTION
- COMPLAIN MANAGEMENT
- PAYMENT COLLECTION
- ANALYTICS
- ASSET MANAGEMENT
- CUSTOMER SERVICE
- NEW CONNECTION
- FIELD STAFF MANAGEMENT
- CONNECTION/DISCONNECTION
- VIGILANCE





We close the loop by connecting consumers and our field force
through a mobile platform



1. Complete field force management on the phone
2. Digital and real time project management
3. Consumer app for
   - Payments
   - Budget monitoring
   - Billing
   - Complains
   - New connection
   - Connection alteration
   - Demand response

Current Progress
We've come a long way in a short span of time

- Serving 4 Utilities | 3 Private Utilities and 1 State Utility | Working in **Bihar, Andhra Pradesh**
- **~10,000 meters supplied | 75,000 consumers mapped | 4 cities being digitized | 70,000 meters in pipeline**
- Demonstrated **loss reduction of greater than 94%** for a Private Utility client
- Raised **multiple rounds of equity capital** from investors in US and Switzerland
- Technology **patented** internationally
- Recognized by all **major national and international publications** such as NY Times, Times of India, Economic Times, The Guardian, Times Now, NDTV, WWF, and many more…

Current Progress
Our roots were formed in rural India, which helped us build robust technology

- Executed **$1M project of USAID for solar powered rural microgrids** and smart meters in India
- Selected by **NASA among the top 10 Cleantech Technologies** around the world
- 'Global Indian' honor **awarded by Prime Minister** Narendra Modi
- Installed **30 Smart Solar Microgrids in Rural Rajasthan with USAID and Ministry of Power**

We're a strong team of 100+ people
and are backed by visionary leaders from across the world

Yashraj Khaitan
Founder & CEO
B.S. in Electrical Engineering & Computer Science at UC-Berkeley

Kishore Khaitan
Chairman
CMD, BWI Pins Pvt. Ltd.
Past Chairman CII

Eric Brewer
Board Member, Chief Technical Advisor
Vice President, Google Inc.
Founder, Inktomi
Professor at UC-Berkeley

Mikkel Vestergaard Frandsen
Investor, Board Member
CEO, **Vestergaard Frandsen**

Richard C. Blum
Investor, Advisor
Chairman, **Blum Capital**

Mithun Sacheti
Board Member
Founder & CEO, Caratlane.com

Vivek Bhandari
Advisor, Board Member
Past Director, IRMA

The Future of Electric Vehicles & the Grid

IADB ICT Conference

Prof. Matthias Preindl

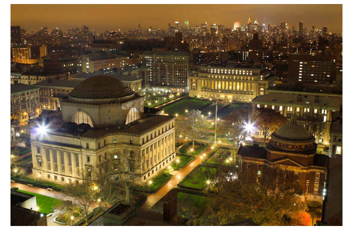
matthias.preindl@columbia.edu

Columbia University in the City of New York

Ivy League Research University
Main Campus located in Manhattan, Morningside Heights

School of Engineering and Applied Science
~ 140 faculty members
~ 2,000 graduate students
~ 1,500 undergraduate students

Department of Electrical Engineering
- 36 faculty members
- Only one working on power conversion



MPLab Matthias Preindl (PI)

matthias.preindl@columbia.edu

Motor Drives and Power Electronics Laboratory (MPLab)
- Founded 2016
- Located on Columbia main campus

People
- Laboratory members
  4 PhD, 1 MSc students
- Co-supervision
  3 PhD students
  1 post-doc, 1 research associate
- Project-based members

MPLab Research Matthias Preindl (PI)

matthias.preindl@columbia.edu

Research
- Advanced control
  - Optimal control
  - Nonlinear control
  - Observers
- Power electronics
  - Wide-bandgap
  - High-frequency (MHz)

Applications
- Electric Vehicle Drivetrains
  - Traction drive systems
  - Energy storage systems
  - Power converters

Graphic: tesla.com

Outline

- Electric Vehicles – Driver's Perspective
- Electric Vehicles – Environmental Impacts
- Electric Vehicles – Market Projections
- Power System – Upcoming Policies
- Vehicle-Grid Interface – Charging Standards
- Smart Interoperation – Vehicle to X (V2x)

Electric Vehicles
Driver's Perspective

Acceleration

Tesla Model S P100D "Ludicrous": fastest 0-60 mph production car

760hp induction machine, 100kWh battery, 0-60mph in <2.3s, price $135k

Graphic: tesla.com

Acceleration

Only 2 cars accelerate faster - ever

Limited editions, price > $800k

"Slower" cars (still < 3s)

Acceleration

Only 2 cars accelerate faster - ever

Limited editions, price > $800k

"Slower" cars (still < 3s)

Range

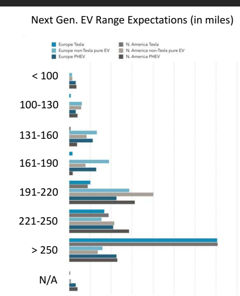
Current vehicles

Premium vehicles (>200 miles)

City/commuter vehicles (~80-100 miles)

Driver expectations

- "Sound barrier" ~ 200 miles
- "Range anxiety anxiety"

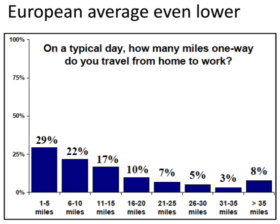


"Electric Car Drivers: Desires, Demands & Who They Are," Cleantechnica, 2017

Range

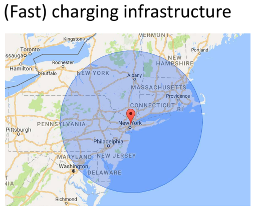
Commute

- US average: <15 miles
- European average even lower



Occasional travel

- Longer ranges beneficial
- (Fast) charging infrastructure



"Average Commute to Work," US Department of Transportation, 2003

EV Owners

EV adoption

- Early adoption: "Trendy greens" and "TCO sensitives"
- Cost-competitiveness (TCO or purchase) is critical for large-scale adoption

Fleets

- (Partial) adoption of EV makes often sense
- Particularly, if driving patterns are predictable and many miles per vehicle per year

Source: "EVolution – Electric Vehicles in Europe: Gearing up for a New Phase ," McKinsey and Company, 2017

Electric Vehicles
Environmental Impacts

Tank-to-wheel evaluation
- Efficiency of the vehicle
- Limitation: electricity is not a primary energy source

Well-to-wheel evaluation
- Efficiency of the transportation system
- Considers generation and distrib. losses
- Results depends on energy mix

"*Electric Car Drivers: Desires, Demands & Who They Are*," Cleantechnica, 2017

Tank-to-wheel evaluation
- Efficiency of the vehicle
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- Efficiency of the transportation system
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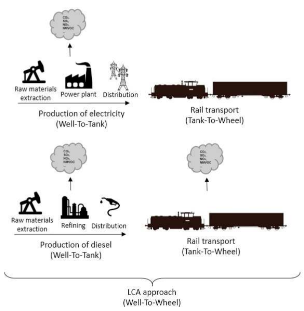
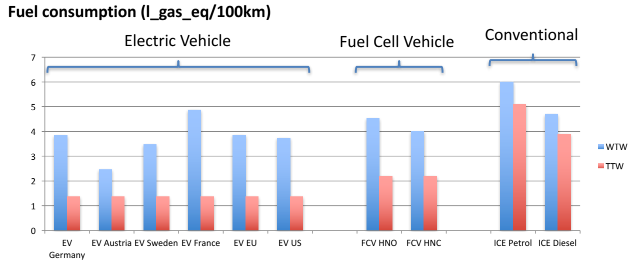
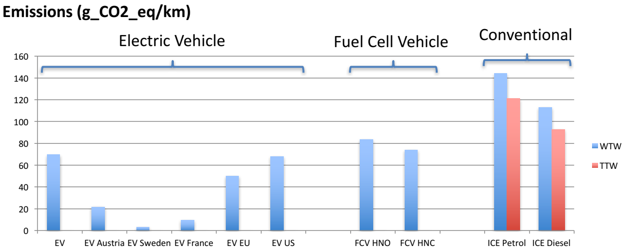


Fuel consumption (l_gas_eq/100km)



S. Ramachandran and U. Stimming, "Well to wheel analysis of low carbon alternatives for road traffic", Energy Environ. Sci., 8, 3313-3324, 2015, doi: 10.1039/C5EE01512J

Emissions (g_CO2_eq/km)



S. Ramachandran and U. Stimming, "Well to wheel analysis of low carbon alternatives for road traffic", Energy Environ. Sci., 8, 3313-3324, 2015, doi: 10.1039/C5EE01512J

Electric Vehicles
Market Projections

Electric Vehicle Outlook

- Electric Vehicles gain significant market shares starting 2025-2030 when unsubsidized EV become price competitive
- May consume 5% of the global el. energy (2040): 1,800TWh from 6TWh (2016)

Figure 1: Annual global light duty vehicle sales

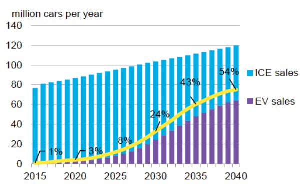
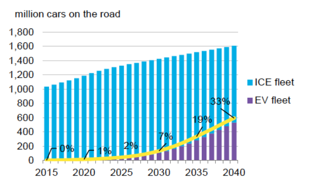


Figure 2: Global light duty vehicle fleet



Source: "Electric Vehicle Outlook 2017," Bloomberg New Energy Finance, 2017

Short and Long-term Outlook

- Short-term sales penetration is higher in Europe, U.S., and China
- PHEV play a role short term (until 2025)
  BEV are more attractive long term

Figure 5: Short-term EV sales penetration by country

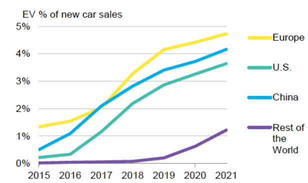
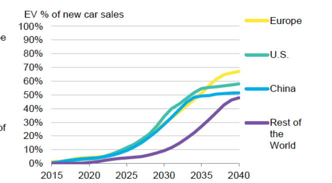


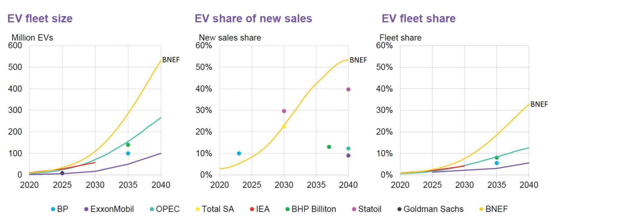
Figure 6: Long-term EV sales penetration by country



Source: Bloomberg New Energy Finance, 2017

Predictions of Different Sources (including Big Oil)

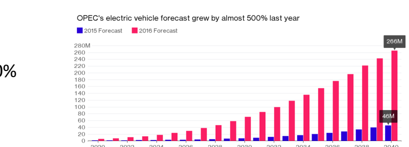
- Predictions vary by source
- IEA, Exxon Mobil, BP, and Statoil ASA roughly doubled predictions in 2017



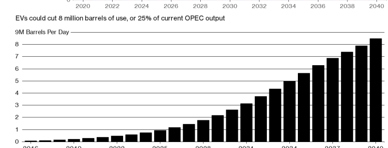
Source: Bloomberg New Energy Finance, 2017

OPEC

- OPEC's forecast grew by 500%
  12% market share by 2040



- EV could cut 8 million barrels (25% of current OPEC output)



Source: Bloomberg New Energy Finance, 2017

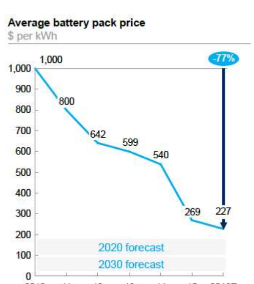
Battery Costs

Electric Vehicle Market Predictions

- Battery prices fall rapidly

Claims

- Tesla (battery pack)
  $190/kWh in 2017
  <$100/kWh in 2020
- GM (LG cells for Bolt)
  $145/kWh in 2016
- Audi (e-tron quattro concept cells)
  100 €/kWh in 2017



Source: "EVolution – Electric Vehicles in Europe: Gearing up for a New Phase ," McKinsey and Company, 2017

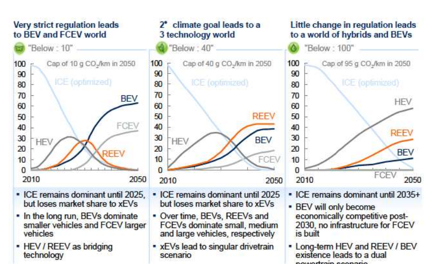
EV Drivetrains

Overall

- Pure IEC plays minor role after ~2030
- Exact drivetrains remain uncertain

Regulation Dependency

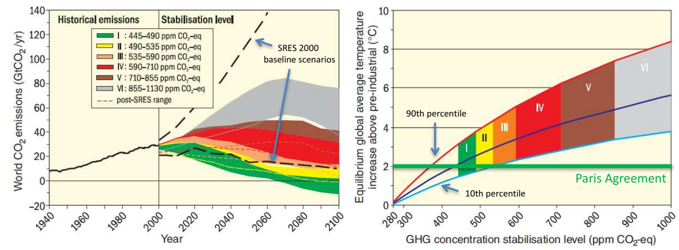
- Low emission scenario: BEV and FCEV
- High emission scenario: HEV keep playing a role



Source: "EVolution – Electric Vehicles in Europe: Gearing up for a New Phase ," McKinsey and Company, 2017

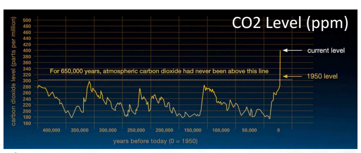
Power System
Upcoming Policies

Climate Projections

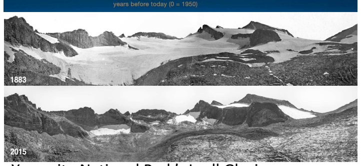


Source: "Climate Change 2007: Synthesis Report", Intergovernmental Panel on Climate Change (IPCC), 2007

Global Warming



Potential effects: wild fire; drought; extreme tropical storms

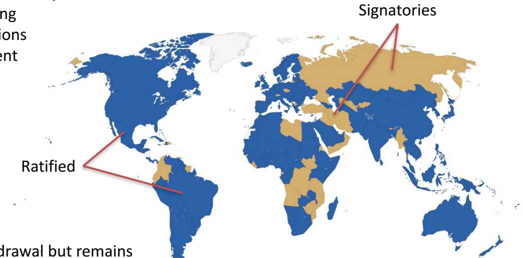


Yosemite National Park's Lyell Glacier

Graphic: nationalgeographic.com; NASA Earth Observatory

Paris Agreement

Entered into force on Nov 4, 2016 when
55 States representing
55% of global emissions
ratified the agreement



US announced withdrawal but remains a member until at least Nov 4, 2020

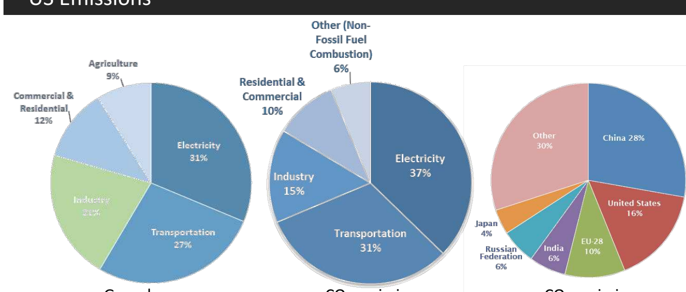
Graphic: climateanalytics.org (2017)

Paris Agreement

- **Limit average global temperature <2 C above pre-industrial levels** pursue efforts to limit the temperature <1.5 C above pre-industrial levels
- Increasing the ability to adapt to the adverse impacts of climate change and foster climate resilience and low greenhouse gas emissions development, in a manner that does not threaten food production.
- Making finance flows consistent with a pathway towards low greenhouse gas emissions and climate-resilient development.

Countries aim to reach "**global peaking of greenhouse gas emissions as soon as possible**".

US Emissions



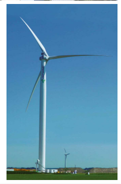
Greenhouse gas emissions

CO_2 emissions

CO_2 emissions

Source: epa.gov (2014 data)

Energy Policies



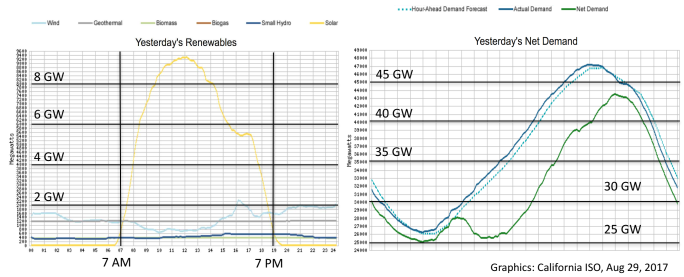
Emission-free Renewable Energy
- Hawaii State House Bill 623:
  100% renewables by 2045 (up from ~10%)
- California
  50% renewables by 2030 (up from ~27%)
- NY State Clean Energy Standard
  50% renewables by 2030 (up from ~24%)
- NY is replacing Indian Point Nuclear Power plant (2GW) with renewables by 2021

Grid controllability
- NY will need for 4GW of multi-hour grid-level storage by 2030
- DER aggregation

Graphics: leitwind.com, wikipedia.org

Demand: California Example

Power mix: 29% Renewables (14% Solar, 8.7% Wind)

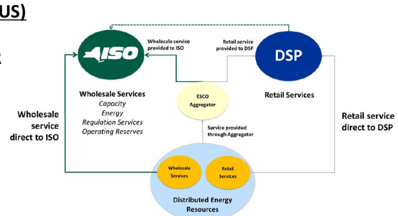


Graphics: California ISO, Aug 29, 2017

Distributed Energy Resources (DER)

Retail services
- Retail service provided to DSP, e.g. demand-response

Wholesale services (upcoming in US)
- Provide any *capacity, energy,* and *ancillary services*, that DER are physically able to provide
- DER aggregation around a given transmission node
- Treated equivalently to "conventional" sources
- EV can be a powerful DER



Graphics: NY ISO

Vehicle - Grid Interface
Charging Standards

AC Charging

SAE J1772 (US): Type 1 (1ϕ or split phase)
- Level 1: 120V single-phase, 16A, 1.92kW
- Level 2: 208-240V split-phase, 12-80A, 2.5-19.5kW
- Level 3 (pending): 208-240 V, 11.6-96 kW
- Typical connector: "Yazaki" (1ϕ)
  120 V 12 A or 16 A to 240 V 32 A or 80 A

IEC 62196 (Europe): Type 2/3 (1ϕ 250V or 3ϕ 400V)
- Mode 1: max 16A, passive (no communication)
- Mode 2: max 32A, semi-active
- Typical connector: "Mennekes" (1ϕ/3ϕ)
  230V 16 A up to 400V 63A (3.7-43.5 kW)

Future: ~100kW

Graphics: wikipedia.org

DC Charging

CHAdeMO
- Up to 62.5 kW of direct current (500 V_{dc}, 125 A)
- Nissan, Mitsubishi, Toyota

Combined Charging System (CCS): AC+DC
- 200–450 V_{dc} and up to 90 kW
- VW, GM, BMW, Daimler, Ford, FCA, Tesla, and Hyundai

Tesla Supercharger
- Up to 120 kW

Future: ~350kW, up to 1kV

Graphics: wikipedia.org

Wireless Charging – Inductive Charging

Magne Charge
- Used by GM EV1
  and some other models

Recent
- AUDI Wireless Charging (AWC)
  3.6kW charger (2016)
- Bombardier-Transportation
  PRIMOVE 3.6kW charger (2015)

Graphics: wikipedia.org

Systems
- Several cities (London, Turin) test inductive charging for busses

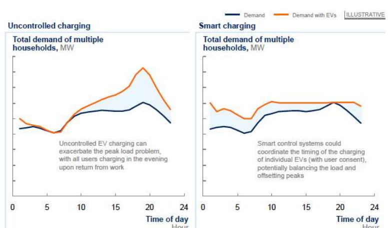
Smart Interoperation
Vehicle to X (V2x)

EV and Grid

Large-scale EV adoption will deeply impact grid, e.g.
EVs charging upon return from work further increase afternoon peak

Grid readiness defines if EV are a
managed problem or
active solution.

Load-shifting
- Shift EV charging to low
  demand periods, e.g. night



Source: "EVolution – Electric Vehicles in Europe: Gearing up for a New Phase ," McKinsey and Company, 2017

EV and Grid

Vehicle to Grid (V2G)
- EV can (potentially) provide energy to grid
- EV can participate in wholesale market
- Particularly valuable services in presence of renewables
  - Real-time energy market
  - Ancillary (regulation) servies

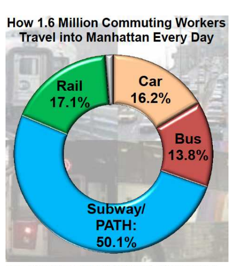
Vehicle to Home (V2H)
- A fully charged EV can power a home for 1 to several days
- Arbitrage: provide energy to home when tariffs are high (evenings)
- Backup power

New York Example

Grid and Vehicle Charging Infrastructure
◦ Approx. 129,600 workers/day commute to
Manhatten by car

If half of them charge an electric vehicle at work
- 3.7kW Level 2 charging: +0.5GW (too slow)
- 10-20kW Level 2 charging: **+1.3GW** to **+2.6GW**
- 50kW Level 3 charging: **+6.5GW**
- Next gen. DC fast charging (350kW): +45.4GW

+7.8GWh of batteries on the network
(with 60kWh/car)



Source: 2005-09 American Community Survey, US Census Bureau
*NOTE: Assumes that all Manhattan residents travel to jobs in Manhattan

Summary

Summary

- EV sales grow significantly after about 2020
- (Fast) charging infrastructure needed
  Competing DC standards
- EV can further strain or support the future gird
  with high penetration of renewables

The End

Thank you.

Smart and Energy-Efficent Buildings

A SENSING, COMMUNICATIONS, AND DATA ANALYTICS PERSPECTIVE

Prof. Fred Jiang
Co-Chair, Smart Cities Center
Data Science Institute and Electrical Engineering
Columbia University

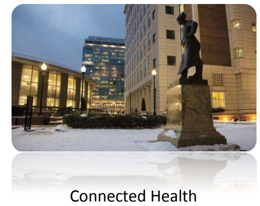
COLUMBIA | ENGINEERING
The Fu Foundation School of Engineering and Applied Science

Columbia ICSL
INTELLIGENT & CONNECTED SYSTEMS LAB

Columbia ICSL
INTELLIGENT & CONNECTED SYSTEMS LAB

Air Quality

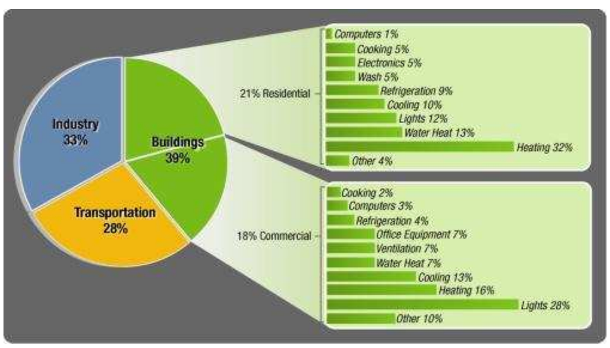
Building Energy



Safety

Connected Health

Commercial Buildings



Source: The 2016 U.S. Energy Information Administration

Existing Solution Inadequate

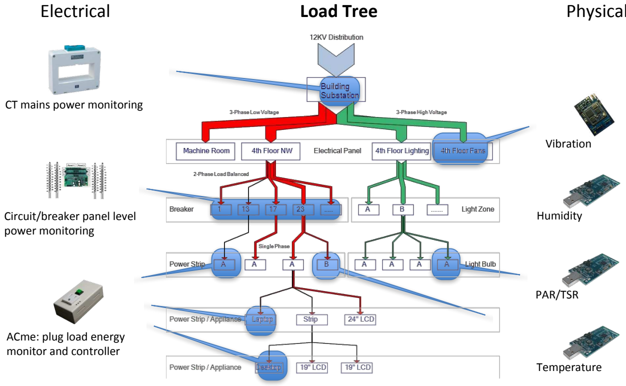
- Mega-watt light bulb
- Aggregate in time
  - Monthly, daily
  - 15 min in newer ones
- Aggregate in space
  - Whole building level
  - Circuit / breaker panel level
- Need detailed visibility

Measuring and Sensing

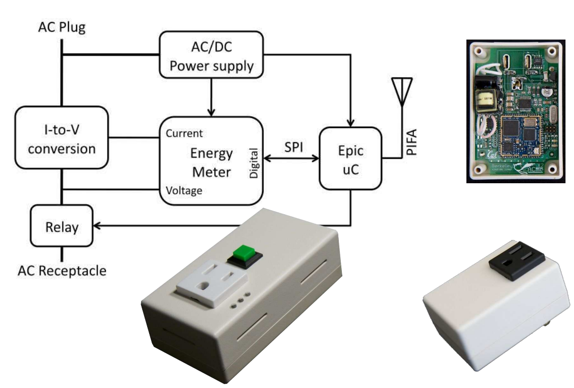
Electrical

Load Tree

Physical

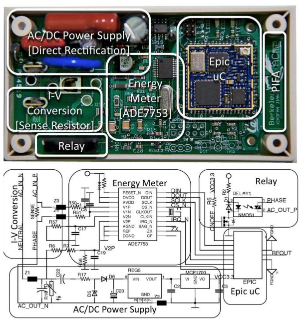


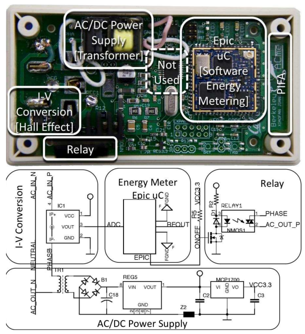
ACme Wireless IPv6 Plug-load Monitor



ACme Wireless IPv6 Plug-load Monitor

Version A	Version B





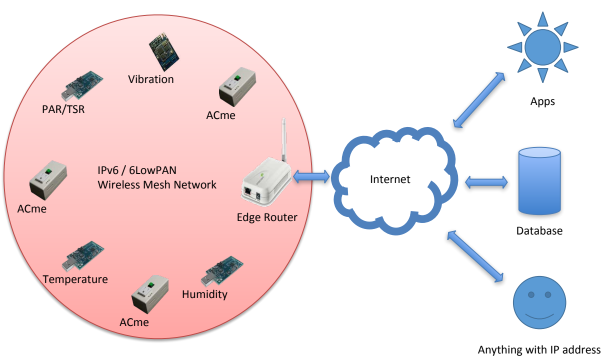
ACme Rev.A vs Rev.B

Version A	Version B
• Resistor + direct rectification + energy metering chip	• Hall-Effect + step-down transformer + software
• Real, reactive, apparent power (power factor)	• Apparent power
• Idle power 1W	• Idle power 0.1W
• Low CPU utilization	• Medium CPU utilization

Version-C

A tradeoff between fidelity and efficiency

Networking Architecture

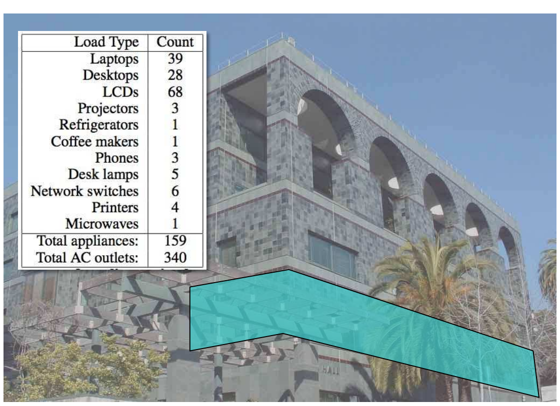


ACme Node Level API

Node API function	Purpose
read() -> (energy, power)	*Read current measurements*
report(ip_addr, rate) -> Null	*Begin sending data*
switch(state) -> Null	*Control the SSR*

- ASCII shell component running on UDP port provides direct access to individual ACme node:
  - Adjust sampling parameter
  - Debug network connection
  - Over-the-air reprogramming
- Separate binary UDP port for data
  - Periodic report to ip_addr at frequency rate

Deployment



Load Type	Count
Laptops	39
Desktops	28
LCDs	68
Projectors	3
Refrigerators	1
Coffee makers	1
Phones	3
Desk lamps	5
Network switches	6
Printers	4
Microwaves	1
Total appliances:	159
Total AC outlets:	340

Deployment

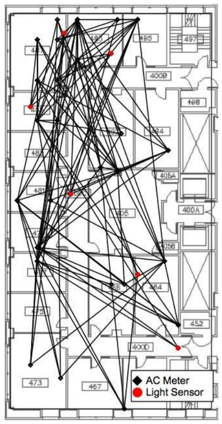
- 38 AC plug-load meters

- 6 light sensors

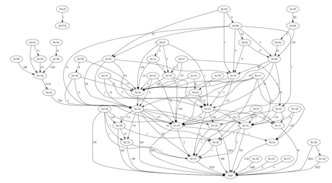
- 1 vibration sensor

Deployment

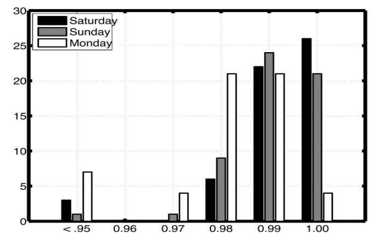
- Ad-hoc deployment
  - Un-planned
- Online "registration" using ID and KEY
  - Meta data collection
  - Security
- Online for over a year
- 20 million rows



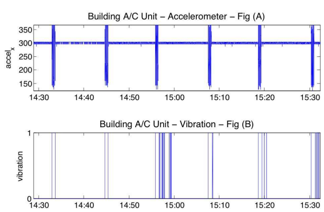
Network Performance

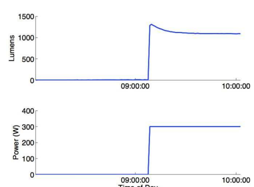


- 44 nodes
- Single edge router
- 802.11 interference (on channel 19)

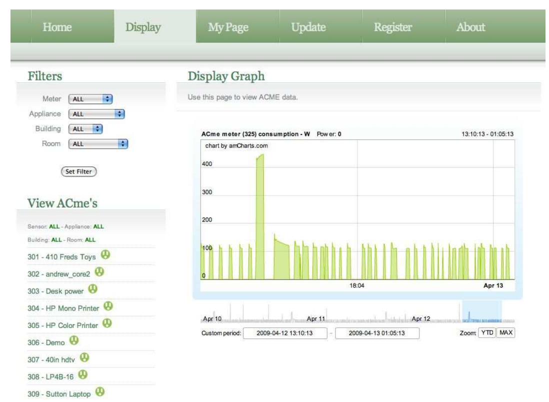


Indirect Sensing

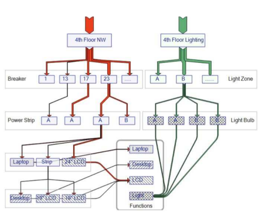


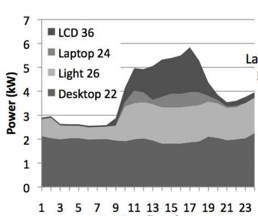


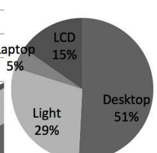
Visualisation Portal



Functional Re-aggregation

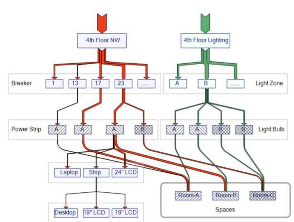


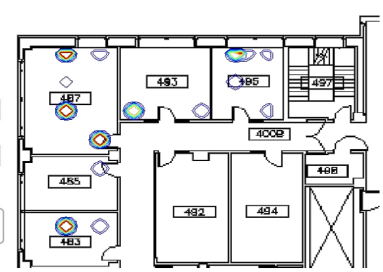




Re-aggregation helps reveal where energy is wasted so that we can act to reduce usage

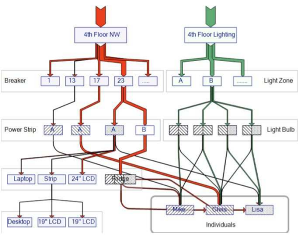
Spatial Re-aggregation

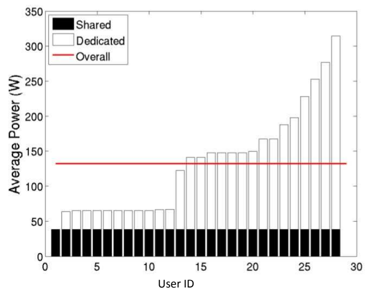




Where to concentrate effort

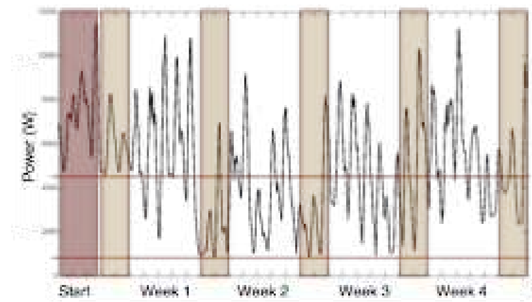
Individual Re-aggregation





And who to blame

Improvements in Energy Usage



High-Fidelity Wireless Building Energy Monitoring

- Identify where energy goes in a building
  - Understanding the load tree
  - Disaggregating energy consumption
- Actionable for reduction
  - Re-aggregation
- 300 ACme's have been deployed at Lawrence Berkeley National Laboratory (LBNL)
- Hundreds of ACme's have been sold through moteware.com to universities and companies around the world, including the U.S., Taiwan, China, Italy, and Singapore.

What actions can *WE* take to reduce?

In Homes

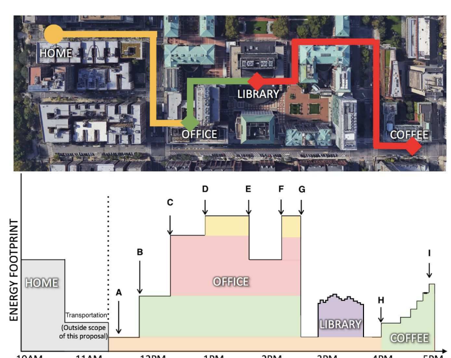
Real-time and personalized energy feedback in homes can lead to reduced energy consumption

In Commercial Buildings

Occupants in commercial buildings have little knowledge of the effects of their actions on their energy consumption.

Energy Footprinting

- Map out a person's **energy foot-print** in real-time
- Enable **accountability** of energy use in commercial buildings
- Provide **personal** and **real-time feedback** of energy impact of everyday interactions
- Creating **actionable** feedback / suggestions



Challenges

Apportionment Policy

Fair apportionment policy in complex, variable shared scenarios

Real-timeliness

Real-time and **low latency** feedback

Scalability

Scalable with building area, energy updates, and location changes

Deployment

Easy **deployment** across diverse types of buildings with disparate infrastructure

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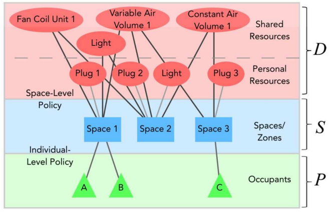

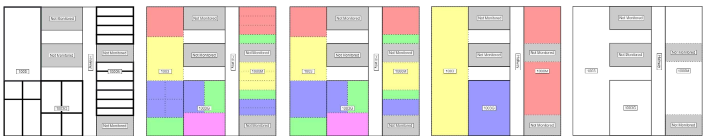

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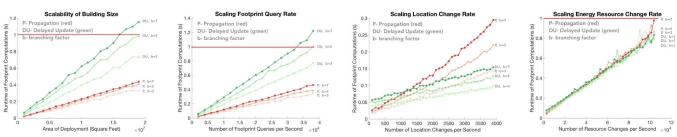

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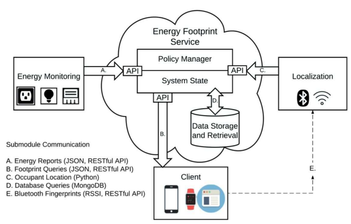

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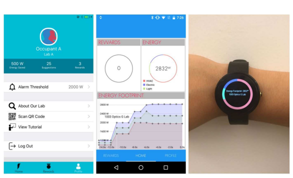

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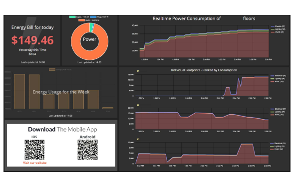
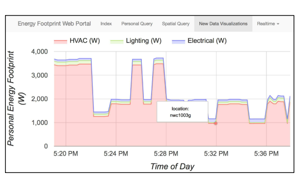
Real-time and **low latency** feedback





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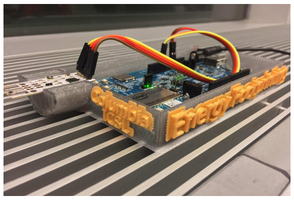

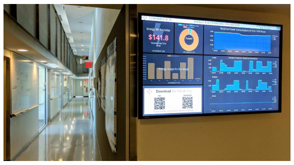

Deployment

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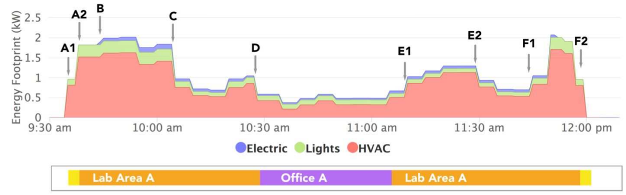
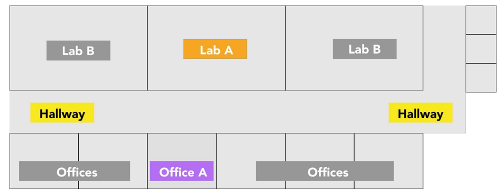
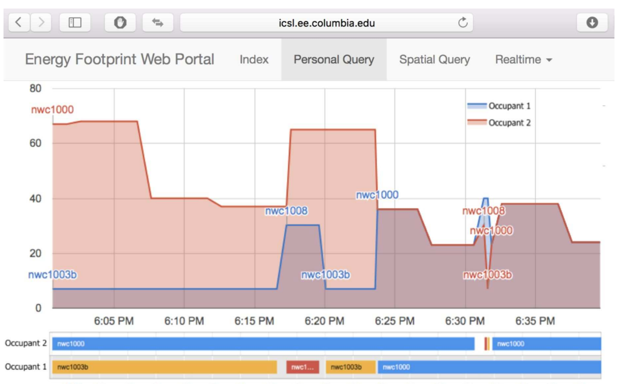
Live Energy Footprint

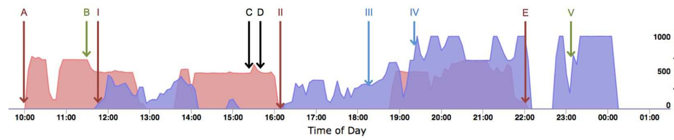


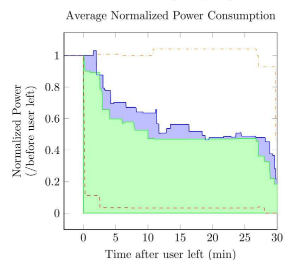


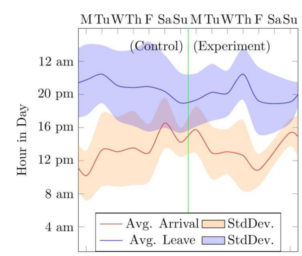
2 Users Crossing Path



Energy Savings





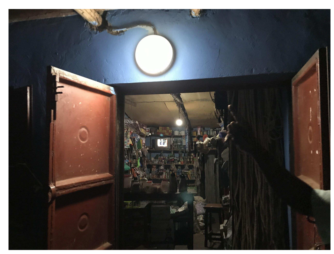


Minigrid Field Experiences
IOT without the internet

Jack Bott and Ji Jia

Acacia Irrigation


Shared Solar


Shared Solar : Station

Why Shared Solar? i.e. Why Share Generation?

Users would prefer their own systems but it is more expensive, it is unlikely utilization will be 100% if reliability is high

Operators want the lowest possible maintenance and generation cost to increase revenue

Build a Sustainable System

Continually generate revenue (Only a functioning system generates revenue)

At minimum set price per kWh to cover maintenance costs

Highlighted Challenges

1. Collecting from customers
2. Communicating with customers
3. Monitoring power
4. System monitoring/communication w/No reliable online service.
5. Cash safety/secure transactions
6. Maintenance
7. Avoiding Power Theft

LOW Cost

Cost efficiency on sales, collecting money, billing and management.

Low system power consumption.

For locations with little to no network connection

Control must be self contained and simple enough to be performed locally

Systems must be robust enough to last where no maintenance or notification of failure is possible

Self maintaining

Cash Safety/Secure System

Credit Safety

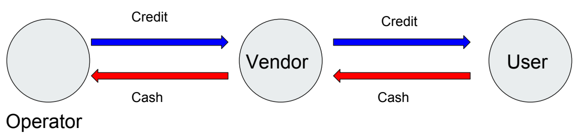
Transaction Safety

Prevent Theft

Operating Model

Operator > Vendor > User

Credit and Cash Flow



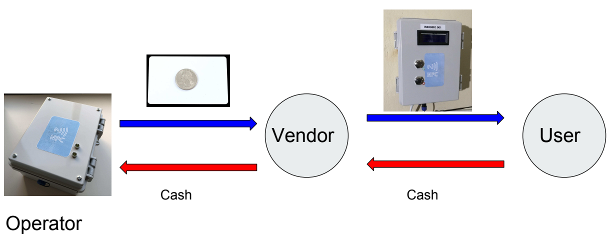
Support System

Website & Operator Module

Transfer credit and identification with NFC cards

Offline payment system

System Flow Diagram



Security

Encrypted card transactions

protected by central secure server. (AES 256)

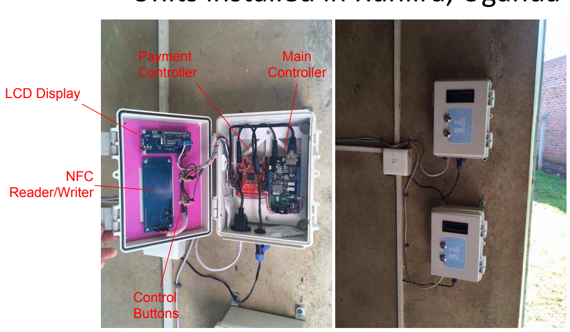
Multiple checks on data accuracy

ex: encryption, defined data format, checksums, private IDs, unique IDs

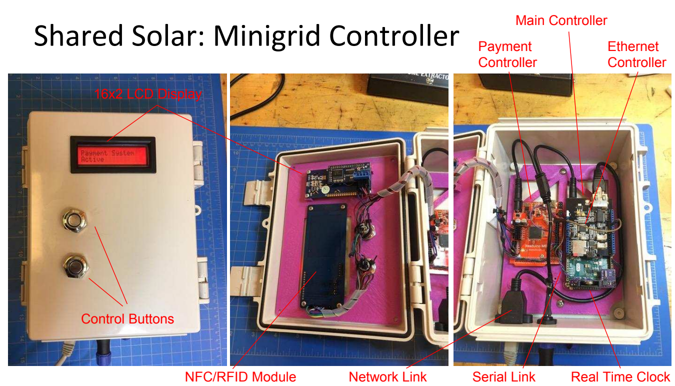
Encrypted transactions from operator to customer.

Vendor Card Security

Units installed in Ruhiira, Uganda



Shared Solar: Minigrid Controller



Shared Solar: Smart Meter

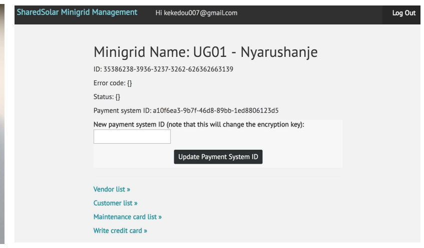
10 User Capacity

1 Watt Accuracy

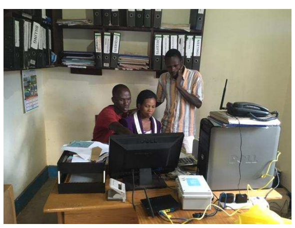
Ethernet Communication

Latching Relay

Shared Solar : Operator



Local Trainings

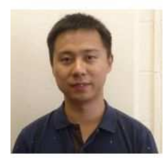


Thank You

Jack Bott

Mechatronics Engineer

Quadracci Sustainable Engineering Lab (QSEL), Columbia University



Ji Jia

Systems Engineer

Quadracci Sustainable Engineering Lab (QSEL), Columbia University

ICT and Electricity Services

- an interactive dialogue towards a knowledge platform

Vijay Modi
Columbia University

Outline

- Geospatial data: Assessment/Design/Management, Ariel
- Sensing, logic, control for Monitoring, Operation, Maintenance
- Digitizing the Utility
- Monitoring: Prerit Agrawal and Shazim Chapra
- Renewable Integration: Balki Iyer
- Commercial Operations: Yash Khaitan
- Electrification of Heating (vijay)
- Electric Vehicles: Matthias Preindl
- Sensing + Communications, wireless: Fred Jiang
- Unique ID, Bank accounts, cashless, Mobile money, payment systems:

Electricity sector

Reliable Access + Efficiency + Renewable Integration: cost-effectively

Changes in sector: RE, DSM, prosumers
Old problems meeting new

DISTRIBUTION SECTOR IN MANY LOW AMD MIDDLE INCOME COUNTRIES (NOT ALL)

What comes first?

- Generation
- Transmission
- Distribution
- Customer

- Transaction costs, politics, unbundling..
- Quality of supply, high losses same places
- Vicious cycle

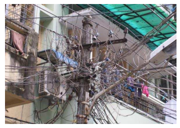
Example: INDIA, Average annual losses of the power sector: $10 Billion, over about 150 million consumers

Accumulated Loss ~ Rs. 3.8 lakh crore (Mar 15) - Total Loss in last 6 years – Rs. 3.66 lakh crore

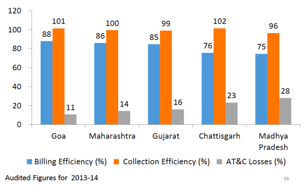
Source: Audited DISCOM Accounts * 2014-15 figure is a projection based on provisional reporting by States

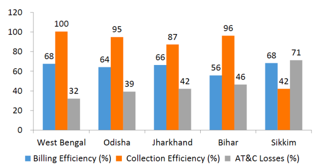
Grid: costs, losses, subsidies, tariffs, transparent transactions, payment sys

West India



East India





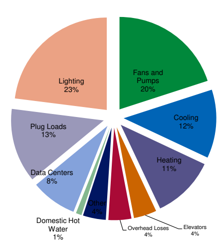
Death Spiral due to poor financial accounting

- Losses/debt not due to wonderful service
- Continued losses/decline
- Generation units rather accept lower PLF than supply
- So reliability could get worse
- Huge exposure to the banking sector
- Temptation to impose high tariffs
- Paying customers suffer, large consumers go captive

Options: enabling ICT technologies

- Conventional Meter- but digital data, can be downloaded or picked up by truck roll
- Protocols for identifying which transformer and which customer
- Low-cost smart meter: digital data + latching relay + communications
- Prepaid or Pay-as-you-go
- Payment Systems

ASHRAE Study for Typical Commercial Office Building

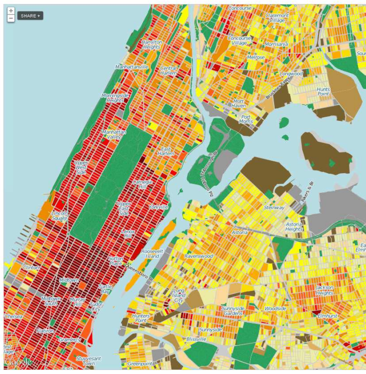


HVAC: 43% of the energy footprint of a typical commercial office building

Heating: 11%
Cooling: 12%

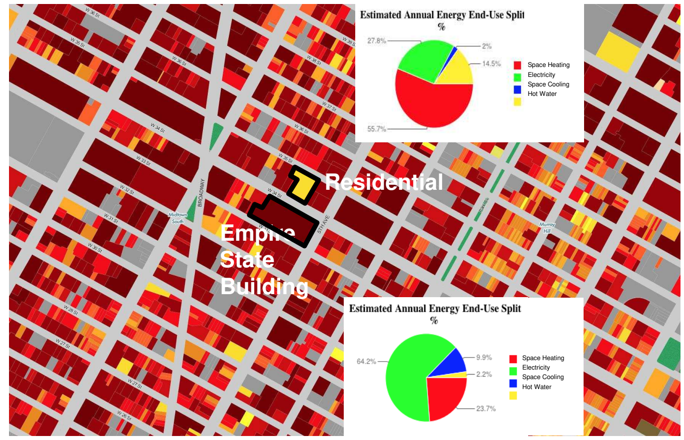
Fans/pumps: 20%

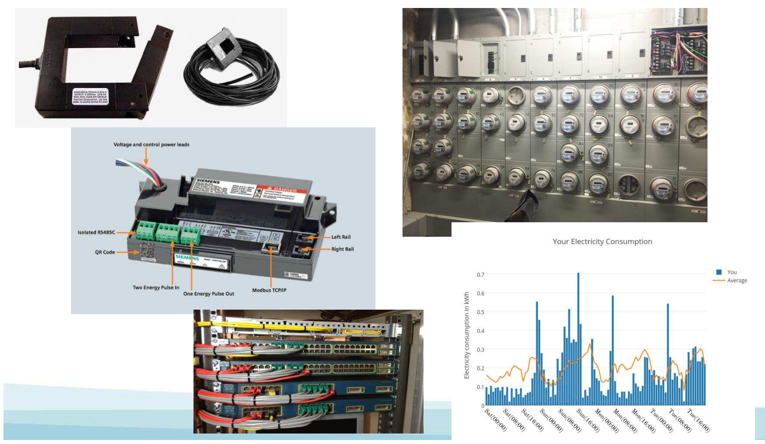
Domestic Hot Water: 1%



New York City Building Energy	
Space Heating	54%
Non Cooling Electricity	28%
Water Heating	14%
Space Cooling	4%
Total (GWh)	142,000

13



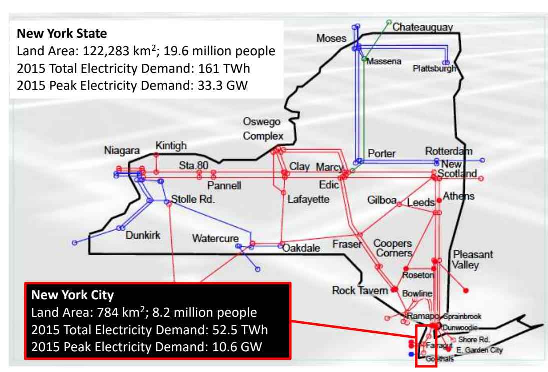


Example: WILL USE study of New York city and new york state

Deep Integration of Renewables

Key observations

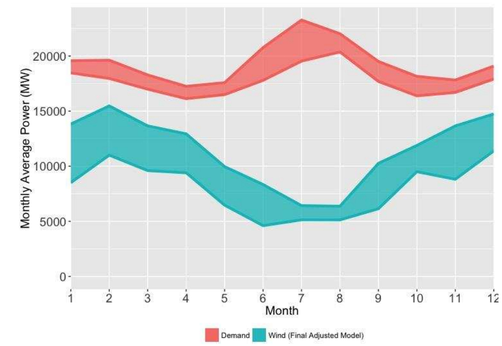
- State/City's 80 by 50 plan
- Efficiency, renewables, elec of heat/transport
- Deep integration of wind
- Changes to demand profile
- Existing infrastructure plays a key role
- IMP: Being COST-EFFECTIVE in your shift
- Low capacity factor techs



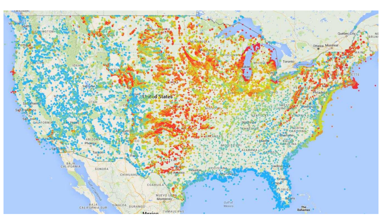
Current New York State Generation Mix

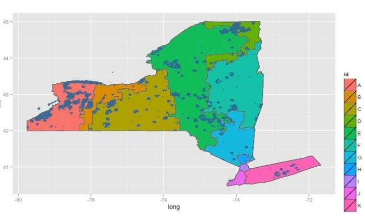
Source	% of Total NYS Electricity Generation (2014)
Natural Gas	41%
Nuclear	31%
Hydro	18%
Coal	3%
Wind	3%
Fuel Oil	1.5%
Other	2%

Ranges of Monthly Average New York State Demand and Wind Power Potential in 6-Year Period (2007-2012)



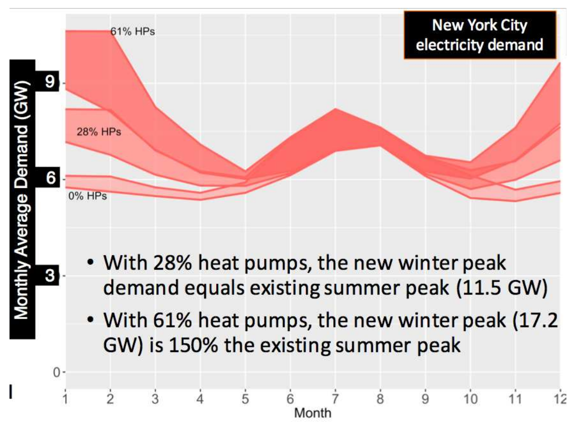
Simulating Wind Power Expansion in New York

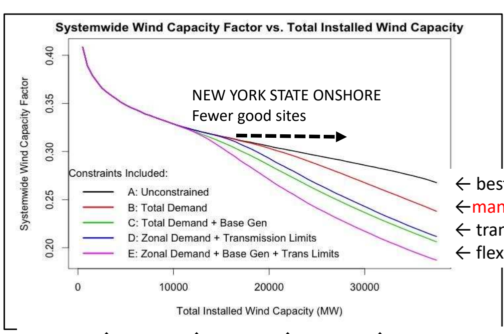




- 37.8 GW wind capacity identified in New York State
- Model data significantly overpredicts electricity generated

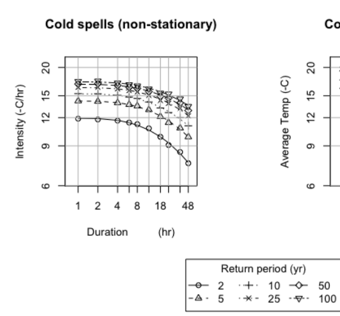
  => Adjusted model data based on logit transform of predicted values





← best
←many options
← transmission
← flex baseload

0% 10% 18% 31% (% energy from wind)



What will scale in LICs first?

Flexibility- examples, L-M ICs

- Hydro → adjustable speed, dispatch
- Irrigation (huge potential in India), pumps
- Appliances (operate over wider voltages)
- AMI/ low-cost meters, driver: non tech losses
- Distribution auto (new + low cost deploy)
- Existing grid: overlay and augment
- Renewables
- Thermal storage and New electric vehicles

Time to mature fully

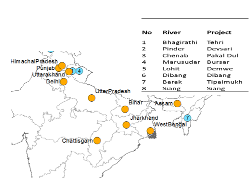
- Expensive to retrofit, even deploy sensors
- Storage: PHS, Grid-scale battery, Electro-fuels
- Real-time market mechanisms, DSM
- Power Electronics, initially without comm..
- Dynamic Balancing, PMUs
- Volt-VAR control, Power Flow Control
- Appliance-level control, communications

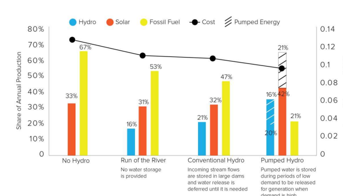
HOSTING CAPACITY- through data

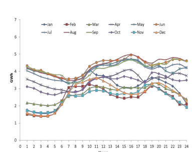
Hydropower: changing role

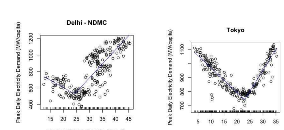
operation than new build out

DEEP INTEGRATION OF RENEWABLES NEEDS FLEXIBLE SOURCES OF POWER









Offgrid: single home, only solar/wind, hard w/out storage

Option 1: 3 kWh/month & $10 /month
LED, phone, small fan/TV **small solar home system.**

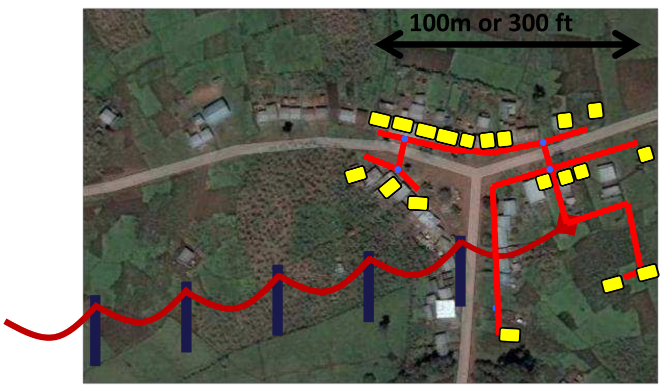
Option 2: 100 kWh/month & $10 to $15/month; lots of light/electronics + fridge + some cooking + AC + pump **GRID**

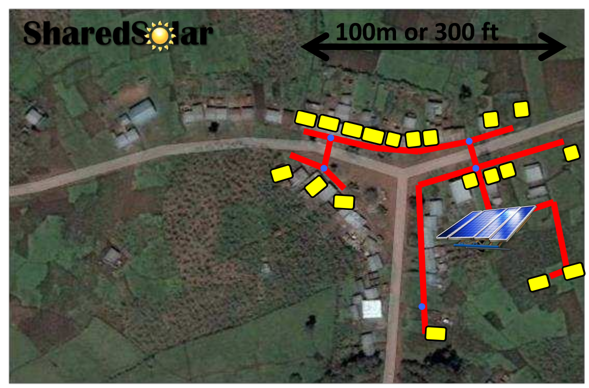
Challenge: Can we do 20 kWh at $10/month? YES

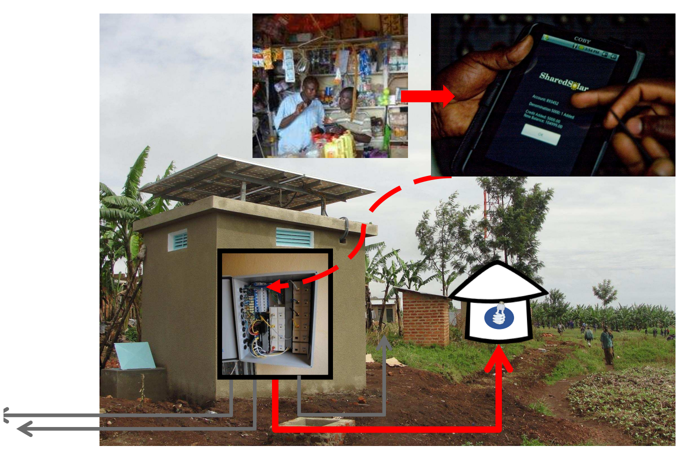
Can 20 kWh do the work of 40?

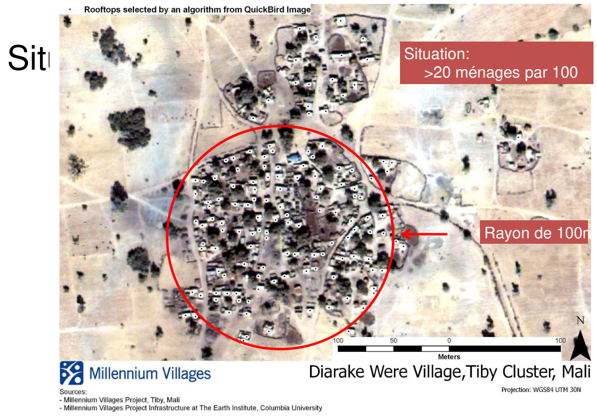
Incremental Infrastructure

- Where demand more than just for small loads one could start local and where/when economic demand densities become high enough and cheaper sources available one can interconnect
- Keeps initial investments small and modular
- Allows demand grows and entrepreneurship to emerge organically

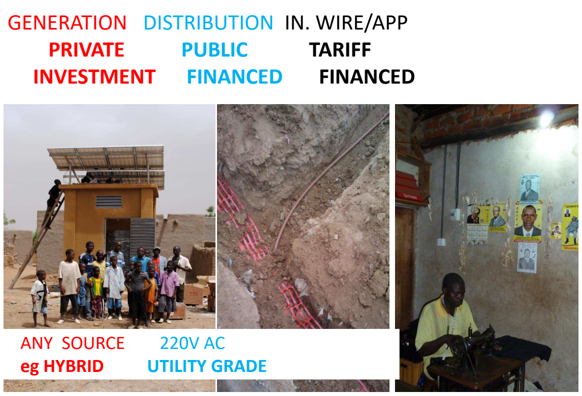




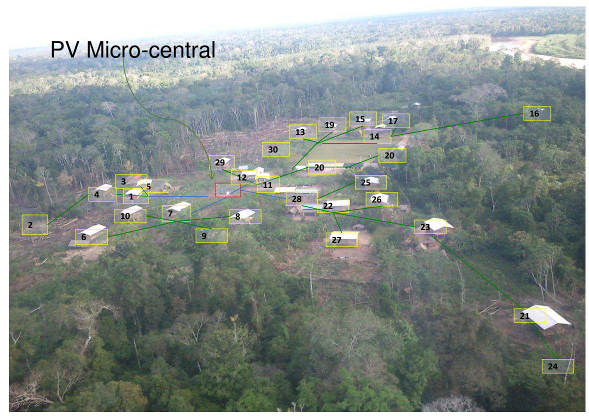




Rooftops selected by an algorithm from QuickBird Image
Sit
Situation:
>20 ménages par 100
Rayon de 100
Millennium Villages
Diarake Were Village,Tiby Cluster, Mali
Projection: WGS84 UTM 30N
Sources:
- Millennium Villages Project, Tiby, Mali
- Millennium Villages Project Infrastructure at The Earth Institute, Columbia University



GENERATION DISTRIBUTION IN. WIRE/APP
PRIVATE PUBLIC TARIFF
INVESTMENT FINANCED FINANCED
ANY SOURCE 220V AC
eg HYBRID UTILITY GRADE



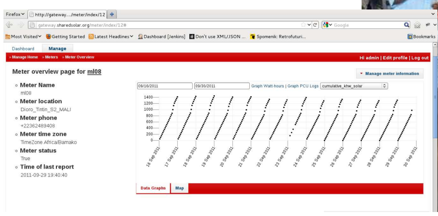
PV Micro-central

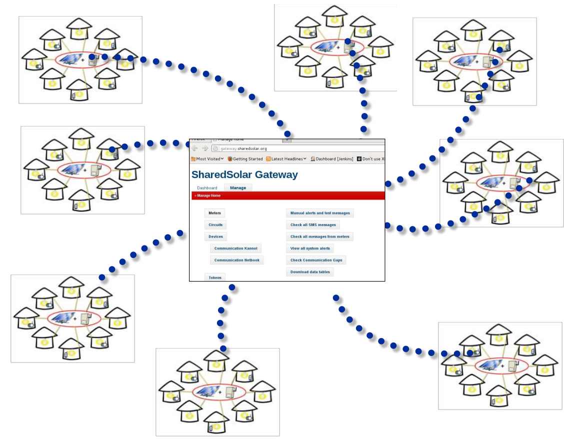
Smart Micro-grids
An smart micro-grid combines clean energy, efficiency and smart allocation of resources to provide reliable and cost-effective energy services

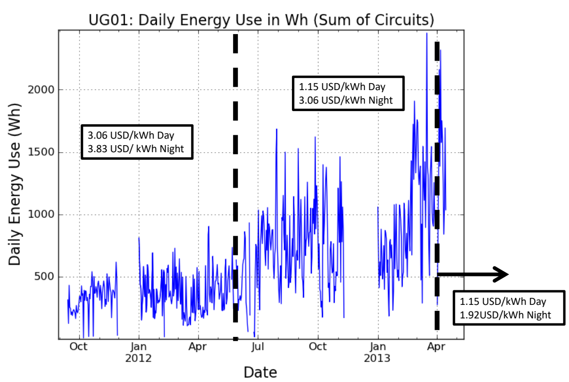
PRE-PAID
PAY-AS-YOU-GO

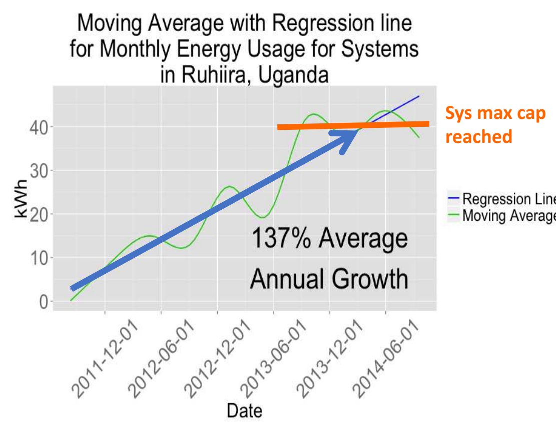
ENTERPRISE MGMT

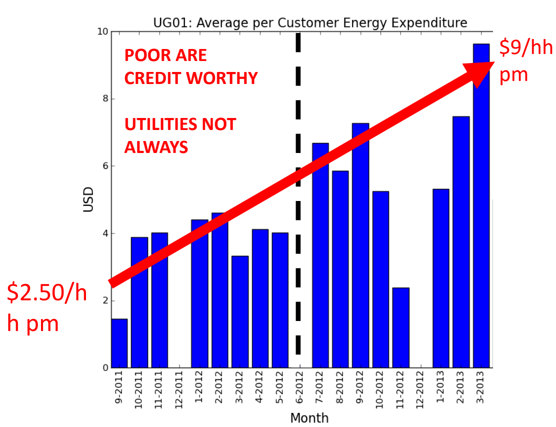
+ PERFORMANCE VERIFICATION

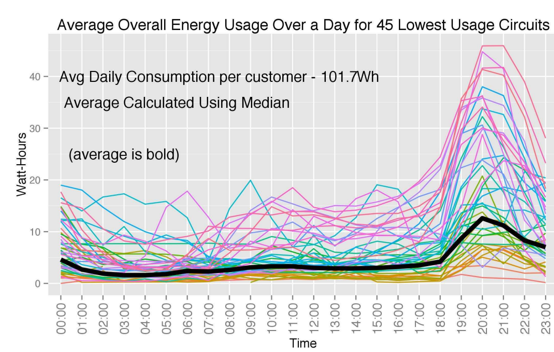


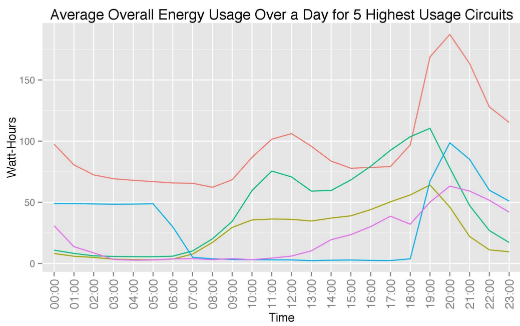


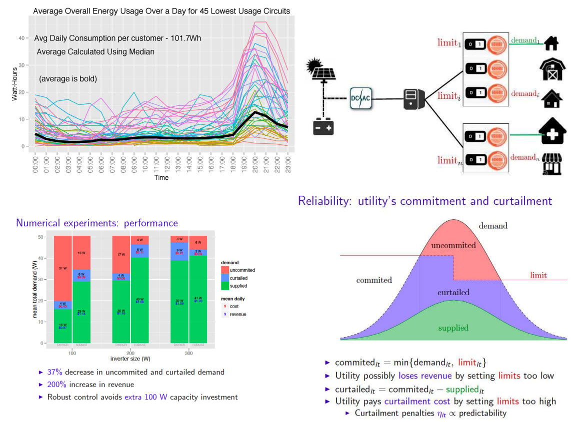




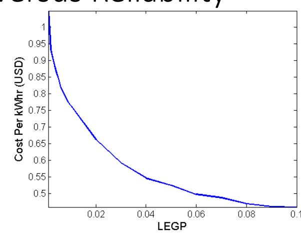








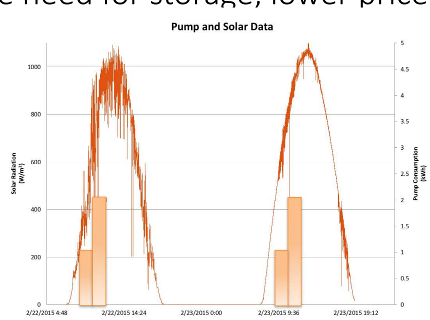
Cost versus Reliability

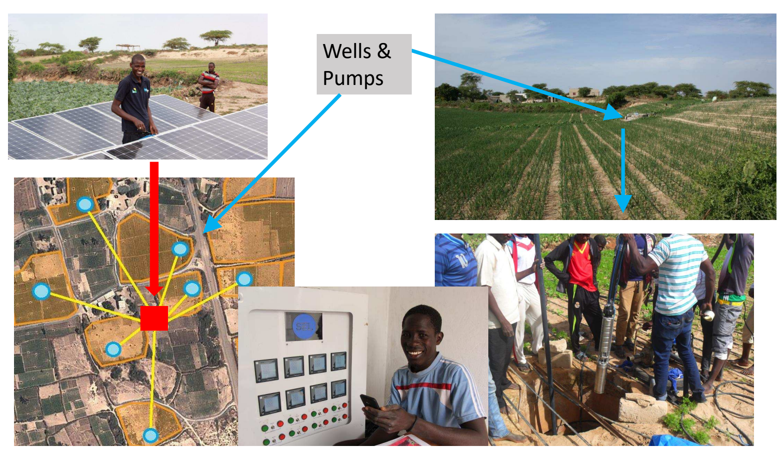


Cost in USD/kW-hr versus *LEGP* of micro-grid with refrigerator base load. The simulation uses the insolation profile from Segou, Mali. *LEGPs* range from 0.001 to 0.10. The cost for a reliability is the optimal combination of PV generation and battery storage which achieves that reliability. Thus, PV generation and battery storage capacity do not have a fixed ratio.

99.9% Reliability ← 90.0% Reliability

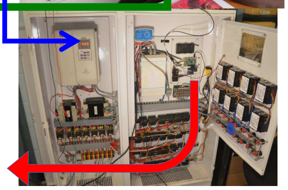
Scheduling load: pump operates when sun shines: can reduce need for storage, lower price power

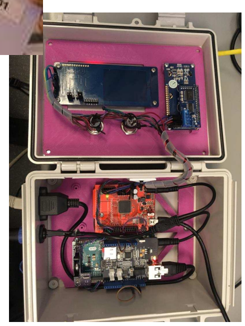




VFD/Control/Payment

- No Batteries!
- Inverter/VFD
- 415V, 3ph, 50 Hz
- **Microprocessor**
- **Payment app**





Some examples
Disruptive
Exponential
Test/Standard/Specify