BHAVE

November 20, 2017

Puerto Rico Energy Commission's Clerk's Office
268 Munoz Rivera Avenue, Suite 202
San Juan, PR 00918

RE: CASE NO. : CEPR-IN-2017-002 Comments on questions in **Appendix I**

Dear Madam or Sir:

I appreciate the opportunity answer the thoughtful, important questions you have raised in the Resolution and Order dated November 10, 2017. As you request, I have responded to the questions listed in Appendix I in the attached.

In 2015, my team did techno-financial modeling of ~ 1 MW microgrids. I was visiting professor of strategy, at Indian Institute of Management, Kozhikode at that time. Our work is written about in my book, **The Microgrid Revolution: Business Strategies for Next Generation Electricity, Praeger, 2016**. I presented some of my results at IEEE Life Members' meeting on June 29, 2017 in San Diego. That presentation is attached.

I believe the work you are doing in Puerto Rico related to microgrids has broad implications for restructuring the electricity industry itself. Its importance and timeliness cannot be overstated. When successful, you will have created the core, replicable elements of the Electricity 2.0 infrastructure for the entire world.

If I can assist in your work in any way, I am happy to help.
Best regards,

Mahesh P. Bhave, Ph.D., LEED AP
Founder, BHAVE Power Systems

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619 847 2777 mobile / 858 259 0267 home
maheshbhave@gmail.com
My book: The Microgrid Revolution: Business Strategies for Next Generation Electricity, 2016, Praeger.

Attached
List of recent microgrid related articles; book cover of my book on microgrids
Answers to Exhibit A questions
Presentation on *"Microgrid Revolution"* to IEEE Life Members

IN20170002A48

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Mahesh P. Bhave: Select microgrid related article in recent years,

619 847 2777 cell, maheshbhave@gmail.com

Puerto Rico - Rebuild with Microgrids, ***Renewable Energy World,*** Oct 4, 2017

Cooking Microgrids: The Case for Application-specific Power Networks, ***Renewable Energy World,*** Jun 9, 2017

The Microgrid Revolution: What Business Models Will Prevail on the New Grid? ***Microgrid Knowledge,*** Apr 17, 2017

Diving into the solar microgrid revolution, ***GreenBiz,*** April 1, 2017

The compelling case for creating a nation of microgrids, ***GreenBiz,*** Mar 15, 2017

Microgrids for Clean Cooking and Internet, ***Renewable Energy World,*** Feb 27, 2017

Microgrids and the Market Capitalization of Utilities, ***Renewable Energy World,*** Nov 30, 2016

Federation of Microgrids: A Moral and Business Necessity, ***Renewable Energy World,*** Oct 4, 2016

The mega wonders of microgrids, ***Business Standard,*** Jul 9, 2015

Why Microgrids are Essential in India's Electricity Generation Mix, Jul 8, 2015, ***Renewable Energy World.***

Tesla E-motorcycles Complement SolarCity Microgrids, ***Renewable Energy World,*** May 20, 2015.

Microgrids as Fact and Metaphor, ***Renewable Energy World,*** Jan 22, 2015.

Microgrid Economics: It Takes a Village, a University, and a Ship, ***Renewable Energy World,*** Sep 30, 2014.

Microgrids: Missing from the UN's Sustainable Energy for All Initiative, ***Renewable Energy World,*** Jul 8, 2014.

Microgrids Create Municipalization Benefits, ***Renewable Energy World,*** Jun 2, 2014.

How many electric utilities does a market need? ***Renewable Energy World,*** **Jan 31, 2014.**

Microgrids by mail can contribute to rural electrification, ***Renewable Energy World,*** Mar 15, 2013.

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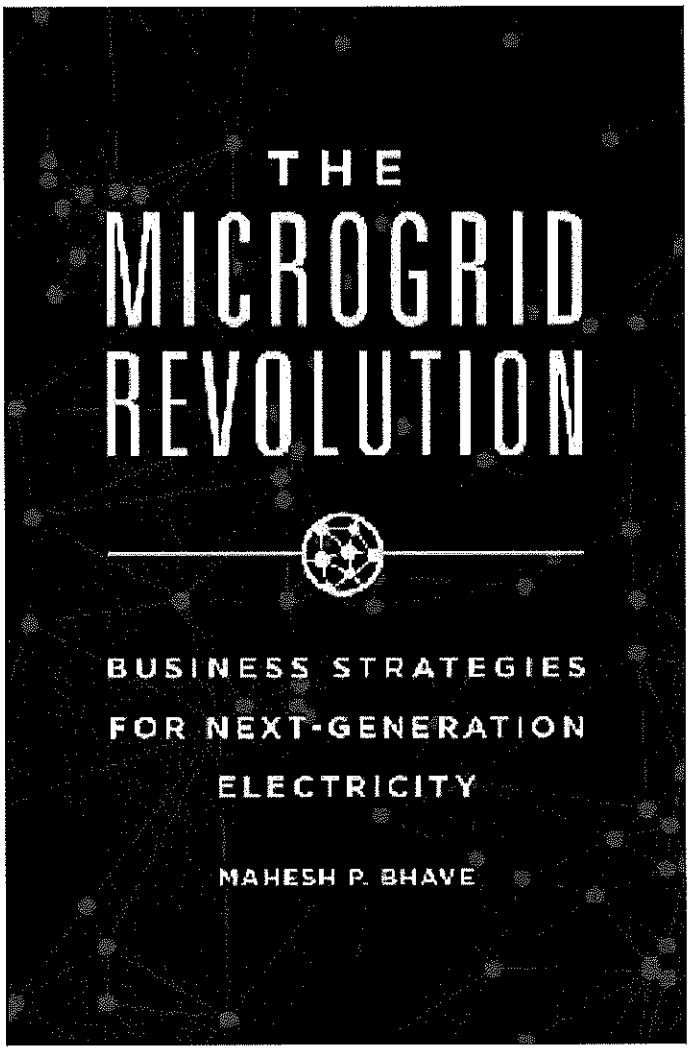

https://www.amazon.com/Microgrid-Revolution-Strategies-Next-Generation-Electricity-ebook/dp/B01LZ0M7GG

CASE NO. : CEPR-IN-2017-002, COMMENTS ON APPENDIX I
Puerto Rico Energy Commission: Regulatory actions to facilitate the tasks of restoring electric service and encourage the deployment of new technologies

1.1 The Commission *needs new authority* to act in the best interests of the people of Puerto Rico, and consistent with technical advances and the evolution of the electricity industry.

- **Inter-microgrid connectivity** for information and electricity exchange will be the norm in the future; the topology of the electricity system of the future is a *federation of microgrids*
- **Inter-connection with PREPA's distribution system** is necessary, though not with the transmission system
- **sale of microgrid output may be to PREPA among others**; the primary user of the output of a microgrid would be the facility or venue that houses the microgrid - for electricity autonomy, self-sufficiency, reliability; Microgrid as a Service (MaaS) is a valid business model too
- sale of microgrid output can be to retail customers, homeowners, shopping malls, office buildings, ... and not necessarily to PREPA; PREPA's role regarding microgrid output is optional or secondary

When market conditions change, for instance, due to lower prices for solar panels, falling prices for batteries, and distributed generation - which is novel and in a break from traditional ways of deploying electricity infrastructure - then existing legal and regulatory criteria need to change to accommodate this new reality. This might be through legislative or other means, possibly prompted by lawsuits, as happened in the case of the old AT&T.

Private entities may challenge the authority of the Commission on constitutional grounds. The old AT&T was challenged in the courts by Microwave Communications Inc. (MCI). That led to de-regulation of the telecommunications business. The market conditions in electricity are at similar crossroads. For instance, the legal structure as it exists derives from *"natural monopoly"* arguments that may have applied in the past but hold no longer. Microgrids cost relatively little compared to the traditional infrastructure, and as a result, the "*barriers to entry*" in electricity have fallen.

Puerto Rico may be the ground zero for legal challenges to the existing electricity regulatory dispensation, nationwide. This is a pioneering, singular moment - bigger in its import than commonly recognized. Puerto Rico leads, albeit in the context of an Act of God. Thus, the commission must seek new legal authority to regulate in conditions of competitive markets and lowered barriers to entry for electricity.

1.2 What you call alternate microgrid ownership structures will be and should be the norm going forward - the barriers to entry in the electricity business have fallen; so called third-parties should be microgrid owners going forward, including cooperatives, businesses, and many other organizational entities. Microgrids are inherently more reliable, economical, and clean.

1.2.1 Regulatory actions should encourage new microgrid ownership by a number of prospective owners. Regulatory role should be limited to ensuring there is no non-competitive behavior by microgrid owners, ensuring safety, and ensuring consistent standards across microgrids for inter-working.

The traditional "rate of return" thinking should disappear; each microgrid will have its own economic basis depending on sunlight availability, size, wind patterns, availability of biomass feedstock, ... and customer attributes. Prices will vary across microgrids, though not much. In any case, since the prices will be lower than what obtains today, all customers will be better off. Over-regulation will not be in the public interest, and one may say: Today's regulatory structure throttles innovation, constrains and inhibits the emergence of microgrids, and the all round benefits they represent.

1.3 Private ownership of business is most American. What obtains in all normal businesses should now prevail in the electricity business. I see no barriers to varied ownership structures consistent with the boundaries governing any normal business. The Commission should relinquish authority over ownership structures in next generation electricity and let the normal business context prevail.

1.4 The Commission indicating a willingness to accommodate novel ownership forms will release all sorts of capital to flow into the electricity business - private, non-profit, cooperatives, communities, ... For after all, microgrids represent lower cost electricity than what obtains today, and thus a new service provider likely will enjoy greater margins even as costs are reduced for end users and customers. My analysis (see my book, *The Microgrid Revolution: Business Strategies for Next Generation Electricity,* 2016, Praeger) proves this for select markets today, and increasingly in more and more markets, worldwide.

1.5 Over the years, the technical and organizational expertise necessary to deploy microgrids exists. What is less clear is whether there is expertise in inter-microgrid connectivity. Such inter-microgrid connectivity should have been supported by DoE and ARPA-E and through the national energy labs. This is not the case. But this is not an insurmountable problem, for after all, inter-networking is the norm in telecom, and lessons from telecom should be extensible with modifications to the electricity infrastructure of microgrids.

There are numerous microgrids already deployed - I have attached my presentation to IEEE Life Members, June 2017, that lists many of them.

2.1 Microgrids will work for urban loads (or population clusters) and remote loads. I propose remote population clusters or businesses be the first priority. This is because the urban centers will merit attention, likely with traditional solutions, anyhow.

Further, the *remote clusters should be inter-linked to each other* ***preferentially*** *instead of to the traditional grid.* The microgrids may be of size, say, 0.5 MW to 5 MW. They should not be owned by PREPA since non-traditional thinking and ownership should be encouraged, though technical expertise may be obtained from PREPA, if needed.

A simple brainstorming exercise to *technically* evaluate the relative deployment sequence among rural loads can be conducted. Of course, deployment should begin urgently everywhere.

2.2 The customer group prioritization should be based on technical, physical, and operational criteria, availability of supply and demand side resources; there is no denying the need for urgent deployment of microgrid solutions for all customers. The prioritization exercise mentioned in 2.1 can address deployment sequence challenges.

2.3 Microgrid economics, as it exists today and over time, will ensure developer interest, and market forces will make them attractive for developers. The Commission's ***intent*** to offer microgrids as a solution, independent of and complementary to PREPA, will ensure funding for microgrid projects.

2.4 The Commission should signal and ensure widespread participation by new businesses in the electricity business; there should be minimal price regulation since prices are likely going to be lower than what obtained before Hurricane Maria anyhow. Microgrid owners should be able to make deals for resource sharing among each other.

3.1 The less regulation, the better; standard practices for any routine business should prevail. For there is little special about electricity anymore. Many can generate it, many can provide it, economies of scale are no longer necessary for low unit cost, and the market can be segmented for service. We may have commodity electricity, as today, and we may have application specific electricity too.

3.1.1 The overwhelming regulatory change needed is to encourage multiple service providers to emerge in the market. Whoever wishes to provide electricity for a market segment should be allowed to provide it, with the consent of the customer (less regulator), and the customer should have the right to reject and replace the service provider if the supply quality is inadequate. Rules by the Commission to facilitate such customer choice are key. There no doubt exists an element of local, natural monopoly

in this arrangement but it can be short-lived provided rules are developed for entry for a competitor or alternative service provider of the customer's choice.

3.1.2 In addition to the option of rejecting a service provider by customers for poor service, as above, *safety practices* should be regulated.

3.1.3 Baseline technical qualifications and financial worthiness should be established by the Commission. This was done by the FCC when spectrum auctions were conducted. Thus, there is precedent for establishing such qualifications.

3.1.4 While the risk of incompetent developers exists, there is sufficient knowledge about microgrids now so that this is less and less likely. Unscrupulous developers - this risk can be reduced through establishing fair, transparent qualifications criteria.

3.2 Well-established standards development processes, say, in telecommunications or electricity through committee work among stakeholders should be sufficient to establish and evolve microgrids standards.

3.2.1 Safety standards - existing electricity safety standards, suitably modified - and likely not much more is needed.

3.2.1.1 They are not - I am especially concerned that there is insufficient work in the industry on ***inter-microgrid resources and information sharing.*** This area deserves the highest priority. The presumption that microgrids should interact only with the megagrid is both false and self-serving for the existing grid operators, and this default assumption is not in the public interest.

3.2.2 To the extent possible, inspections should be eliminated, and the emerging microgrid industry should self-regulate, self-monitor, and work to industry established standards. Inspections are also an area that breeds corruption. Violation of standards, if found, should invite appropriate penalty. Safety is the only area that may merit some, but minimal, inspection.

"Technical specifications for interconnecting a microgrid to PREPA's transmission or distribution system" - this likely does not belong in 3.2.2 dealing with inspections.

However, the presumption that microgrids should connect necessarily (or only) with PREPA's infrastructure is false and undermines the promise of microgrids. Microgrids should work with each other too for the same or better resiliency that is presumed with inter-connection with the megagrid.

3.2.3 The microgrids deployed may not connect with PREPA at all - distribution or transmission or sub-transmission. They may connect, for legacy reasons, for a while,

and that is fine. But linking with the megagrid for resiliency is strictly not necessary - a cluster of microgrids can be equally or more resilient.

3.3 Several natural microgrid hubs suggest themselves - shopping malls or centers, hospitals, sub-stations, office buildings, railroad stations, schools, colleges, campuses, ... See my IEEE presentation on likely locations and the interaction among venues.

3.3.1 No, there should be generally no limit on the size of a microgrid. For typical residential settings, however, it seems microgrids can range in size from 0.5 MW to 5 MW in steps. These may be mapped to population served, area in square feet, load type, .. Microgrids can be larger too, especially for commercial or industrial settings.

3.3.2 Franchise rights is a good idea; performance of the microgrid grid (reliability metrics, quality of electricity, down time in a year, safety, ...) should be the main criteria for a service provider to enjoy that right. Customers may challenge a provider; the Commission should provide guidelines for replacing one provider with another.

3.4 It is unclear to me why consumer (more generally customer) protections should vary with the ownership of microgrids.

3.4.1.1 I think the Commission may not set pricing in the way it is done today based on cost plus methods or rate of return guarantees. Market forces should set prices. The prices should be based on competitive, market pressures. Excessively high prices should carry the threat with it of a customer going to the next service provider during suitable transition windows, much like the expiration of franchise rights for retailers, or even as happens with today's IOUs.

Yes, it is reasonable for the Commission to charge an administration fee for their oversight services, recognizing that the regulatory overheads today are likely excessive, and the new regulatory dispensation will likely be far cheaper since microgrids will largely self-regulate, and maintain industry standards in a competitive market. The industry is no longer a "natural monopoly." Entry and exit barriers are largely gone with microgrids. Regulations should thus change, but diminish.

3.4.2.1 The Commission should stay out of determining such standard contract terms, and it is incorrect to assume the contract terms will be with microgrid service providers and PREPA; the contracts ought largely be among microgrid service providers in *many-to-many* format and relationships. The Commission ought to recognize that with a microgrid-centric electricity system, the central or dominant role for PREPA diminishes.

3.4.2.2 No, standard terms should not be prescribed by the Commission at all. Competitive pressures should create the best terms for all customer groups, residential and small-residential, who should have choice, and they should determine contract terms best for them, much like a customer chooses among mobile service providers.

3.3.2.3 No, setting standard terms should not be a part of the Commission's mandate at all, no matter who the supplier or the customer.

3.3.2.4 No commission review is necessary. The Commission should not interject itself in market processes, except when absolutely necessary. Normal business laws should operate just as they do for any other industry.

3.3.2.5 No, the Commission may not - the customer should choose the duration in its best interests, and should have the right to throw out a non-performing microgrid electricity supplier, just as any normal business would throw out a non-performer.

3.3.2.6 The customer can choose another microgrid service provider, or be their own microgrid - the Commission should have no role.

3.3.2.7 "Unanimous" appears too strong a word; if the number of customer decision makers is sufficient large, or they have a managing board, the decision of the managing board can serve as proxy for the majority, and without the requirement of unanimity.

3.2.2.8 Over time, it is possible and even likely that individual customers can become their own service providers - grid-defection or microgrid defection - and this ought to be permitted. Such a customer may still choose to stay connected to the local microgrid or megagrid for a small fee, as "insurance," or "just in case." This option for individual customers may not be discouraged by the Commission. Disadvantage or advantage - the question has to be asked: From whose point of view? The customer's point of view should prevail.

3.4.3 I think deposits or pre-payment by microgrid operators with the Commission are appropriate in that the microgrid operator may be compelled to maintain certain performance standards as a result. The amount should be potentially punitive, and not be a token amount. The amount may be a function of customers served, size of the microgrid in MW, or some combination of these, or some other suitable criteria.

3.4.4 Non discriminatory rules should be presumed to apply both to microgrid service providers and customers.

3.4.5 It might be worthwhile to consider other protections both for customers and service providers in a brainstorming discussion with interested stakeholders. I am happy to participate in such sessions.

3.5 Whether pricing is based on metering - as obtains today in kWh units - may not be the only pricing mechanism in the future. It is possible to have flat rate pricing, or "buckets of service" based pricing, as has happened in telecommunications. Electricity service providers may charge by "lumens" or "water pumped" or "heating (or air

conditioning) delivered" to a standard throughout a season for a flat fee, or based on "meals cooked in a month", ... and so forth. This should be a welcome development for the customer enjoys the satisfaction of flat rate pricing, and the supplier has incentive to reduce operating costs and increasing efficiency to improve margins.

3.6.1 No and no. Why should the Commission know type of customers and their number? Target Department Stores does not have to disclose to anyone what types of customers visit their stores nor how many.

3.6.2 No - the capacity and its type is entirely up to the service provider, and the service provider has the right to change that mix based on the best economics and performance it determines for itself, so long as the customer is properly served.

3.6.3. No - cost management is entirely the service provider's domain of responsibility. The service provider owes no explanation about it to anyone.

3.6.4 Pricing - should be entirely between the service provider and the customer, for a given contract period. The customer should have the right to terminate the contract for non-performance or dis-satisfactory service, and the service provider may terminate service to any customer for non-payment of dues, for instance.

3.7 The Commission should not take much time at all - say, a week at most - in approving microgrid proposals. If a microgrid service provider is technically qualified and financially viable, the approval must be practically automatic, and with little room for discretion with the Commission. It is after all the right of any corporate entity to offer services, and of customers to choose their service provider - the Commission's role is that of a facilitator, not policeman or judge.

4.1.1 through 4.1.3 and 4.2 appear to be specific to Pattern Santa Isabel LLC, require local knowledge of assets, and I am unable to answer the questions. The problems appear to be readily fixable.

4.3 and 4.3.1 The facilities, even under contract to PREPA, may be used in a microgrid, assuming PREPA is unable to take up the power generated today. Why should the generator lose revenue just because PREPA is unavailable? Yes, a facility other than PREPA should be able to develop a microgrid using the generation facilities, and serve customer needs right away. There might be some "extenuating circumstance" clause in the contract that says in case PREPA is unable to off-take the power generated, the supplier may sell or use it elsewhere until such time as PREPA is able to use it.

4.4 Yes.

4.5 Yes, it is legal, it is practical, and it may be sometimes necessary to use some fossil fuel based generation to maintain service continuity when the sun does not shine, or

batteries have drained, or to optimize operations for either lowest cost infrastructure or for optimal operating efficiencies.

The microgrid my team modeled had solar, batteries, and a diesel generator. The latter charged the batteries at night occasionally when the batteries drained, or when there was less sunshine to charge the batteries fully during daytime due overcast skies.

4.5.1 No one uses fossil fuel-based generation because it is economical - the preference is to use maximum solar, maximum batteries, and only supplementary diesel generators. This is because diesel generators produce the most expensive electricity of the three. The use of diesel generators need not affect the "renewable" status of the overall facility. How much diesel to use will depend on the season, load profile, available sunlight and so forth. In any case it will be less than 30% of the overall requirement, more likely 20%, that is, about four hours in a twenty hour period.

5.1 through 5.6 relate to CHP and since I do not have specific information about the use of CHP in Puerto Rico, I am unable to address these issues.

6.1.1 through 6.1.4 are questions directed at PREPA.

6.1.5 If PREPA wishes to deploy microgrids, in some markets or for some customers, the Commission should ensure there is a level playing field. The option to offer those very customers and venues by other microgrid providers should not be precluded by PREPA being the preferential microgrid provider. PREPA should be one among equals for microgrid service provision.

If PREPA is perceived to be favored as provider, this will discourage other microgrid providers from entering the market; this outcome will not serve the public interest.

6.2 Why should PREPA get any reservation for any markets or customers for microgrid provision? They should be one among equals.

7.1 Any unused equipment belonging to PREPA may be made available for microgrid use for anyone qualified provided fair compensation is paid to PREPA for it. Why only metering equipment? This should apply to all equipment.

This is routine in telecommunications, see for instance, "co-location" regulations. The provider makes available "common carrier" facilities to others, that is, competitors on the same terms as it uses or makes available for itself.

7.1.1 PREPA should be compensated monthly based on amortized costs of it.

7.1.1.1 Commission should ensure PREPA calculates the price per month of the asset fairly, and that should be charged to third party users.

7.1.1.2 The microgrid should pay a monthly fee; it is unclear why the microgrid operator should wish to buy the equipment, at least in the early stages. Eventually, should PREPA not use the equipment, it may be sold.

7.2 Yes, making such equipment available to microgrid operators would be in the public interest and will expedite the deployment of electricity services.

7.2.1 PREPA should be compensated on a per month basis starting the date of the contract with the microgrid service provider.

8. Regarding behind the meter systems, please review the second part of my article in *Renewable Energy World* - **Puerto Rico - Rebuild with Microgrids.** Stand-alone, off-grid, home "systems-in-a-box" of the kind I recommend may be put together and distributed to those in need all over the island, urban and rural and remote areas alike. They are emergency systems that permit lighting, phone and electronic appliances charging, fans, TVs, and cooking. These systems can be assembled relatively quickly, and should cost ~ $1,000 in volumes of thousands. To quote:

"The buildout of microgrids, optimal though it is, may take a little time. Here is what may be done immediately. In a warehouse, assemble solar panels, of say, 500 W capacity, pair them with up to 3 kWh Li-ion batteries, include an induction or resistive hob for cooking plus a multi-port USB plug, box them, and deliver them to all families who need it. Total cost per set up should be around $1,200. Self-installation, IKEA-like, is easy. Home cooking can begin immediately, and basic lighting, phone and laptop charging, even fans and TV will be supported. The battery drains with daily use, and is recharged with the sun — no grid necessary.

"Let us acknowledge it — the electricity infrastructure of towers, poles, and cables strung across distances is obsolete; only inertia, the monopoly power of incumbent utilities, and the fact that it works, so far, keeps it going. In Puerto Rico, albeit in the context of a tragedy, we have a greenfield opportunity to do right, and not only for the island, but for the world."
http://www.renewableenergyworld.com/ugc/articles/2017/10/04/puerto-rico-rebuild-with-microgrids.html

8.1 I don't know what the technical or other short falls are, and thus unable to answer.

8.2 Probably, a website with basic information with option for online Q & A might help.

Zugeily Col[illegible] Del Valle <zcolon@energia.pr.gov>

Fwd: Desk-Sized Turbine That Can Power A Small Town

1 message

María del Mar Cintrón Alvarado <mcintron@energia.pr.gov> Mon, Nov 27, 2017 at 8:03 AM
To: Zugeily Colón Del Valle <zcolon@energia.pr.gov>

Para registrar y circular

---------- Forwarded message ---------
From: RICARDO E MELENDEZ RIVERA <ricardo.melendez@claropr.com>
Date: Sun, Nov 26, 2017 at 6:42 AM
Subject: Desk-Sized Turbine That Can Power A Small Town
To: María del Mar Cintrón Alvarado <mcintron@energia.pr.gov>, RICARDO E MELENDEZ RIVERA <ricardo.melendez@claropr.com>

To work, carbon dioxide is kept under high heat and extreme pressure. Given these conditions, the carbon dioxide goes into a physical state somewhere in the middle of gas and liquid. The turbine then harnesses the energy, transferring half of the heat to become electricity.
https://futurism.com/meet-desk-sized-turbine-can-power-small-town

Enviado desde mi LG de Claro

------ Original message------
From: María del Mar Cintrón Alvarado
Date: Tue, Nov 21, 2017 11:07
To: RICARDO E MELENDEZ RIVERA;
Cc:
Subject: Re: DC Microgrids and the Virtues of Local Electricity

RECEIPT
CEPR-IN-2017-0002
In re: Energy Commission investigation regarding the state of Puerto Rico electric system after Hurricane María
Subject: Comments on the implementation of regulatory actions to facilitate the task of restoring electric service and encourage the deployment of new technologies

The Puerto Rico Energy Commission has received the comments sent by you regarding the Case No. CEPR-IN-2017-0002.

Cordially.

Lcda. María del Mar Cintrón Alvarado
Secretaria
Comisión de Energía de Puerto Rico
Tel: (787) 523- 0270

On Thu, Nov 16, 2017 at 1:31 PM, RICARDO E MELENDEZ RIVERA <ricardo.melendez@claropr.com> wrote:

> Today, locally produced DC power (say, from photovoltaic panels) is typically converted to AC using inverters. Much of the time, though, the power supply in the end user's equipment just converts the AC fed to it back to DC.
>
> With the decreasing cost of electricity generated by photovoltaics and wind turbines, DC microgrids may be the most efficacious way to provide electrical energy to those who have none. Just as cellphone use in the developing world exploded without the prior installation of landlines, DC microgrids could leapfrog over the traditional system of centralized AC

generation. The market for microgrids in the developing world could be huge, and the benefits they would bring to what are now grossly underserved regions are monumental.

Clearly, DC microgrids hold extraordinary promise for a wide variety of situations. Why then are they still so few and far between?

Some of the blame, at least in developed countries, can be placed on antiquated building codes that make it difficult to set up the infrastructure needed for generating and distributing DC power locally, perhaps within a single building. And even if property owners can overcome this hurdle, they will still struggle to find advice on how to construct such a system.

One of the few resources now available is the EMerge Alliance, an organization of more than 100 member companies interested in fostering the development of DC microgrids for commercial buildings. Alliance members are working to speed the adoption of this approach to improving energy efficiency, in part by setting relevant standards.

The EMerge standard for occupied spaces specifies that power be distributed at 24 volts DC, with current limited to about 4 amperes on each circuit. This combination is considered intrinsically safe with respect to shock and fire hazards, allowing electricians to install relatively simple wiring (without grounding or metal junction boxes, for example) and still meet the United States' National Electrical Code.

The EMerge Alliance is also promoting a standard for data and telecom centers. It calls for DC to be created and distributed at 380 V, which saves energy by eliminating the AC-to-DC conversions in each individual piece of electronic equipment plugged into the building's power grid.

Setting technical standards for DC microgrids, while challenging in its own way, is not the only problem by far. Another barrier comes from the regulatory environment that people or companies face when they want to share the power they generate, even if they just want to send it to others in their immediate vicinity.

Distributing power from rooftop solar panels to several apartments in one building, for example, might be very easy from a technical standpoint, but someone interested in doing that must navigate through some rocky legal shoals. Would selling power to those apartment dwellers violate the monopoly granted to the local electric utility? What if you need to supplement the power you're providing by drawing some energy from the AC grid and converting it to DC? Would your purchase of electricity from the utility then be considered a wholesale transaction (which in the United States would be governed by federal law rather than by the rules of a state utility commission)?

Such questions are hard to answer, and it will surely take a long while yet for federal and state authorities to sort out the many legal sticking points that DC microgrids raise. The same is true for other countries, each of which will face struggles of their own developing public policies that can accommodate these unconventional grids. But it's important to do that if we want to move forward.

For more than a century, AC power grids have provided the foundation for industrialized societies. The adoption of AC allowed voltages to be shifted using simple transformers, allowing electricity to be carried over long distances even with the earliest systems. Edison's competing DC approach wouldn't have permitted that. And because electricity was initially used mostly to power induction motors and incandescent lights, AC served well.

Things are different now. For one, we have solid-state DC-to-DC power converters with efficiencies that are already about 95 percent. (When we begin to use the new wide-bandgap semiconductors in this equipment, efficiencies should rise even further.) So there is no longer any worry about how to shift DC voltage levels or carry voltage over long distances. Indeed, high-voltage DC transmission lines are often used to link separate AC grids, in part because they obviate the need for intergrid synchronization.

Another fundamental change that has come about since Tesla and Edison's day involves the kinds of things we plug into our outlets. Most of the loads now are essentially DC, so supplying them from a DC source would simplify their power circuitry and save energy overall.

These developments make you wonder why DC hasn't replaced AC entirely for power grids big and small. In addition to providing energy savings, such a move would mean that it would no longer be necessary for electronic-equipment manufacturers to accommodate the different AC voltage and frequency standards found around the world.

The prime reason AC continues to reign supreme is just that it would be enormously difficult to replace it entirely with DC equipment. So we continue to use it, even though the original justification for doing so no longer exists. This situation is all too common. We no longer have to worry about typewriter hammers sticking together, for example, yet we still use QWERTY keyboards, which are even older than our AC power grids.

But sometimes a shift to new technologies is inevitable, even when the transition promises to be expensive or otherwise disruptive. And for power grids, we have the luxury of being able to start small. So it's high time for the world to embrace DC microgrids, an old-yet-new model for providing people with electricity.

"It really was a fierce battle between Thomas Edison, who advocated his system of DC technology, and Westinghouse and his partner Nikola Tesla who were advocating AC," Reed explained. "The disadvantage Edison really had with DC back then was he had no way of controlling the current on the DC cables. As he began to deliver DC to longer and longer distances, as he got to beyond a mile (1.6 km) or more, currents got so large that it wasn't safe. The cables had to become so large that it wasn't economical. So in his system he needed a power plant about every mile to feed this DC network."

This problem has now been solved. We can safely control the currents in DC delivery lines. Suddenly, converting AC to DC for long distance transportation opened up new possibilities.

voanews.com/a/can-ac-and-dc-power-systems-integrate/3292427.

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Lcda. María del Mar Cintrón Alvarado
Secretaria
Comisión de Energía de Puerto Rico
Tel: (787) 523- 0270

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The Microgrid Revolution:
Business Strategies for Next Generation Electricity

IEEE San Diego Section Life Member Meeting/Luncheon

Mahesh P. Bhave, PhD. LEED AP

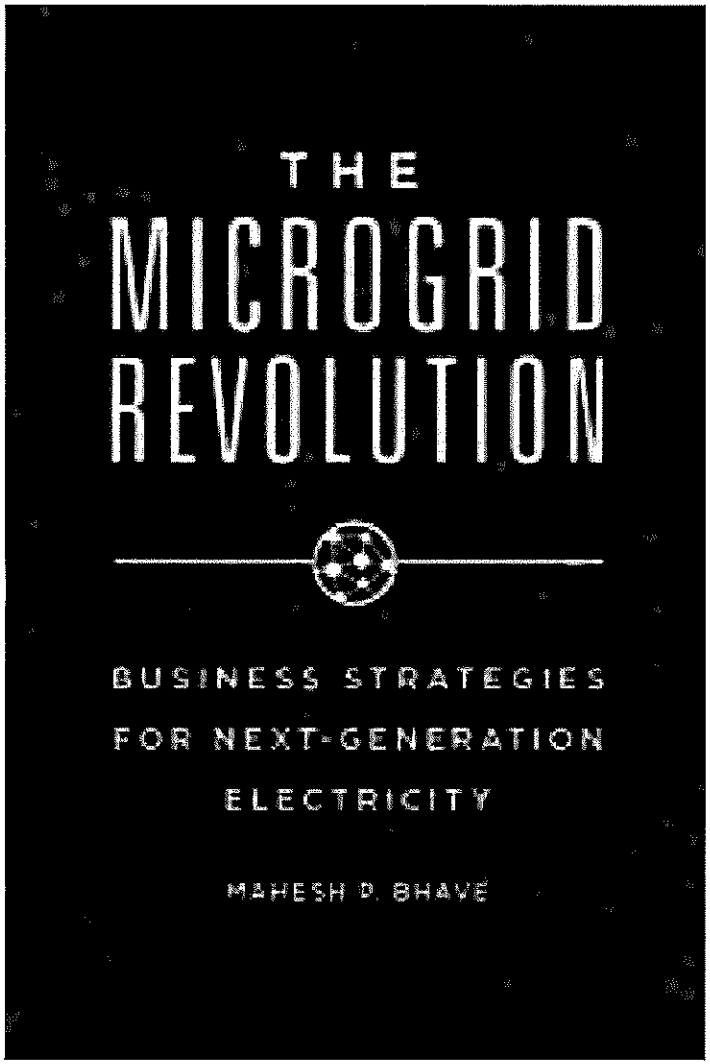
June 26, 2017, 11 am

maheshbhave@gmail.com

Tel. 619 847 2777 mobile

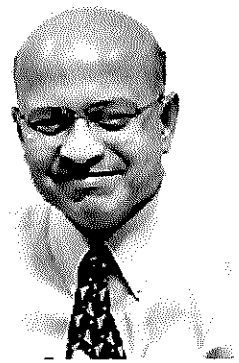
Overview of the presentation

1. State of the electricity industry
2. State of microgrids development
3. What does this mean?



Praeger imprint, October 2016

Amazon https://www.amazon.com/Microgrid-Revolution-Strategies-Next-Generation-Electricity/dp/144083315X



About the author

Mahesh P. Bhave is a chemical engineer from Indian Institute of Technology (IIT), New Delhi, and has a masters and PhD from Maxwell School, Syracuse University. He was faculty at CUNY, Baruch College, NY before working in corporate strategy and new business development at Citizens Utilities, Sprint, Hughes Network Systems, and start-ups. Until December 2016, he was visiting professor, strategy, at Indian Institute of Management (IIM), Kozhikode, where he completed his book. He lives in San Diego, CA.

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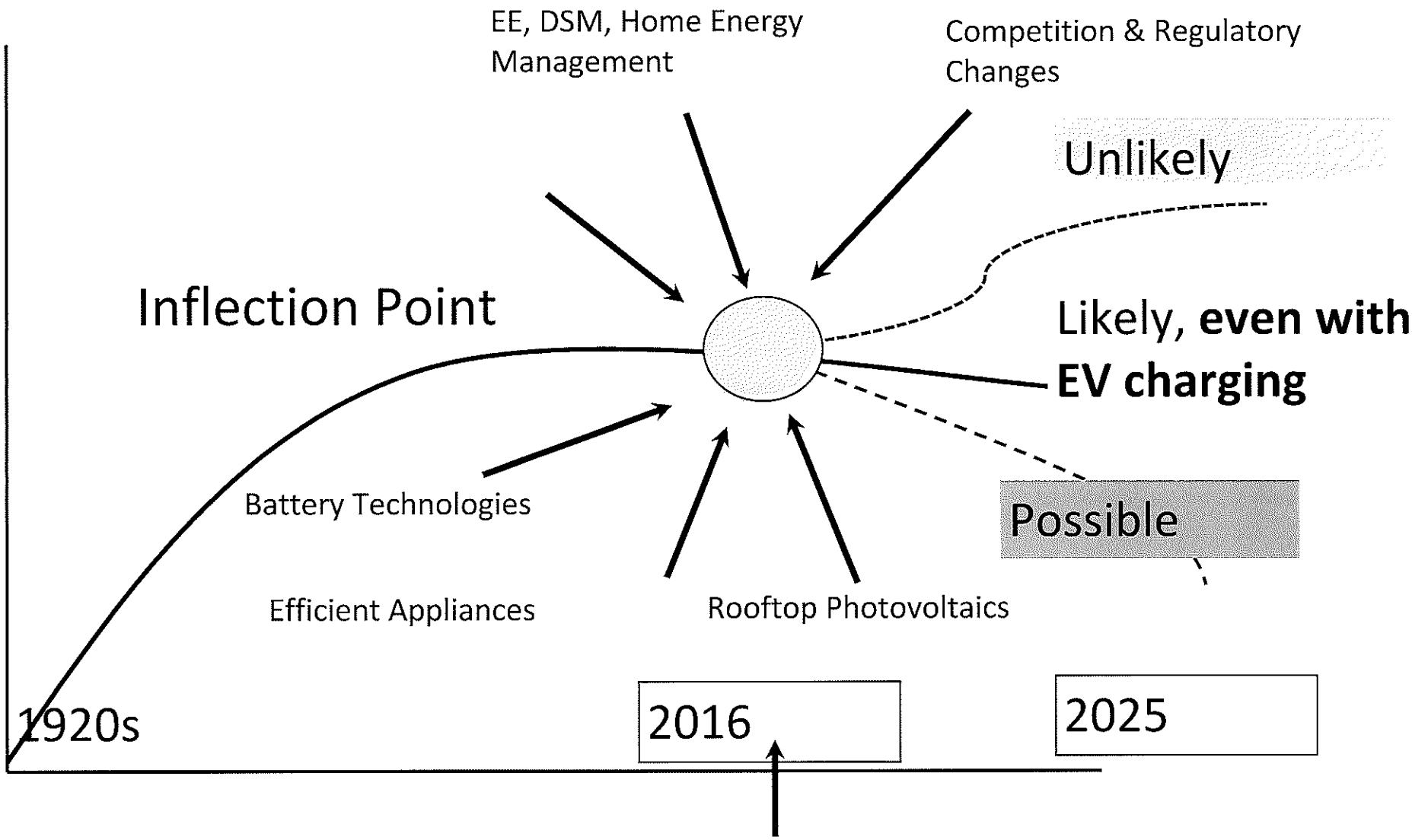
1. State of the electricity industry

Context: Industry at inflection point

(peak use in 2007)



Industry structure obsolete - Basis of historical market design dead

- **Barriers to entry have fallen;** we are all in the electricity business
- **Economies of scale do not matter;** unit costs independent of size
- **Traditional industry boundaries breached** - electricity? IT? Internet? *EPB in Chattanooga, TN, an electric utility also in the ISP business*

Industry structure obsolete - Implications

- Traditional regulations also dead - *rate of return*, *stranded cost* recovery, *public interest definition*, ….
- Competition, market forces define next generation "electricity"
- *"Local generation, local consumption, local autonomy"* - why do we need the network?
- "Grid" usurped by the electricity industry!
- "Grid" dead? Mostly a local area electricity network

"Electricity LAN" called "Off grid" solutions

Dear Electric Company CEO: Merry Xmas

"Your bankers never told you this, the ratings agency hasn't downgraded your bonds and you'll never convince your board of directors. So, let's add really stockholder- friendly advice.

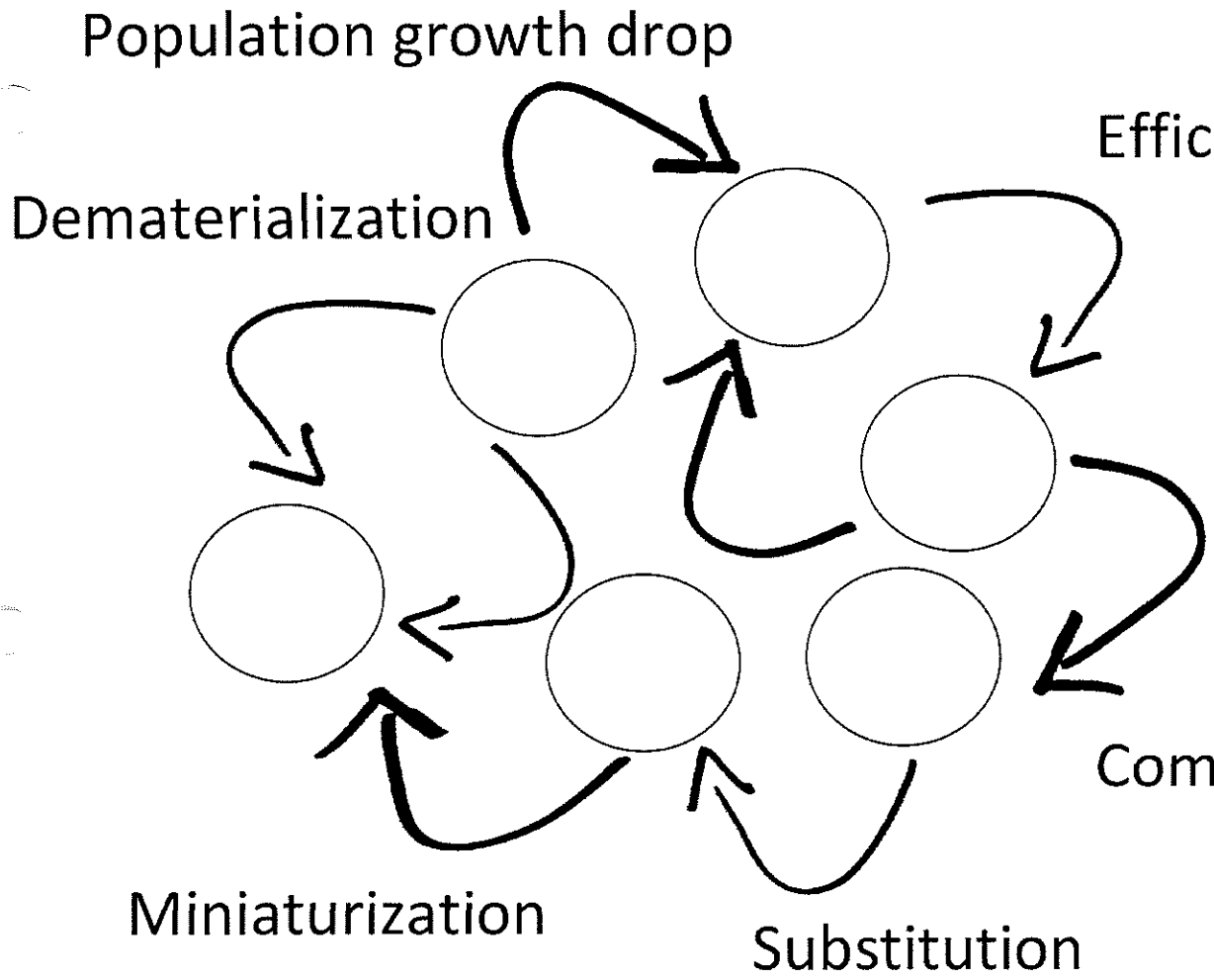
Sell the company now for top dollar. …. Right now, yield starved investors, infrastructure funds and utilities are looking for "earnings accretive" growth-by-acquisition…

Sell now while your business still looks attractive *and low interest rates make deals look good."*

Leonard Hyman & William Tilles, Dec 22, 2015

http://oilprice.com/Energy/Energy-General/Dear-Electric-Company-CEO-Merry-Xmas-and-Cut-the-Dividend.html

Forces gutting demand, revenue

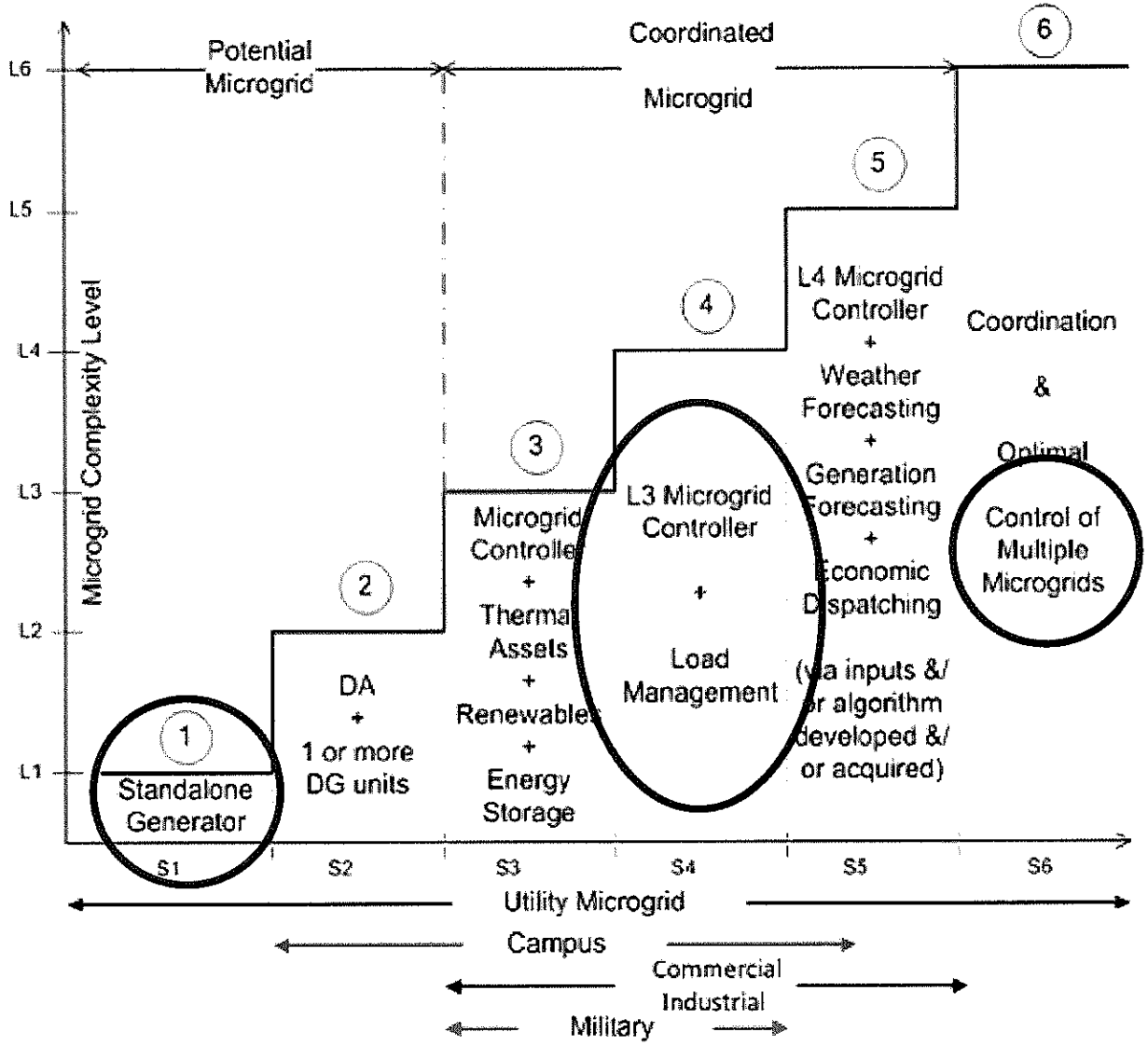


⇒ **What should the new strategy be?**

Loss of demand, revenue
Melting industry boundaries

2. State of microgrids development

Microgrids levels



Credit: S&C Electric

Microgrids: Are They Economical?

What's the cost, $/kWh of microgrid electricity? For a ~1 MW microgrid? Compared to grid pricing at the location?

Until December 2014, it appears, ***no one knew!***

We decided to model IIM K's academic hill, and a homeowners' association in San Diego, California

CASE STUDY
MICROGRID

S&C ELECTRIC COMPANY
Excellence Through Innovation

S&C Builds Ameren a Microgrid To Study Distribution Use Cases

S&C Featured Solution: EPC

Location: Champaign, Illinois

Customer Challenge

Ameren Illinois, a regulated electricity-delivery company whose parent Ameren Corporation serves 2.4 million electricity customers, was interested in building a microgrid with two nested microgrids at its Technology Applications Center near the University of Illinois campus to support the center and a 1-MW

"S&C was instrumental in helping Ameren pave the way for the industry in microgrid research, use cases, and understanding how to apply microgrids on the distribution level."

—Richard J. Mark, Chairman and President, Ameren Illinois

S&C Completes Ameren Microgrid Project near University of Illinois Urbana-Champaign

CHICAGO, May 23, 2017 – S&C Electric Company, a smart grid leader shaping the future of power delivery announced today that it has provided the intelligent automation and control systems for Ameren Corporation's microgrid facility in Champaign, Illinois. Located at Ameren's Technology Applications Center (TAC) near the University of Illinois campus, the Ameren microgrid provides multiple sources of distributed generation - solar, wind, natural gas and battery storage - as well as advanced automation to support the TAC and a 1 MW residential load.

The Ameren microgrid can produce up to 1,475 kilowatts, enough to power more than 190 homes. The leased generation assets located on site include:

- Northern Power Systems Wind Turbine – 100 kilowatts
- Yingli Solar Array – 125 kilowatts
- Caterpillar Natural Gas Generator – 1,000 kilowatts
- S&C Electric Company Battery Storage – 250 kilowatts

"Our focus on building a next generation energy delivery system has enabled Illinois to emerge as a national leader in smart grid innovation," said Richard J. Mark, Chairman and President of Ameren Illinois. "As the technologies we are testing at this microgrid facility become more accessible in the future, our customers will be able to count on Ameren Illinois to help them safely install and cost-

Interworking microgrids

MICROGRID KNOWLEDGE

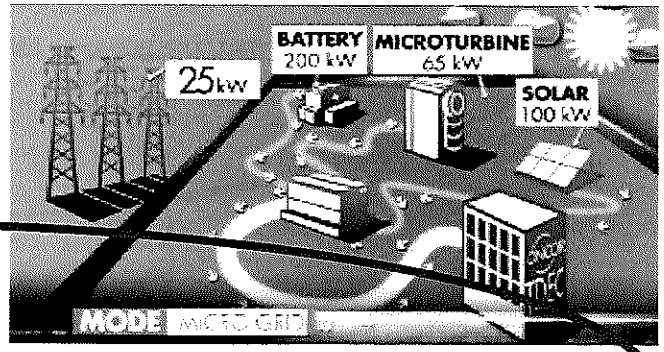
Markets & Policy | Players | Microgrids | Infrastructure | Distributed Energy | Res

The Oncor Microgrid: What Makes it Like No Other

April 7, 2015 By Elisa Wood | Leave a Comment

0 SHARES

Details are finally out about the Oncor microgrid, a project of the Texas utility, S&C Electric and Schneider Electric that has created industry buzz because of its sophistication. Today the companies lifted the veil off the completed project near Lancaster, Texas.



The new microgrid isn't particularly large (1.25 MW), but oh what's inside. Not one microgrid exactly, but four working together (or apart), offering a first-of-a kind automation that hints at the distributed grid to come.

FEATURE

Oncor microgrid gives a peek into the future of distributed energy

Municipalities as electric utilities

Schneider Electric and Duke Energy Renewables Agree to Deliver Two Advanced Microgrids for Montgomery County, Maryland

-- Increases resiliency and sustainability at Public Safety HQ and Correctional Facility

-- Incorporates solar and high-efficiency combined heat and power into off-grid operation

-- Delivered via unique Microgrid-as-a-Service model eliminating up-front costs

Modeling and optimization: Needed

Contents lists available at ScienceDirect

Energy Policy

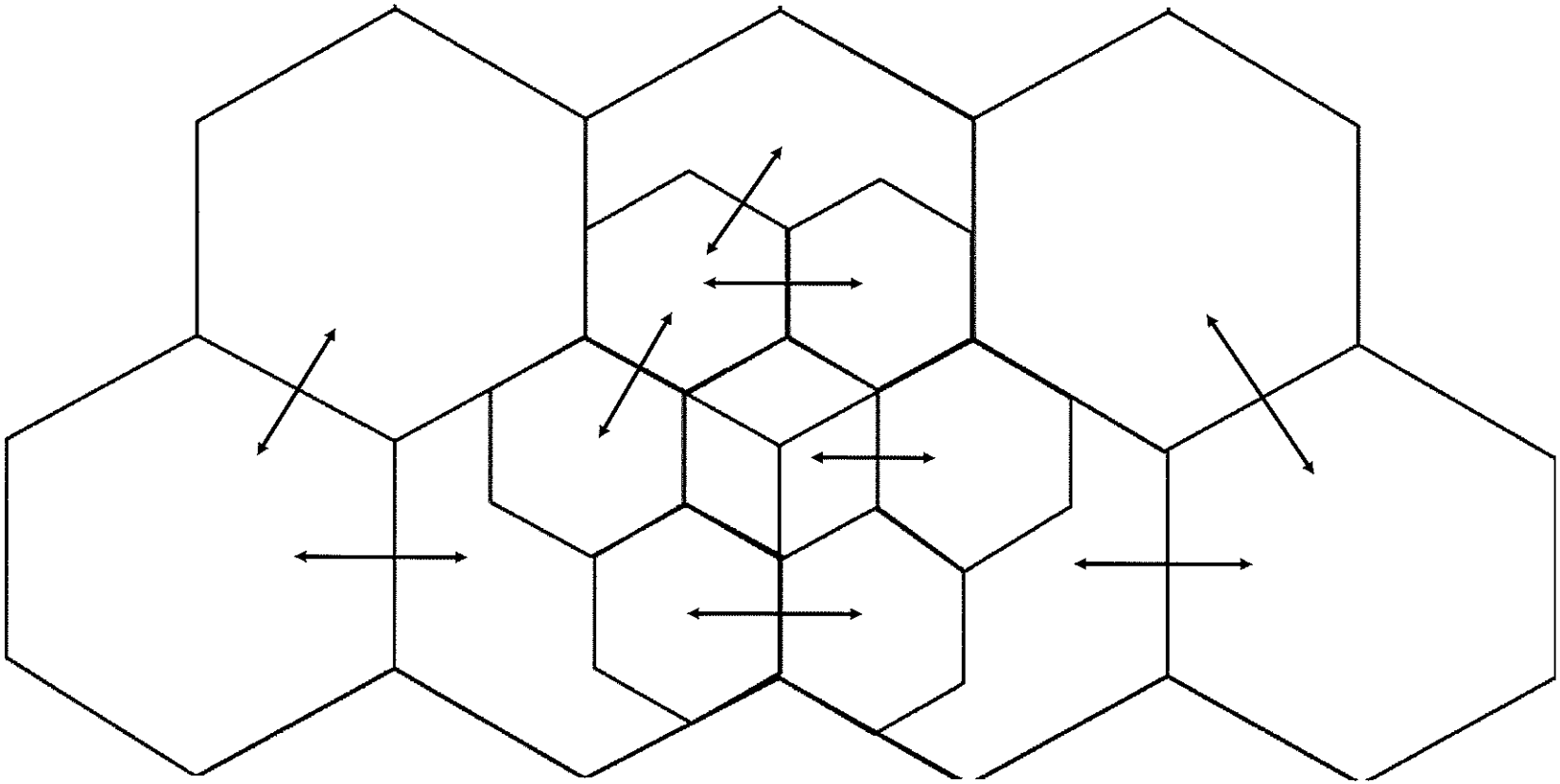
journal homepage: www.elsevier.com/locate/enpol

Evaluating business models for microgrids: Interactions of technology and policy

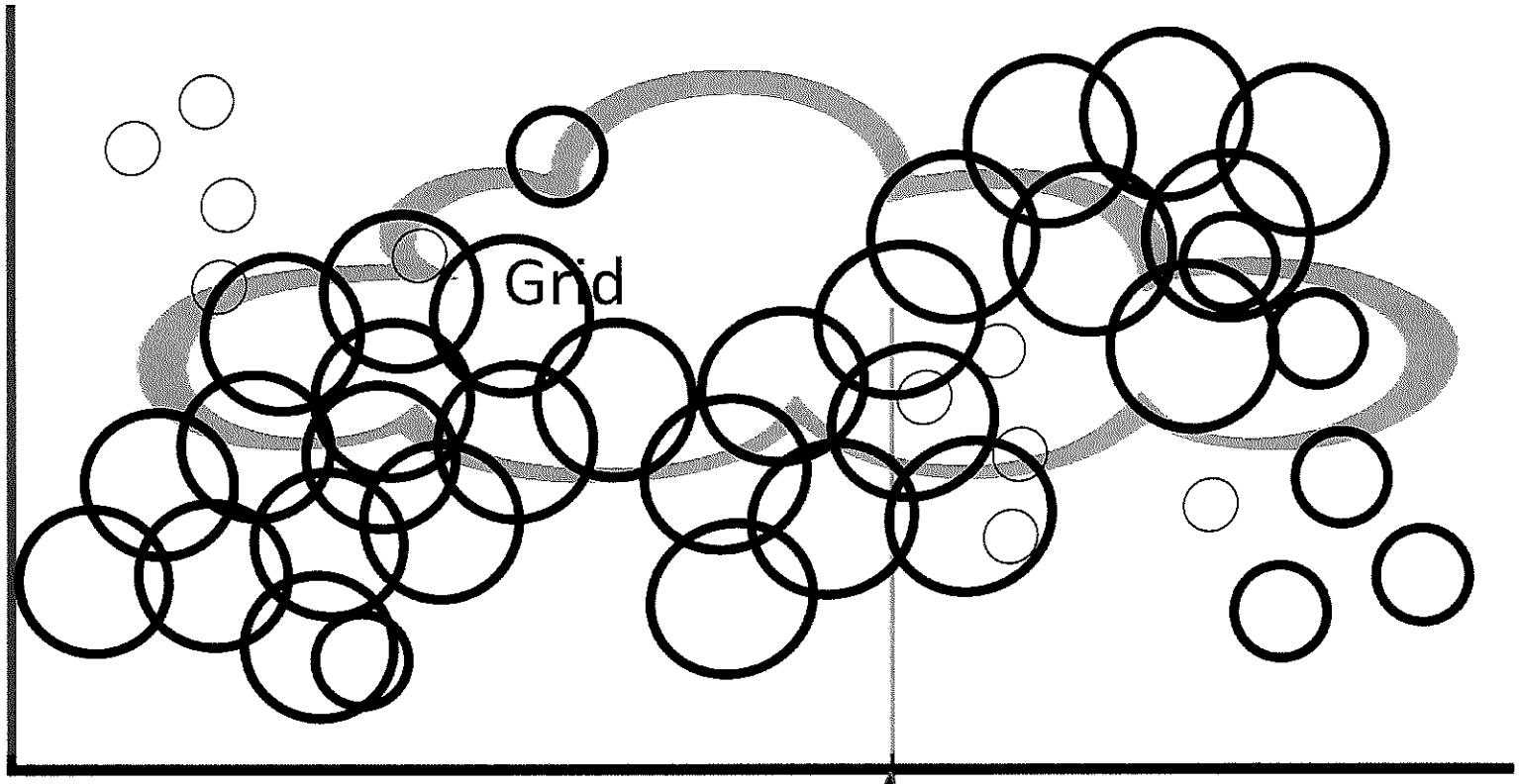
Ryan Hanna[a,b,*], Mohamed Ghonima[a], Jan Kleissl[a,b,c], George Tynan[b,c], David G. Victor[b,c,d,e]

Even more, inter-microgrid interworking, and techno-financial analysis

Federation of microgrids



Rural Reach: Grid topology evolution



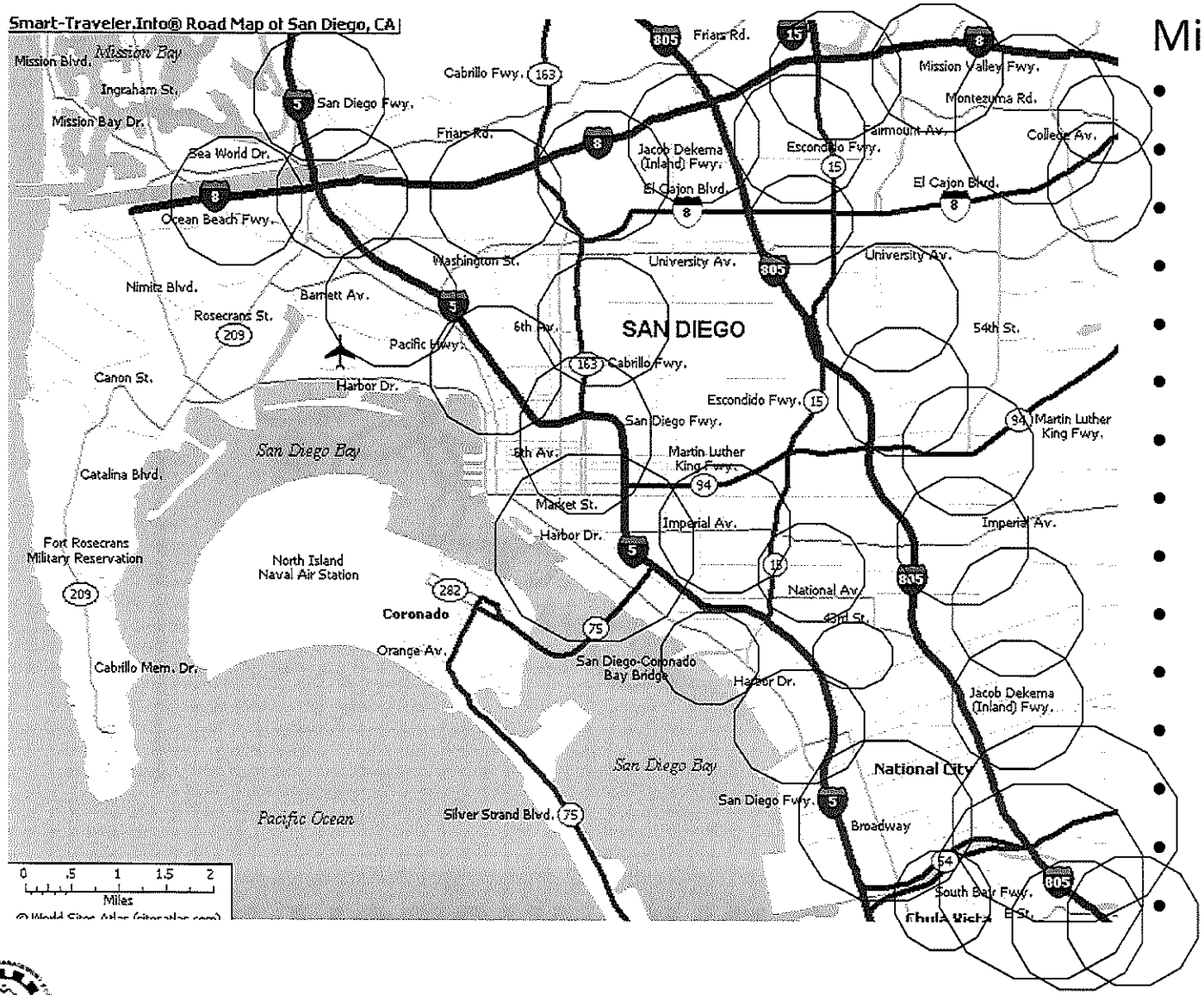
= Solar Home System

= Microgrid

Electricity everywhere

Point of Grid Infeasibility

Federation of Microgrids – Infrastructure of the future

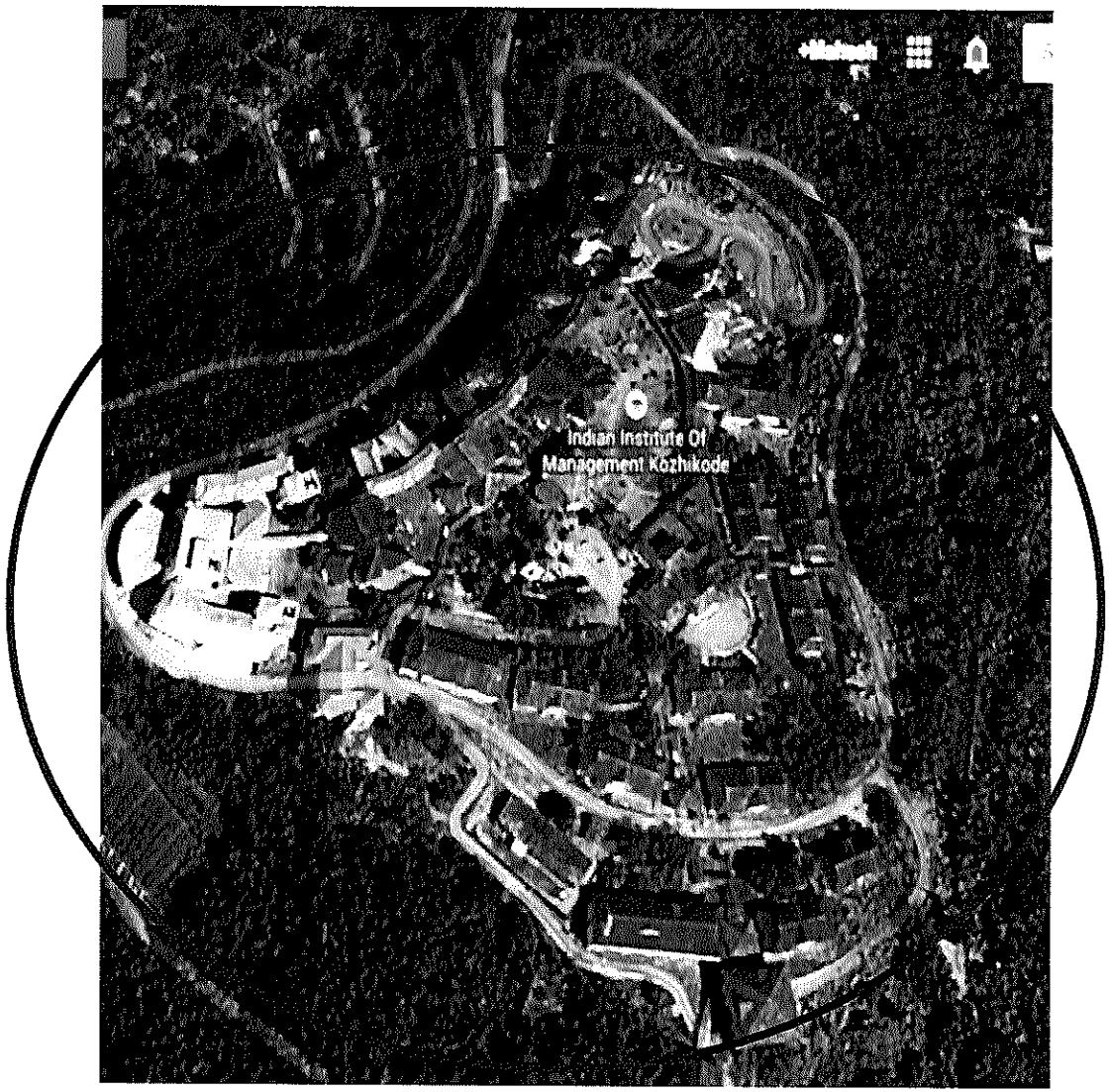


Microgrid Sites include:

- schools,
- colleges,
- universities,
- military,
- data centers,
- hospitals,
- remote islands,
- municipalities,
- hotels,
- malls,
- grocery stores,
- office buildings,
- housing societies,
- factories,
- homeowners' association, …

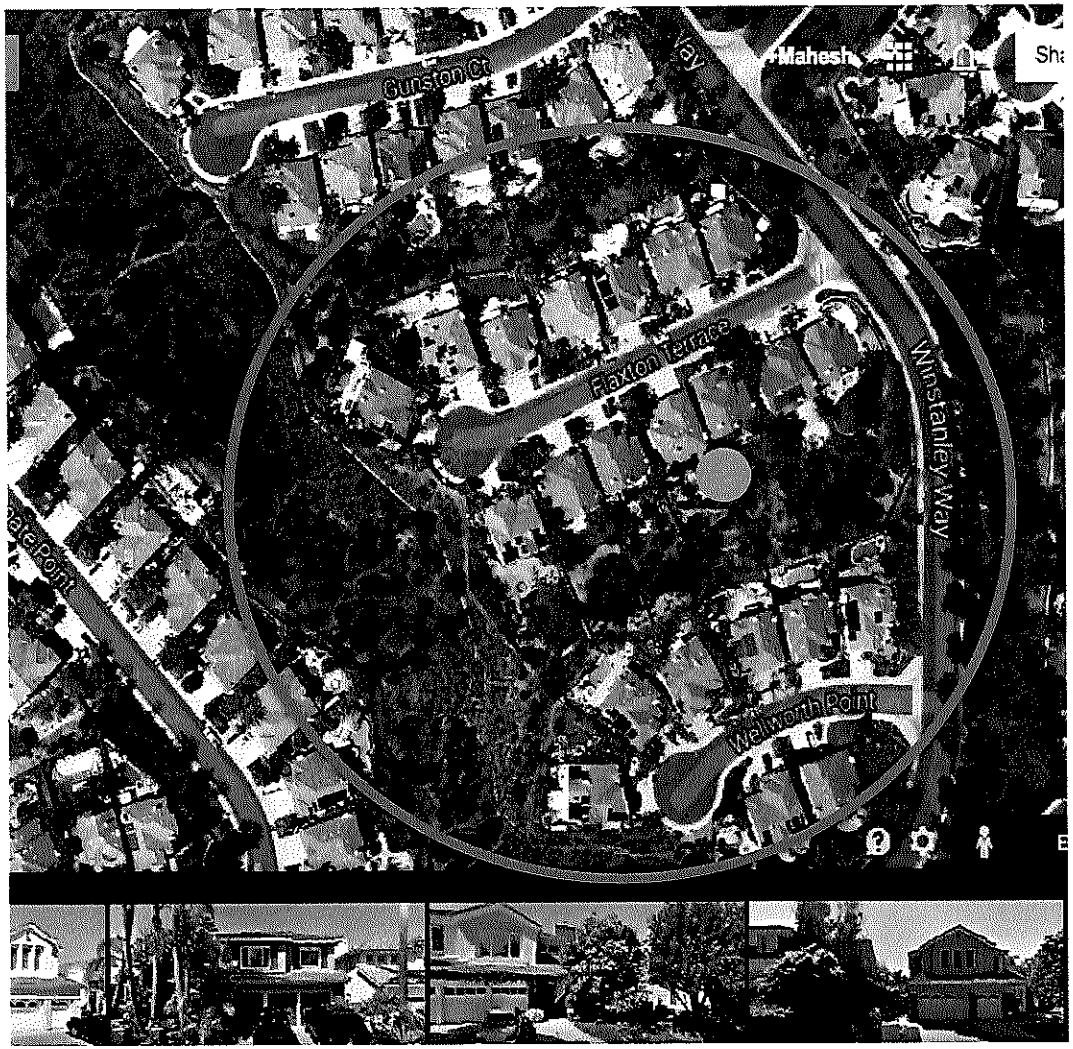
IIM K campus – aerial view

Academic hill: IIM Kozhikode, India



~ 1 MW system

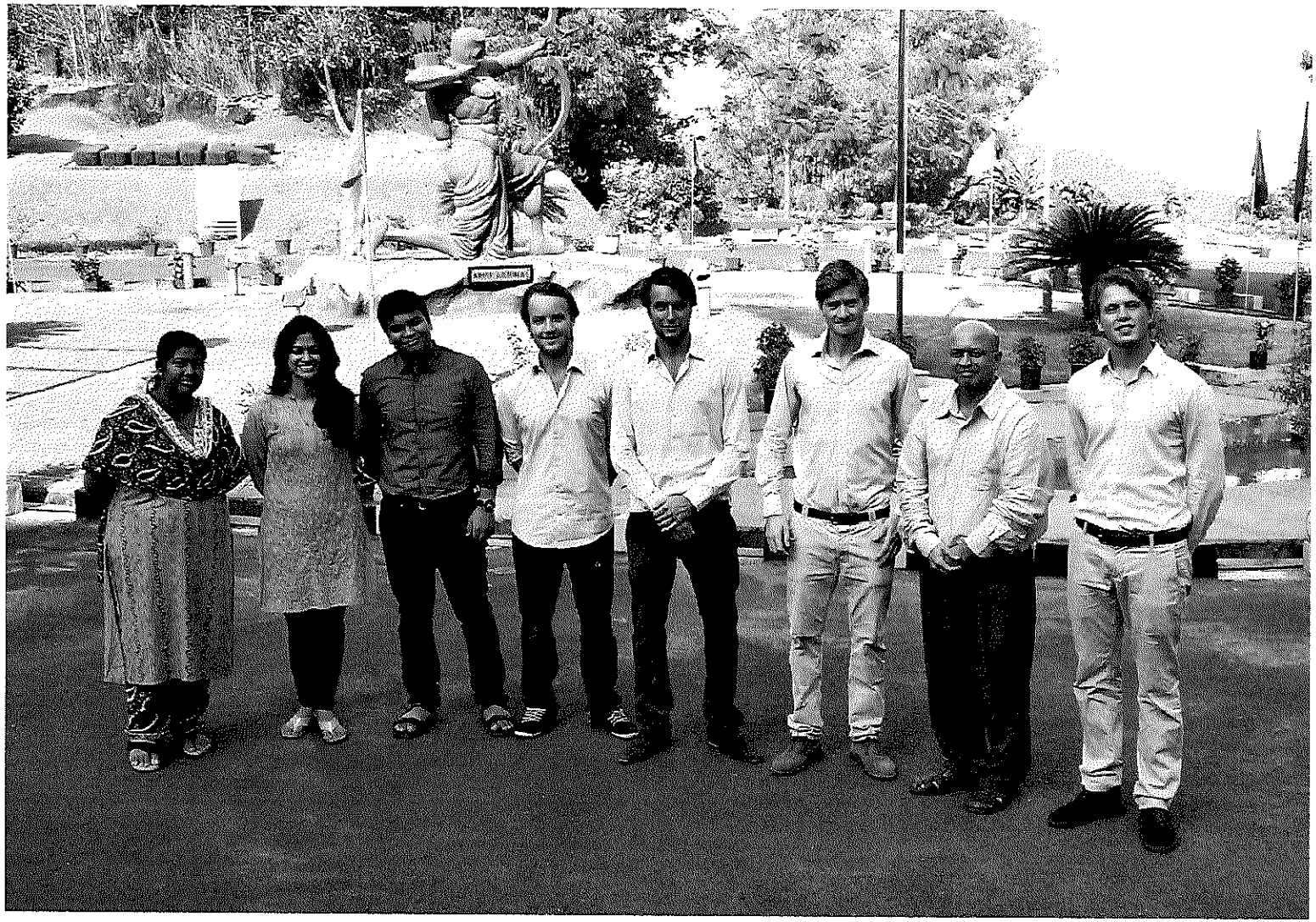
Homeowners' association as microgrid



Can a microgrid of ~ 20 homes be viable? **Of 120 homes? Also, ~ 1 MW**

Most homes have enough roof for a 5 kW solar system each

The IIM K microgrid modeling team



TU Delft engineering students and IIM K MBA students with engineering and finance training

3. What does this mean?

***Opportunity costs* of microgrid delays**

***Municipalization* or Community Microgrids**

Entry into ISP business

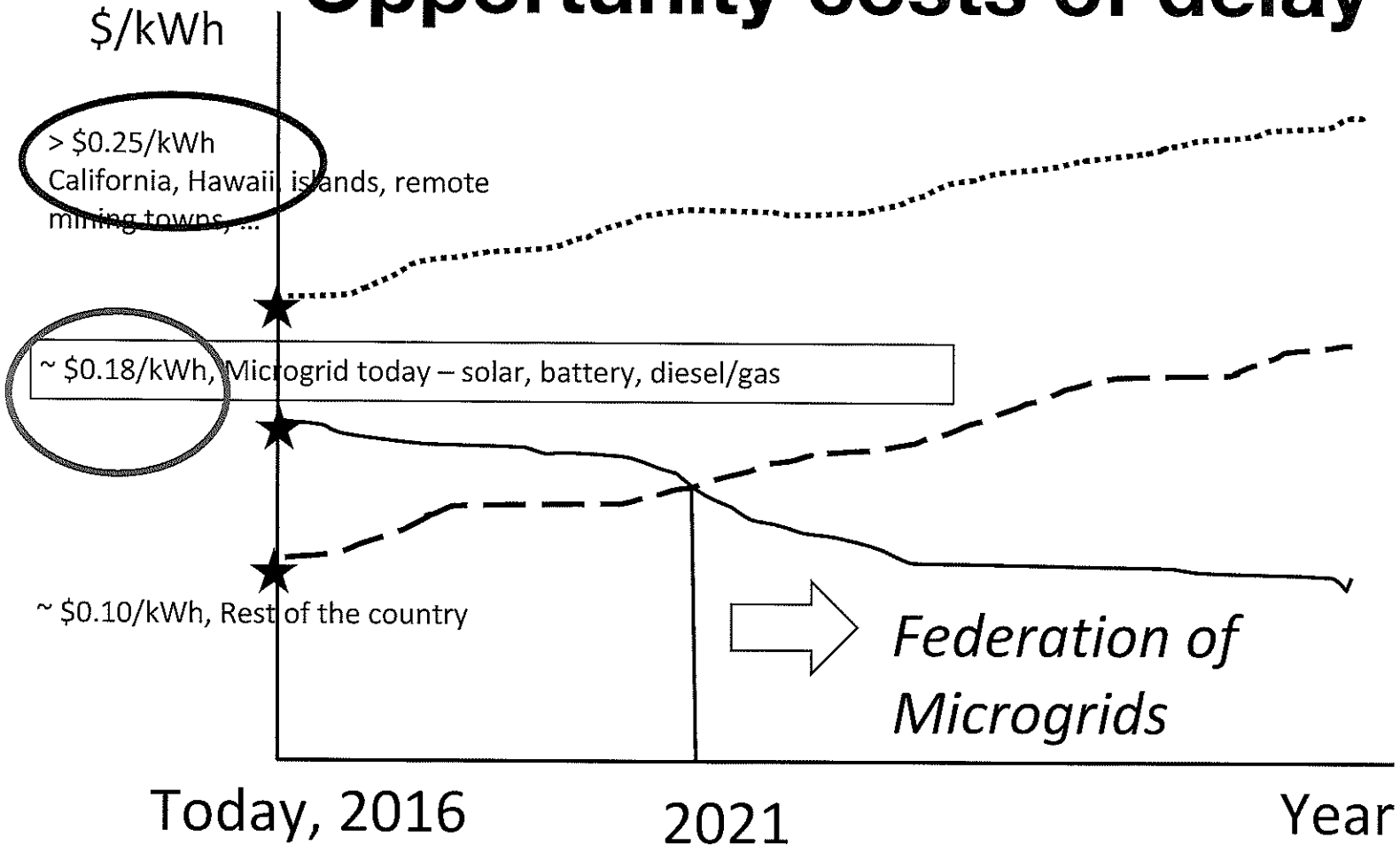
***Federation of Microgrids* or microgrids as clusters**

Miniaturize:* *Market Capitalization of microgrid operators

Fractionate:* *Market Capitalization from break-up

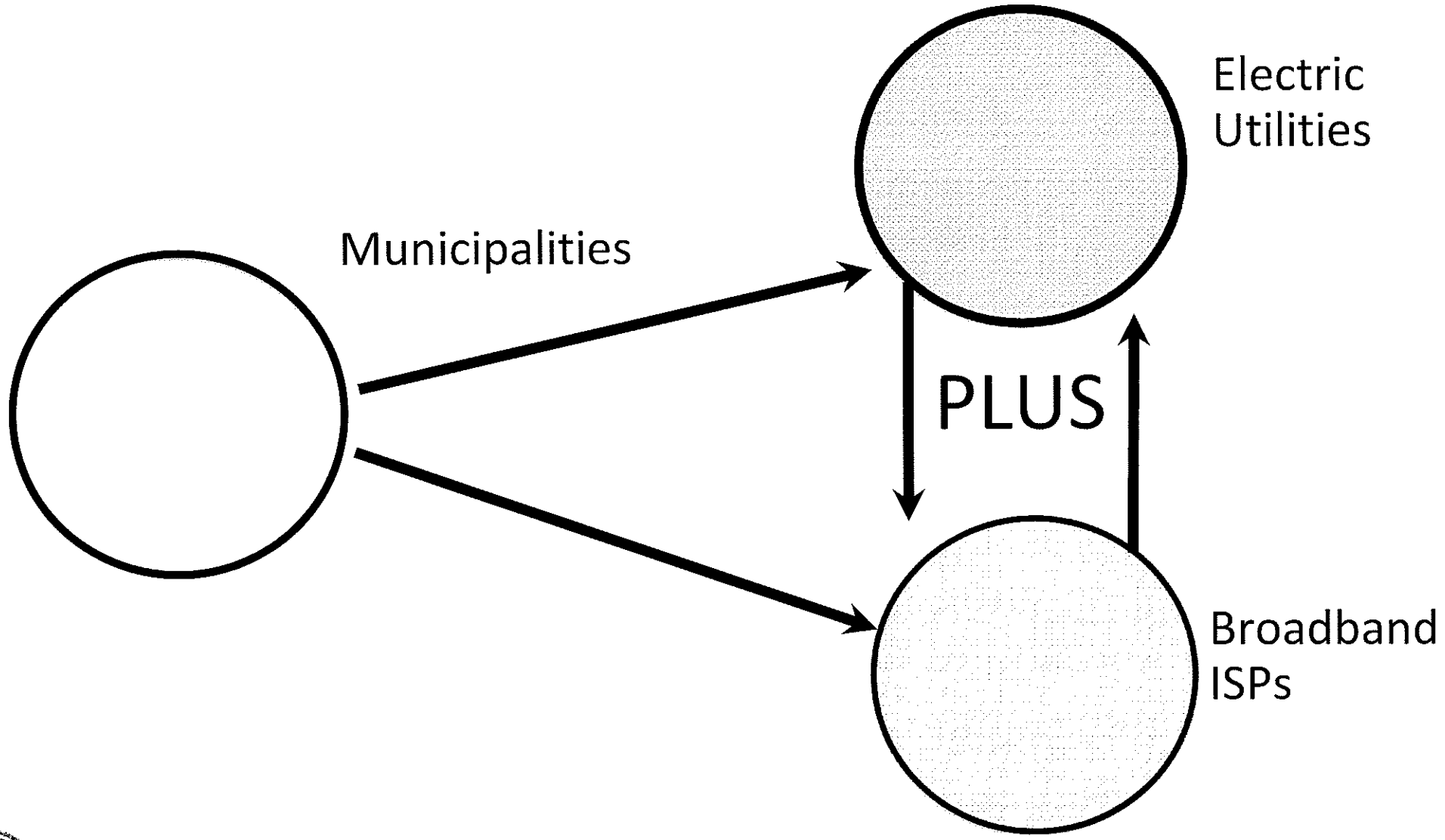
Strategies for Next Generation Electricity

What microgrid economics means: Opportunity costs of delay

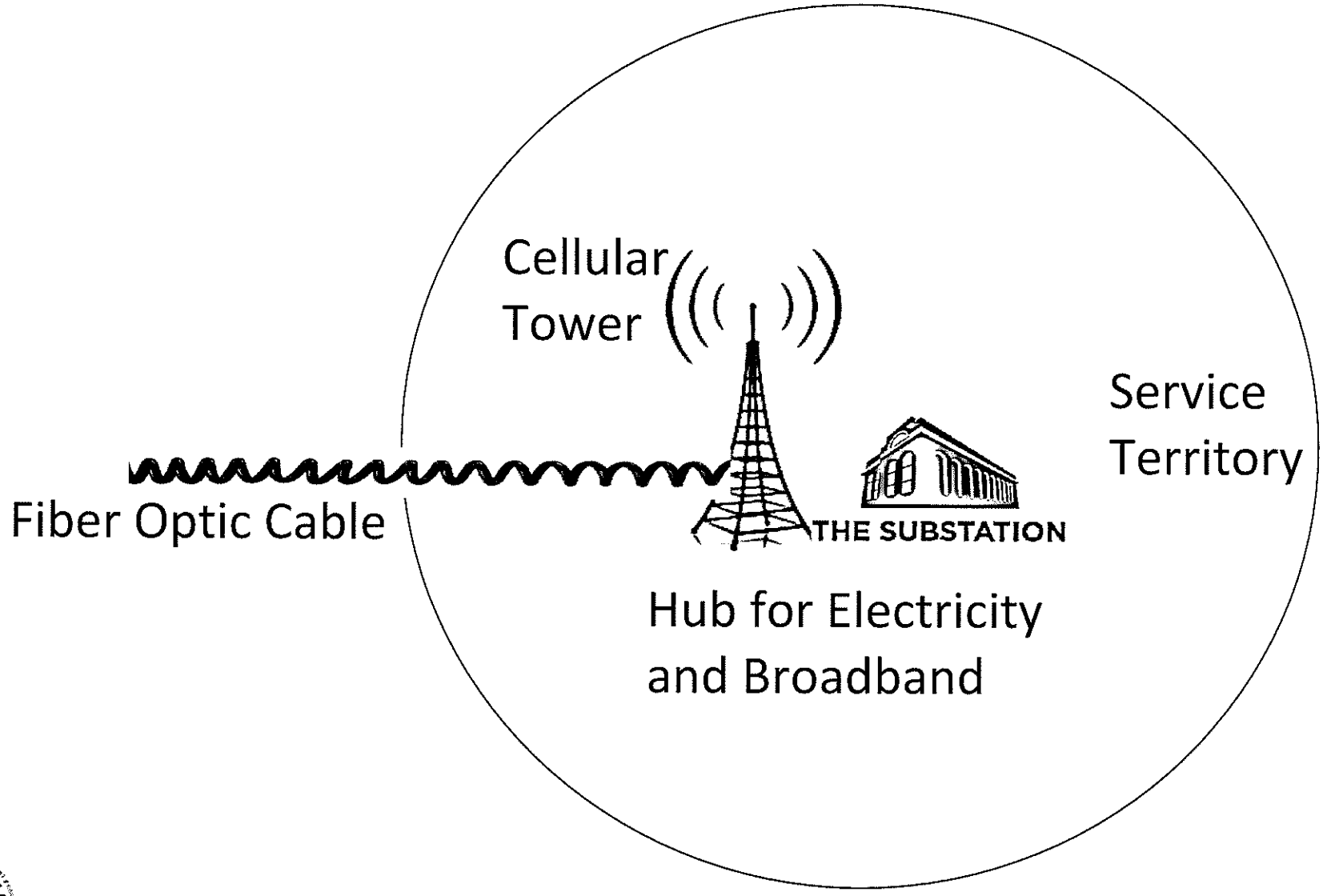


Strategy: Identify, lock up sites *today*. **Opportunity costs of delay**

Competition:
Municipalities in Electricity, ISP Business



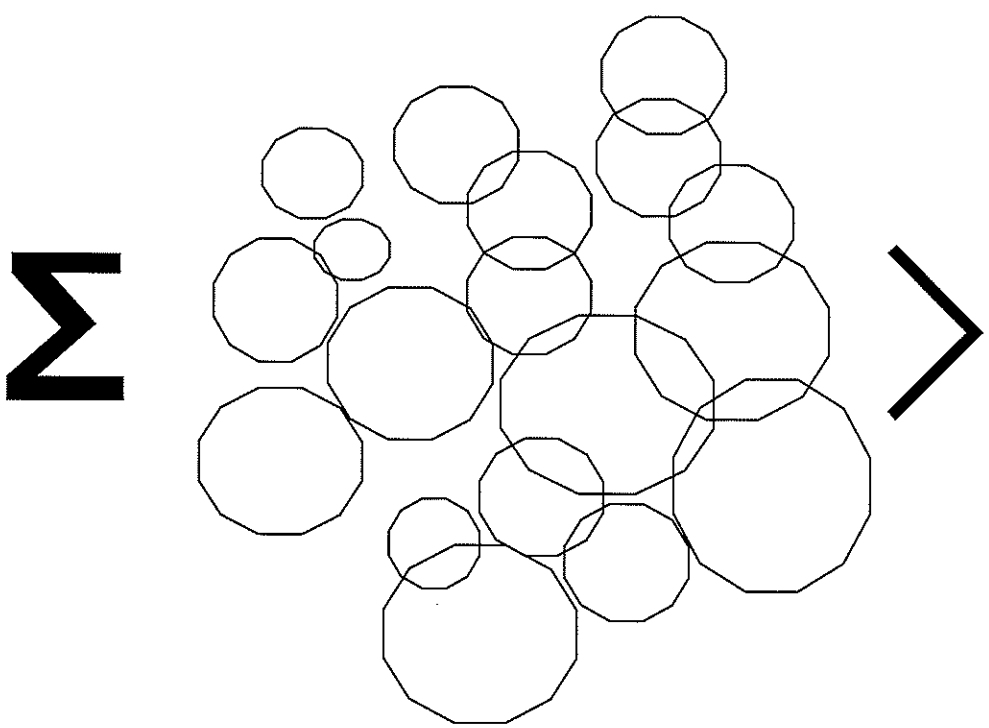
Offset revenue loss: Enter ISP business
Substation + cellular tower as hub

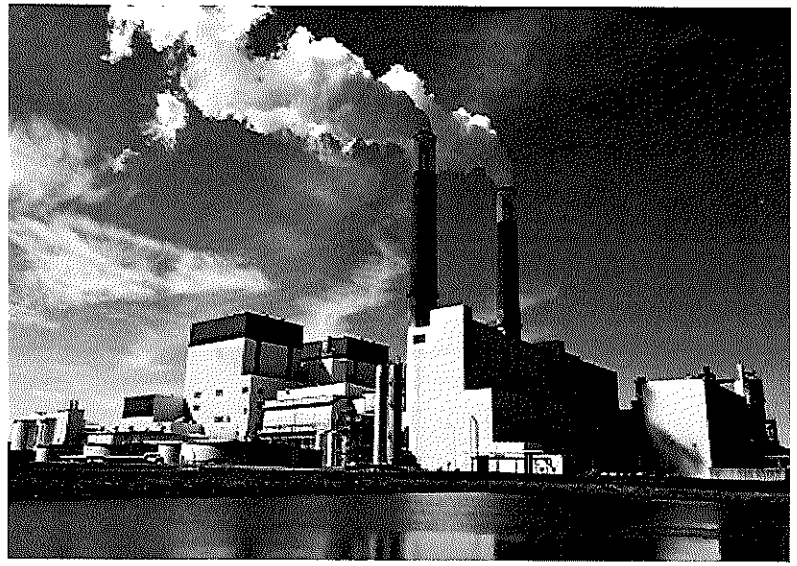


Enter broadband: revenue, margins rise

Revenue Margin Cost	Revenue Margin Cost	Revenue Margin Cost
Today's regulated business	Regulated with renewables	Electricity plus ISP business
Economies of scale; large scale generation for unit cost reduction. Prices expected to rise due to rising fuel costs, carbon pricing, demand drop, and grid defection	*Economies of numbers; large numbers for unit cost reduction. Somewhat expensive today, costs likely to fall leading to improved margins*	*Economies of numbers + business expansion by leveraging current assets - rights of way, poles, cabling…*
Upto2020	**2020through2030**	**2015through2040andbeyond**

Miniaturize: Value from microgrids

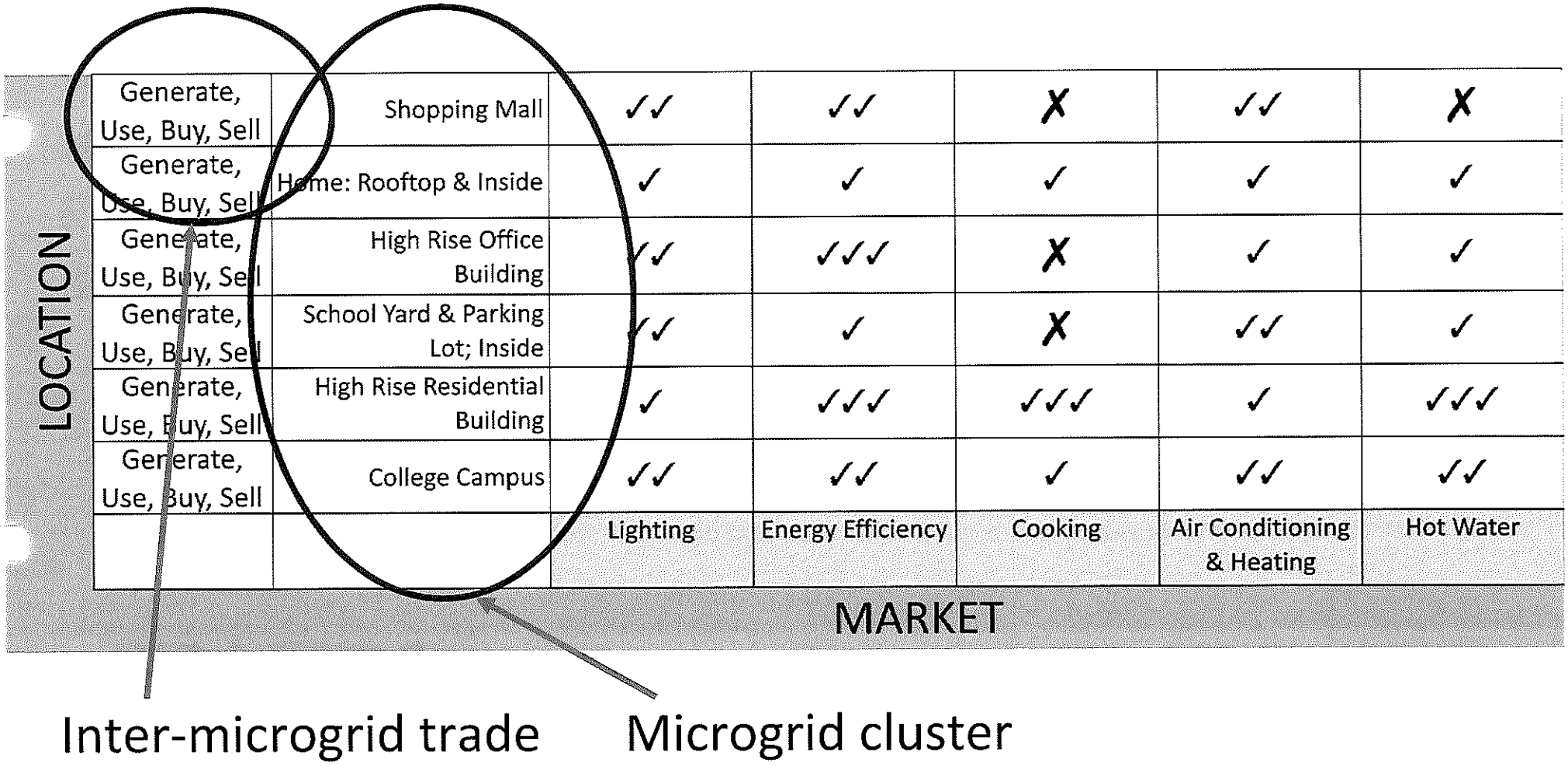




Traditional macrogrid

Hypothesis: For a given service territory and a set of customers, the sum of the value of microgrids exceeds the value of the corresponding macrogrid

Business development, entrepreneurial opportunities, *or competition*

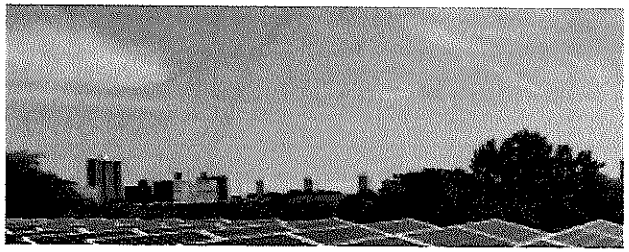


LOCATION		Lighting	Energy Efficiency	Cooking	Air Conditioning & Heating	Hot Water
Generate, Use, Buy, Sell	Shopping Mall	✓✓	✓✓	✗	✓✓	✗
Generate, Use, Buy, Sell	Home: Rooftop & Inside	✓	✓	✓	✓	✓
Generate, Use, Buy, Sell	High Rise Office Building	✓✓	✓✓✓	✗	✓	✓
Generate, Use, Buy, Sell	School Yard & Parking Lot; Inside	✓✓	✓	✗	✓✓	✓
Generate, Use, Buy, Sell	High Rise Residential Building	✓	✓✓✓	✓✓✓	✓	✓✓✓
Generate, Use, Buy, Sell	College Campus	✓✓	✓✓	✓	✓✓	✓✓
		MARKET				

Inter-microgrid trade

Microgrid cluster

ComEd Looks to Build Microgrid Clusters to Support the 'Community of the Future'

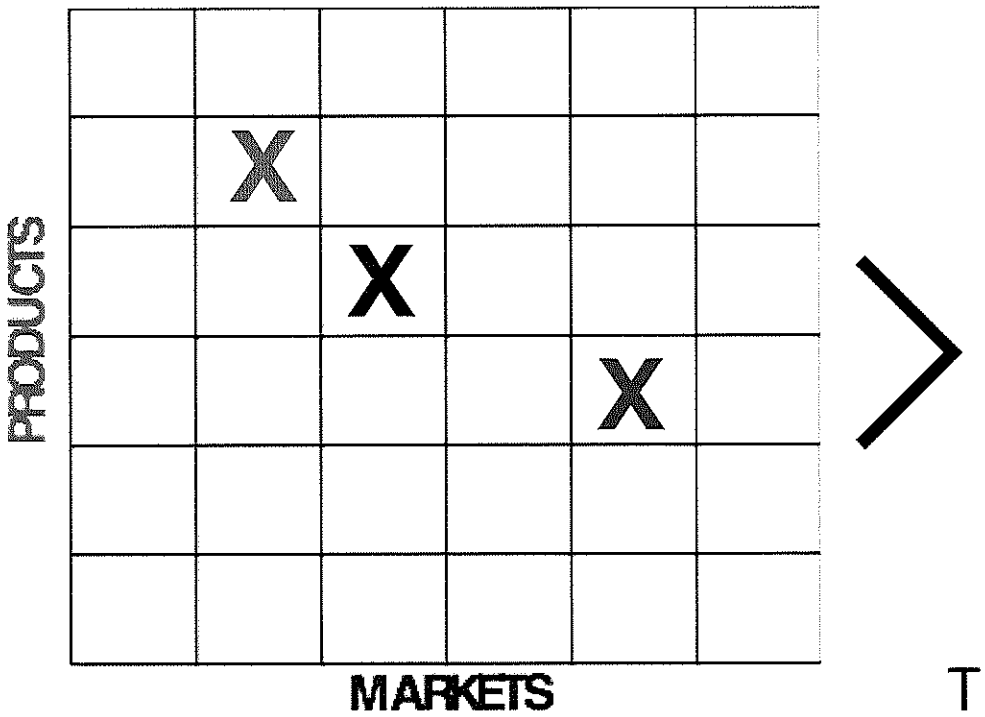


ComEd plans for microgrids, smart streetlights and more.

by Katherine Tweed
March 18, 2016

The micro-controller was developed by Argonne National Laboratory and S&C Electric. **The goal is for the microgrid to look like a self-contained node to the grid operators, but for *the two microgrids to be able to communicate with each other to balance load and generation,* especially in island mode.**

Value from Fractionation



Traditional macrogrid

Hypothesis: The sum of the value of "product-markets" exceeds the value of the macrogrid for the same set of customers

LaaS, CaaS, IaaS, ... "X" as a Service

INSIGHTS Blog Buildings Thinking Outside the Bulb: Innovative Companies Switch on L

Lumens
Cooking As A Service
Irrigation

Thinking Outside the Bulb: Innovative Companies Switch on Lumens as a Service

May 23, 2017 | By David Lab

RENEWABLE ENERGY WORLD

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Cooking Microgrids: The Case for Application-specific Power Networks

June 9, 2017

By Mahesh Bhave

from IIT Delh
University's I
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Forested pathway - Lumens as a Service

Select strategies

- *Miniaturize*
- *Fractionate*
- *Divest,* including Municipalize
- Consolidate
- a) Privatize b) Public Ownership

- *Auction*
- *Diversify*

- **Extend geographically with specialization - *Linearly Extensive***
- Grow intensively in region

- Organize differently – cooperatives, franchises, Public-Private-Partnerships

Why save the grid? Let it die, …

Jacobson et al - Abstract, PNAS article

This study addresses the **greatest concern** ***facing the large-scale integration of wind, water, and solar (WWS) into a power grid:*** the high cost of avoiding load loss caused by WWS variability and uncertainty. It uses ***a new grid integration model*** and finds low-cost, no-load-loss, nonunique solutions to this problem on electrification of all US energy sectors *[highlights mine]*

Q. Is **renewables integration into the grid** the problem?
Q. Is **new grid integration model** the need?

In my view, no.

for "Creative Destruction" is the norm

- Pagers
- CDs
- CRT monitors
- Magnetic tapes

...

- Class 5 switches
- Circuit switched networks
- CableTV
- RJ15

Rotating hard drives

"The fundamental impulse that sets and keeps the capitalist engine in motion comes from the new consumers' goods, the new methods of production or transportation, the new markets, the new forms of industrial organization that capitalist enterprise creates,... ***incessantly revolutionizes the economic structure from within, incessantly destroying the old one, incessantly creating a new one. This process of Creative Destruction is the essential fact about capitalism."***

- Joseph A. Schumpeter, "Capitalism, Socialism, Democracy"

Little sacred about the grid, its regulatory underpinnings.
Subject to time, chance, technical, and business obsolescence too

What is the new public interest?

- *Reliability*
- *Resiliency*
- *Security*
- *Affordability*
- *Cost savings …*

So yesterday! Should be a given

* **Entrepreneurial new entry, reduced barriers**
* **Competition**
* **Widespread ownership**
* **Economies of numbers**

Recent Debate: Original study

PNAS PNAS

Low-cost solution to the grid reliability problem with 100% penetration of intermittent wind, water, and solar for all purposes

Mark Z. Jacobson[a,1], Mark A. Delucchi[b], Mary A. Cameron[a], and Bethany A. Frew[a]

[a]Department of Civil and Environmental Engineering, Stanford University, Stanford, CA 94305; and [b]Institute of Transportation Studies, University of California, Berkeley, CA 94720

Edited by Stephen Polasky, University of Minnesota, St. Paul, MN, and approved November 2, 2015 (received for review May 26, 2015)

This study addresses the greatest concern facing the large-scale integration of wind, water, and solar (WWS) into a power grid: the high cost of avoiding load loss caused by WWS variability and uncertainty. It uses a new grid integration model and finds low-cost, no-load-loss, nonunique solutions to this problem on electrification of all US energy sectors (electricity, transportation, heating/cooling, and industry) while accounting for wind and solar time series data from a 3D global weather model that simulates extreme events and competition among wind turbines for available kinetic energy. Solutions are obtained by prioritizing storage for heat (in soil and water); cold (in ice and water); and electricity (in phase-change materials, pumped hydro, hydropower, and hydrogen), and using demand response. No natural gas, biofuels, nuclear power, or stationary batteries are needed. The resulting 2050–2055 US electricity social cost for a full system is much less than for fossil fuels. These results hold for many conditions, suggesting that low-cost, reliable 100% WWS systems should work many places worldwide.

energy security | climate change | grid stability | renewable energy | energy cost

accounting for modest improvements in end-use energy efficiency (22). Annual loads in each sector are next separated into cooling and heating loads that can be met with thermal energy storage (TES), loads that can be met with hydrogen production and storage, flexible loads that can be met with DR, and inflexible loads (Table 1).

Most (50–95%) air conditioning and refrigeration and most (85–95%) air heating and water heating are coupled with TES (Table 1). Cooling coupled with storage is tied to chilled water (sensible-heat) TES (STES) and ice production and melting [phase-change material (PCM)-ice] (*SI Appendix*, Table S1). All building air- and water-heating coupled with storage uses underground TES (UTES) in soil. UTES storage is patterned after the seasonal and short-term district heating UTES system at the Drake Landing Community, Canada (23). The fluid (e.g., glycol solution) that heats water that heats the soil and rocks is itself heated by sunlight or excess electricity.

Overall, 85% of the transportation load and 70% of the loads for industrial high temperature, chemical, and electrical processes are assumed to be flexible or produced from H_2 (Table 1).

Six types of storage are treated (*SI Appendix*, Table S1): three for air and water heating/cooling (STES, UTES, and PCM-ice); two for electric power generation [pumped hydropower storage (PHS) and phase-change materials coupled with concentrated solar power plants (PCM-CSP)]; and one for transport or high-temperature processes (hydrogen). Hydropower (with

http://www.pnas.org/content/112/49/15060.full.pdf?sid=fde192c3-8cd6-45c7-b82b-6ead62c341e9

Challenge, and rebuttal

PNAS PNAS

Evaluation of a proposal for reliable low-cost grid power with 100% wind, water, and solar

Christopher T. M. Clack[a,b,1,2], Staffan A. Qvist[c], Jay Apt[d,e], Morgan Bazilian[f], Adam R. Brandt[g], Ken Caldeira[h], Steven J. Davis[i], Victor Diakov[j], Mark A. Handschy[b,k], Paul D. H. Hines[l], Paulina Jaramillo[d], Daniel M. Kammen[m,n,o], Jane C. S. Long[p,3], M. Granger Morgan[d], Adam Reed[q], Varun Sivaram[r], James Sweeney[s,t], George R. Tynan[u], David G. Victor[v,w], John P. Weyant[s,t], and Jay F. Whitacre[d]

[a]Earth System Research Laboratory, National Oceanic and Atmospheric Administration, Boulder, CO 80305; [b]Cooperative Institute for Research in Environmental Sciences, University of Colorado, Boulder, CO 80305; [c]Department of Physics and Astronomy, Uppsala University, 752 37 Uppsala, Sweden; [d]Department of Engineering and Public Policy, Carnegie Mellon University, Pittsburgh, PA 15213; [e]Tepper School of Business, Carnegie Mellon University, Pittsburgh, PA 15213; [f]Center for Global Energy Policy, Columbia University, New York, NY 10027; [g]Department of Energy Resources Engineering, Stanford University, Stanford, CA 94305; [h]Department of Global Ecology, Carnegie Institution for Science, Stanford, CA 94305; [i]Department of Earth System Science, University of California, Irvine, CA 92697; [j]Omni Optimum, Evergreen, CO 80437; [k]Enduring Energy, LLC, Boulder, CO 80303; [l]Electrical Engineering and Complex Systems Center, University of Vermont, Burlington, VT 05405; [m]Energy and Resources Group, University of California, Berkeley, CA 94720; [n]Goldman School of Public Policy, University of California, Berkeley, CA 94720; [o]Renewable and Appropriate Energy Laboratory, University of California, Berkeley, CA 94720-3050; [p]Lawrence Livermore National Laboratory, Livermore, CA 94550; [q]Renewable and Sustainable Energy Institute, University of Colorado, Boulder, CO 80305; [r]Council on Foreign Relations, New York, NY 10065; [s]Precourt Energy Efficiency Center, Stanford University, Stanford, CA 94305-4206; [t]Management Science and Engineering Department, Huang Engineering Center, Stanford University, Stanford, CA 94305; [u]Department of Mechanical and Aerospace Engineering, Jacobs School of Engineering, University of California, San Diego, La Jolla, CA 92093; [v]School of Global Policy and Strategy, University of California, San Diego, La Jolla, CA 92093; and [w]Brookings Institution, Washington, DC 20036

http://www.pnas.org/content/early/2017/06/16/1610381114.full.pdf

PNAS

The United States can keep the grid stable at low cost with 100% clean, renewable energy in all sectors despite inaccurate claims

LETTER

Mark Z. Jacobson[a,1], Mark A. Delucchi[b], Mary A. Cameron[a], and Bethany A. Frew[a]

The United States can keep the grid stable at low cost with 100% clean, renewable energy in all sectors despite inaccurate claims http://www.pnas.org/content/early/2017/06/16/1708069114.extract (paid access)

Media coverage of the debate

ENERGY & ENVIRONMENT

Fisticuffs Over the Route to a Clean-Energy Future

Eduardo Porter
ECONOMIC SCENE JUNE 20, 2017

https://www.nytimes.com/2017/06/20/business/energy-environment/renewable-energy-national-academy-matt-jacobson.html?emc=edit_th_20170621&nl=todaysheadlines&nlid=55088538

In Sharp Rebuttal, Scientists Squash Hopes for 100 Percent Renewables

https://www.technologyreview.com/s/608126/in-sharp-rebuttal-scientists-squash-hopes-for-100-percent-renewables/?set=608129

A bitter scientific debate just erupted over the future of America's power grid

https://www.washingtonpost.com/news/energy-environment/wp/2017/06/19/a-bitter-scientific-debate-just-erupted-over-the-future-of-the-u-s-electric-grid/

Agenda lost due to poor debate terms

The pros and the cons *both* assume the grid needs to be saved. Why? Let entrepreneurial and competitive forces dismantle it… and

convert the grid into a federation of complementary microgrids, with widespread ownership, distributed control, minimal regulations, ease of competitive entry, and ease of market based exit. This is old, Schumpeterian "creative destruction."

The right question to ask is: ***By what industry structuring, driven by policy, business, and entrepreneurial forces, will we get an electricity (including transport) industry that is clean?***

No one is addressing this topological, ownership, and technical discussion. **The existing utilities and fossil fuel advocates smile at the ineptitude of the debate terms, for now.**

The compelling case for creating a nation of microgrids

Mahesh Bhave
Wednesday, March 15, 2017 - 1:45am

https://www.greenbiz.com/article/compelling-case-creating-nation-microgrids

"Consider a scenario in which the layout of today's electricity grid is transformed into a cluster of interworking microgrids. This investment could cost an estimated $1 trillion over 10 years if you consider a scenario in which roughly 500 gigawatts of the U.S. generating capacity (roughly half of the total) is transformed into solar panels, batteries, inverters and related technologies at $2 per watt installed. Much of this spending could come from the private sector and, in theory, could create about 1 million well-paying domestic jobs. It also could increase the annual GDP growth rate by up to 0.5 percent."

Thank you!

Additional reading - 1

Feature | Energy | Renewables

Nanogrids, Microgrids, and Big Data: The Future of the Power Grid

Distributed generation and automated transactions will change how we produce and consume electricity

By **ROBERT HEBNER** Posted 31 Mar 2017 | 18:00 GMT

http://spectrum.ieee.org/energy/renewables/nanogrids-microgr

Additional reading - 2

Feature | Energy | Renewables

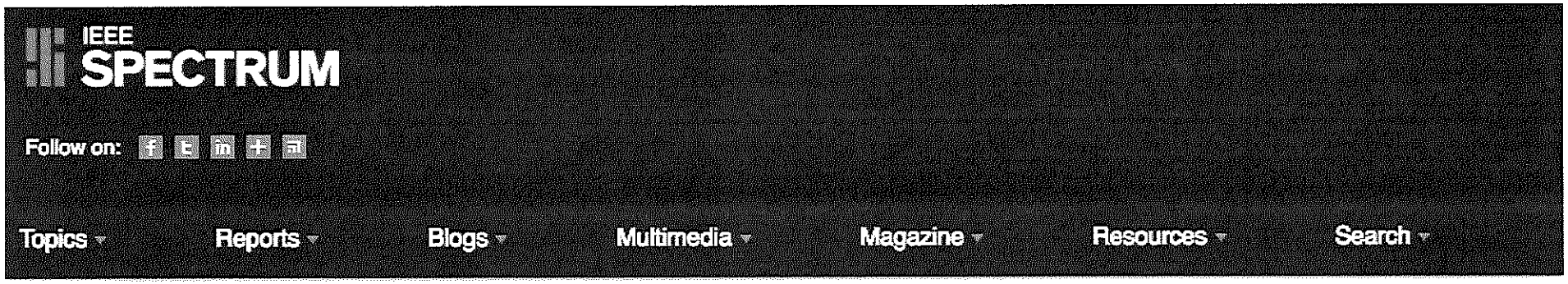
Innovative Direct-Current Microgrids to Solve India's Power Woes

Solar DC microgrids could do for electrification what mobile phones did for telephony

By **ASHOK JHUNJHUNWALA** Posted 31 Jan 2017 | 17:02 GMT

http://spectrum.ieee.org/energy/renewables/innovative-direct-curre

Additional reading - 3



Feature | Green Tech | Buildings

DC Microgrids and the Virtues of Local Electricity

It's time to revisit Thomas Edison's strategy for providing people with electricity

By **RAJENDRA SINGH AND KRISHNA SHENAI**
Posted 6 Feb 2014 | 22:58 GMT

http://spectrum.ieee.org/green-tech/buildings/dc-microgrids-and-th

Supplement: Q&A with microgrid supplier

a) What is the economics of a typical ~ 1 MW microgrid? Would the price per unit be less than the grid prices today? All depends on energy sources. Yes, we have seen price at less than .05/kWh … There is a clear business case now
b) Is any work being done on inter-microgrid connectivity - a cluster of microgrids working synergistically? Yes, ComEd will be the first utility.
c) Who will drive the deployment of microgrids? Utilities? Venues? Homeowners' associations? Anyone - we work with Utilities, C&I users and third parties.
d) Should the utilities NOT drive microgrid deployments, the industry will grow very slowly? Utilities have the most to gain from Microgrids, but others have proven business models too
e) Would microgrids development be driven from outside the US, say China, India, Africa, through the off-grid route? India and China will be slower to take off since financing is more difficult.
f) What might regulators do to accelerate deployment? Allow utilities to own generation.
g) Public interest - what is the new public interest in the age of microgrids? ... Resiliency, Security and Cost Savings.
h) Will NY lead, or California, or Illinois? MA is leading the way.