Smart Grid Pilot Projects

M. Hammersley | Protocol Labs | Oct 2018

Summary

There are thousands of smart grid pilot projects all around the world, having begun largely in the early 2000s. With the introduction of blockchain, and with the grid becoming more unpredictable and decentralized, several use cases are becoming apparent for blockchain. This report points to work that has already been done on Smart Grids -- particularly in the United States and Europe -- as well as to several blockchain projects underway. The space is quickly becoming saturated, with over 120 blockchain companies as of mid 2018.

Introduction

Because the smart grid encompasses so many different technologies, and the interplays between them all can quickly become complicated and unpredictable, it is useful to learn from the lessons of others as they test, separately and together, each of the various elements.

Happily, a number of organizations have arrived at the same conclusion, and have created summaries and reviews of a number of pilot projects, grants, smart-meter roll-outs, and other related efforts both in the United States and around the world. In the United States, the American Recovery and Reinvestment Act of 2009 gave the Department of Energy $4.5 billion in funding [1] for grid modernization purposes. Funds went to programs ranging from under $500,000 for workforce training programs up to several programs of $200 million of federal money (combined with private funding) for demonstration projects.

In Europe, funding and planning efforts are much more decentralized. Data collection efforts performed by the Joint Research Centre of the European Commission have identified (as of 2017) 950 projects with approximately €5 billion of investment in all 28 member states (plus Sweden and Norway) [2].

The Global Smart Grid Federation, a loose collective of organizations around the world dedicated to advancing the Smart Grid, also releases reports pointing to additional pilot projects, as well as reports on microgrids, flexibility, storage, and standards/ interoperability [3].

United States Smart Grid Programs and Projects

The Office of Electricity Delivery and Energy Reliability (within the US Department of Energy) split the $4.5 billion of economic stimulus into three main areas [4]:

● Renewable and Distributed Systems Integration Program (RDSI);
● Smart Grid Demonstration Program (SGDP); and
● Smart Grid Investment Grant Program (SGIG).

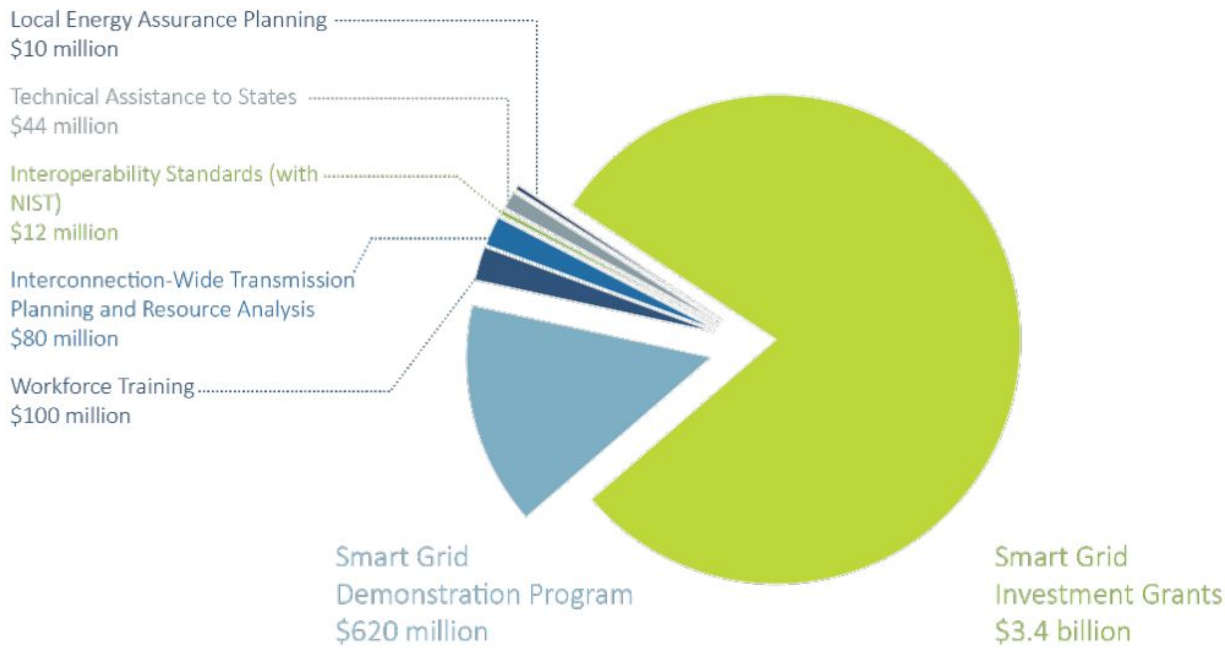

Figure 1. Breakdown of funding from the American Recovery and Reinvestment Act (reproduced from [4], p2).

Renewable and Distributed Systems Integration Program (RDSI)

A report was issued by the Department of Energy in May of 2015 that gave updates on the RDSI and SGDP programs [5]. These are listed individually in tables 1 and 2.

Table 1. List of projects and the key technologies present in those projects (adapted from [5]).

Project	**Key Technologies**
Monongahela Power	microgrid, FLIRS, DER
ATK Launch Systems	DER, storage
Chevron Energy Solutions	microgrid, DER, storage
City of Fort Collins	DER, DR
Consolidated Edison Co of NY	DR
Illinois Institute of Technology	microgrid, DER

San Diego Gas and Electric	microgrid, storage
Hawaii Natural Energy Institute	DER, storage,DR
University of Nevada	DER, DR

Notable is Monongahela, in that it was deemed economically non-viable, and so the project was terminated in Sept 2013. Only two projects -- the IIT microgrid and Con Edison's Demand Response Control Center (DRCC) had positive business cases.

At the time the 2015 progress report [5] was written, two projects didn't have final reports: the Fort Collins and University of Nevada projects. As of this writing (Oct 2018), those final reports had not been uploaded to the smartgrid.gov website. No further progress reports are planned.

More complete summaries of each project are detailed in [5].

Smart Grid Demonstration Program

The Smart Grid Demonstration Program itself was split into two subparts: 16 projects were funded as regional demonstration projects; and another 16 were conceived of specifically as energy storage projects. The first sixteen are tabulated in table 2, and have more complete summaries in the progress report.

Table 2. Projects and Key Technologies for smart grid demonstration projects (adapted from [5]).

Project	**Key Technologies**
Battelle Memorial Institute AEP	20 technologies, including DA, CVR, AMI, storage, DER, DR, commnication
AEP Ohio	AMI, DACR, VVO, TOU pricing
LA Department of Water & Power	CBS, DR, AMI, EV, cybersecurity
Consolidated Edison Co of NY	storage, AMI, DER, DR, HAN, BMS, MDMS, ADMS, communications
Southern California Edison	SCADA, ADMS, storage, DR, EV
National Rural Electric Cooperative Association	AMI, SCADA, MDMS, DR, VVO, CVR, DA, communications
Kansas City Power & Light Co	23 distinct technologies, including AMI, ADMS, DA, DR, HEMP, TOU, DER, storage, DERMS

Center for Commercialization of Electric Technologies	ADMS, storage
Long Island Power Authority	AMI, DA/SA, RTU, DER
SuperPower	DA, SA
Pecan Street Project	AMI, HAN, DER, EV
Boeing Co	cybersecurity
Northeast Utilities Service Co (AMR)	AMR/TOU, IHD, CBS
Oncor Electric Delivery Co	DLR
Northeast Utilities Service Co (Urban Grid Monitoring)	AMR, SCADA, DER
Power Authority of the State of New York	DLR

The 16 storage projects are testing specific battery technologies more than grid integration (with the exception of voltage smoothing and peak shifting); as such, they're not included here, but are listed, along with more complete summaries, in [5].

Smart Grid Investment Grants (SGIG)

The Smart Grid Investment Program funded 99 competitively-selected projects to support the the grid integration and regional demonstrations described previously; to upgrade the transmission systems; and to deploy smart metering, among other projects. It is comprehensively summarized in a 2016 report put out by the Department of Energy [6]. Awards ranged from $150k for job training programs at colleges to a maximum of $200 million; six projects received this larger amount.

The 99 projects were generally categorized as touching on either advanced metering infrastructure (AMI), customer systems (CS), electric distribution systems (EDS), electric transmission systems (ETS), or some combination of the above. Most projects included at least two of the four elements; while 5 touched on all four. Of the 99 projects, 65 included AMI; 66 included CS; 57 included EDS; and 19 included ETS.

Overall, the authors of the report conclude that the following development challenges exist in developing a smart grid:

- Data management and visualization tools for SCADA systems;
- Control algorithms that can quickly respond to the high-volume data streams advanced SCADA systems will be generating;

- Low-cost, high-resolution, low-latency sensors for distribution systems;
- Resilient and adaptive control systems with secure, low-latency communication networks;
- Strong support from both utilities and regulators as new architectures and DER systems develop.

A full list of the 99 projects, as well as links to the project pages, is included at the end of the SGIG report.

Also noteworthy are the topical reports that were written as a result of these studies, which touched on the following subjects:

- Advanced metering infrastructure [7];
- Distribution automation [8];
- Synchrophasor technology [9]; and
- Customer behavior studies [10]

along with several other reports.

European smart grid efforts

As of 2017, the Joint Research Centre of the European Commission has identified 950 projects, with a total of approximately €5 billion of investment, in all 28 member states (plus Sweden and Norway). Approximately two thirds of these are listed on an inventory on their website that allows for rudimentary searching: https://ses.jrc.ec.europa.eu/inventory [12].

As with the United States projects, a given project can fit into multiple categories. The 527 smart grid projects listed are each labeled with at least one of the following categories (the percentage indicates how many of the 527 containing this label):

- Smart Network Management (36%)
- Electric Vehicles and Vehicle2Grid applications (17%)
- Smart Customer and Smart Home (23%)
- Integration of DER (22%)
- Integration of large scale RES (9%)
- Aggregation (Demand Response; VPP) (18%)
- Other (14%)

An additional 73 projects (14%) had no labels; see figure 2 for a more precise count.

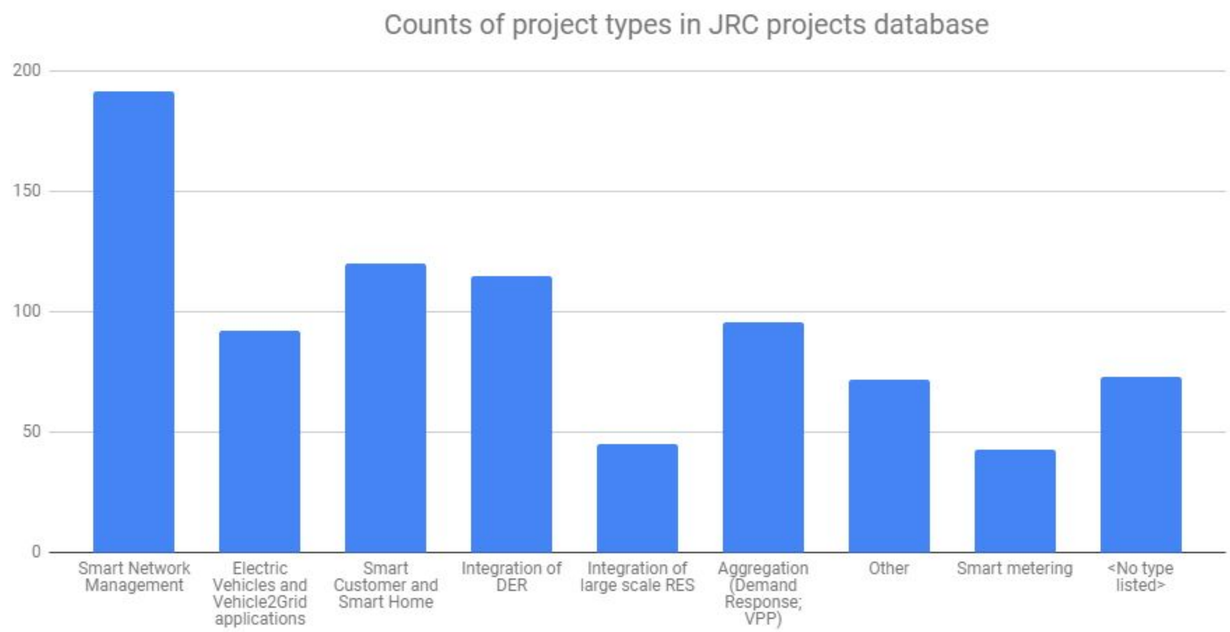

Figure 2. Counts of project types in the HRC Smart Grid Projects List database [12].

Most countries have their own national smart grid organizations promulgating and funding particular smart grid projects, with Germany, the UK, France, and Spain investing the most [2]. Interestingly, the single largest funders, as a category, are Distribution System Operators: the JRC identifies them as investing 830 million euros into the projects they've identified, and 70% of that capital is private (see figure 3, taken from the same). The authors believe this level investment is the DSOs' way to respond to rapid changes in electricity distribution. They explain that

> *[s]mart grid technologies and solutions are expected to radically change local electricity industry and markets at the distribution level [...] DSOs are therefore proactively investigating and testing new solutions, as well as new roles and business models, in order to get ready to take up the new tasks, responsibilities and opportunities that are shaping up in the evolving power system.* [2, p39]

The Global Smart Grid Federation, a "global stakeholder organization committed to creating smarter, cleaner electrical systems around the world" identified in 2012 the following European projects as being "notable", having been nominated by their peers in the federation [13]:

- ADDRESS, a demonstration project in France, Italy, and Spain integrating demand and distributed energy resources (though its website appears to not have been updated since 2013) [14];
- GRID4EU, a state-of-the-art R&D smart grid with sites in Italy, France, Spain, the Czech Republic, Germany, and Sweden that was completed in 2016 [15];
- Green eMOTION, which had 9 electric mobility/EV demonstration projects integrating a virtual marketplace, car charging stations, and business model testing [16];

- Low Carbon London, which integrated a number of low-carbon technologies (including DERs, electric vehicles, wind, etc.) along with several dynamic pricing models

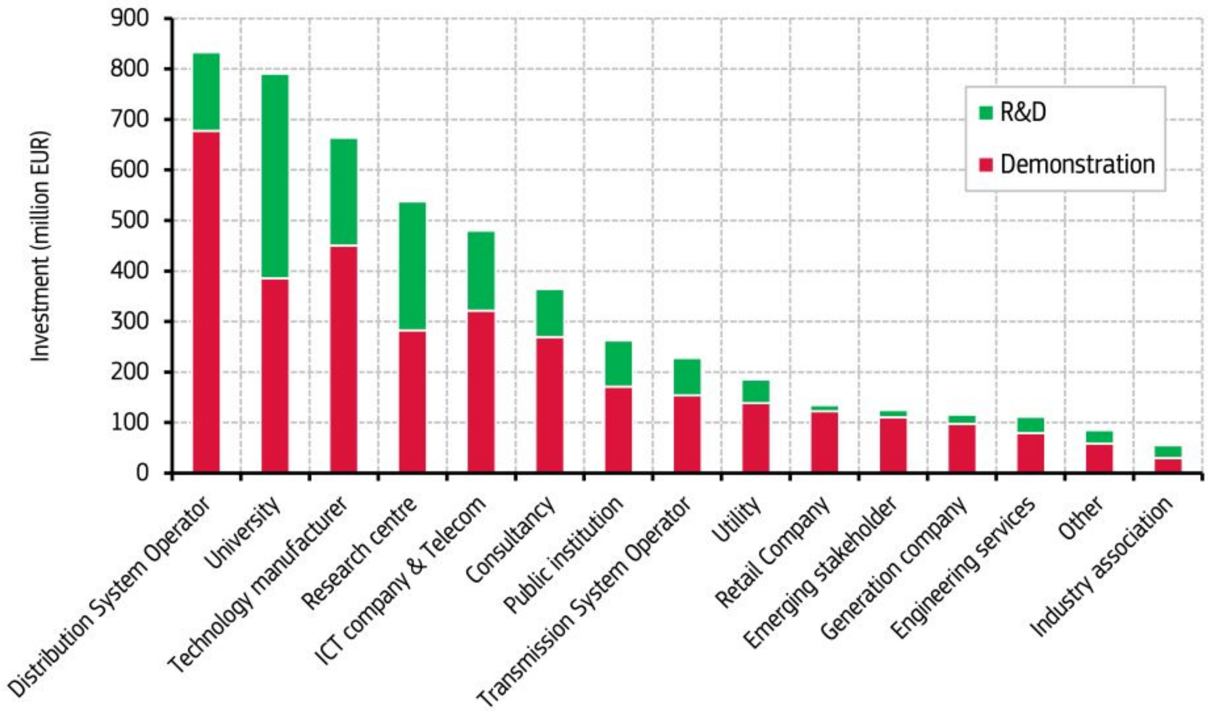

Figure 3. Total R & D and demonstration investment per stakeholder category (reproduced taken from [2]).

The Global Smart Grid Federation, in its lessons gleaned from these pilot projects, points to the need for winning customer support and communicating with consumers -- preferably with at least in-person forums. Indeed, the Netherlands initially prevented a roll-out of smart meters because of serious privacy concerns; the project proceeded only when it no longer became mandatory for any given customer to install one [18].

Other projects around the world

While much more information is readily available on US and European energy efforts, other countries also have plenty of projects. China's "Strong and Smart Grid" already comprised 263 smart grid pilot projects in 2012 [19]; and Japan, South Korea, India, and Australia, also have several notable projects of their own [13]. Similarly, there are a number of experiments with microgrids in Africa [20]; and projects are also developing in South America [21].

Blockchain pilot projects

Max Luke, of NERA Economic Consulting, *et al.* published in early 2018 a brief history of blockchain projects related to energy. The first transactions were taking place in 2014, and growth since then has been explosive, with 122 energy sector organizations involved in blockchain technology and 40 publicly announced deployed projects [22]. SolarPlaza, a conference organizer, identified 66 blockchain companies involved in energy in 2017 as part of their "Comprehensive Guide to Companies involved in Blockchain & Energy" [23].

Luke *et al.* categorize their efforts as falling into the following categories, and lists several examples of companies in each:

- Wholesale energy trading;
- Retail electricity markets;
- Peer-to-peer marketplaces;
- Flexibility services (i.e., demand response);
- Electric vehicle charging and coordination;
- Network management and security; and
- Environmental attribute markets (e.g., confirming the generation of electricity as part of a carbon-credits system)

Academic research

Where companies have begun, formal academic interest has followed.

Livingston *et al.* of The Council of Foreign Relations performed a review on the applications of blockchain technology to the grid [24]. They have identified 55 start-up companies operating in many of the same categories that Luke has found (though they add the use case of energy financing; SolarDAO in Russia is using a blockchain to crowdfund solar power); 50 utilities exploring initiatives involving blockchain, mostly involving grid and peer-to-peer transactions; and 16 regulatory initiatives around the world utilizing blockchain in the energy sector. They are less bullish in their assessments of three of the more developed blockchain projects:

- **LO3 Energy**, in the Brooklyn microgrid, is utilizing blockchain for peer-to-peer trading. However, the peer-to-peer trading employed is purely virtual: the flow of electricity remains unchanged, and so -- at least in its first iteration -- is not providing any resilience, cost, or sustainability benefits to the grid.
- **Grid+**, in Texas, sells residential customers tokens in order to let them buy electricity at wholesale rates. Because they require customers to pre-pay for tokens, they pass on the credit risk to wholesale producers; blockchain technology in particular isn't strictly necessary for Grid+ to benefit.
- **Electron,** in the UK, is piloting a distribution market and matching buyers and sellers of flexibility (demand response). In this case, blockchain could help process transactions swiftly, transparently, and cheaply; the results from the pilot project, when complete, will reveal more.

While about half of companies are utilizing Ethereum as their base blockchain, plenty of of companies are using other blockchains, including ERC20, Quasar, Tendermint, and Hyperledger (as well as several proprietary blockchains) [24]. To prevent conflict among them all, the Energy Web Foundation is creating a “blockchain of blockchains” to ensure interoperability in global energy trading [25].

Alisa Orlov, as part of a master’s thesis for the Norwegian School of Economics and HEC Paris, identifies and analyzes business models for blockchain more generally [26]. She identifies seven unique business model archetypes for use with blockchain:

- **Retailer**, in which blockchain companies replace typical intermediaries by purchasing directly from independent energy producers or the wholesale market;
- **Renewable energy certificates**, in which producers of renewable energy are rewarded with tokens guaranteeing their sources that can be directly purchased;
- **Transparency regarding energy mix**, in which any purchaser of electricity can see the immediate source of that energy to ensure its green provenance;
- **Crowdsale platforms**, in which blockchains are used to finance energy projects (particularly solar photovoltaics);
- **Over-the-counter (OTC) trading platform,** which is wholesale energy trading;
- **Flexibility-trading platform,** a form of demand response in which prosumers, consumers, and system operators are rewarded for minimizing or shifting electricity demand; and
- **P2P energy trading platform**, in which energy is directly traded peer-to-peer quickly, transparently, and inexpensively.

Orlov found P2P as the most common case, representing 50% of the cases she reviewed; and peer-to-peer (P2P) markets more generally receive their own comprehensive treatment [27]. In a pre-print, Sousa describes and tests three P2P markets, as well as pointing to 10 R&D projects (4 of which are complete, and not all of which utilize a blockchain approach).

Utility interest is also directly explored; Charlotta Edeland *et al.* interviewed several dozen employees and executives from a handful of utilities, universities, and companies to see where they think blockchain would be most useful [28]. Edeland’s findings are best summarized in a table of use cases, reproduced in full below:

Table 3. Use cases, key actors, and expert opinion on the feasibility and need for blockchain as it relates to utilities (reproduced from [28, p 123]).

Cluster	Definition	Key actors	Expert Opinion
P2P Trading	The direct trading of energy between prosumers or small scale producers of energy without the use of a third party intermediary	Power Ledger, LO3 Energy, Conjoule, OmegaGrid, We Power, Grid+,	High strategic relevance for an energy utility but the customer demand in the Nordics can be questioned
Tokens to reward sustainable behaviour	Platform allowing for information sharing of activities that affects the individual carbon footprint with the purpose of awarding tokens for sustainable behaviour	Energimine, CarbonX, RecycleToCoin, Eco coin	-
EV Charging & Management	The use of smart contracts in order to facilitate the charging and charging management infrastructure for EVs	Share & Charge, Oxygen Initiative, Car eWallet, Everty	Considered to have high potential for a near-term implementation. Natural use case to initiate blockchain efforts given the current development and existing infrastructure.
Environmental Commodity Management & Trading	The issuing, tracking and trading of REC's and Carbon assets. Involves both the currently implemented system as well as the tokenization of renewable energy.	Energy Web Foundation, Energy Blockchain Labs together with IBM, SolarCoin, The Climate Chain Coalition	Very relevant use case for blockchain as the current system is error prone and involve multiple parties
Wholesale Energy Trading and Settlement	The trade of energy commodities on wholesale markets. The focus is on supporting the trading volumes and reduce transaction costs in Over the Counter trading.	Enerchain developed by Ponton, European trading project and OneOffice developed by BTL	Beneficial use case in the short term as it targets on improving operations within existing systems. Remains to be seen how big part of all the trades that will actually be done over blockchain.
Grid Stabilization & Management	The processes connected to the frequency balancing of the grid and congestion management. Involves both the coordination of participating actors and appliances as well as distribution of compensation.	TenneT, Sonnen and Vandebron together with IBM, Electron	High relevance in the future given the transformation of the energy system. Blockchain is deemed to be necessary for a successful implementation
Disaggregated Billing	The tracking and division of home electricity consumption to specific devices and/or other divisions in order to facilitate separate, unbatched, payments.	Enexis together with IBM, Electron	Important step towards a servicification of electricity and home appliances. Blockchain allows for a coordination of a large number of transactions with low value.
Energy Data Exchange Platform	Data exchange platforms for the communication between energy companies, regulatory agencies and grid operators.	Grid Singularity, Clearwatts, ElectriCChain, Qiwi together with Tavrida Electric	-
Cryptocurrency Based Payment Systems	The use of cryptocurrencies for both traditional payments of invoices and the use of blockchain aware pay-as-you-go meters.	BAS Nederland, Marubeni, Enercity, Restart Energy, Bankymoon, M-PAYG	Some potential is seen in pre-paid electricity options but the overall market for cryptocurrencies is deemed to be insignificant for Vattenfall's core markets at this point.

Additional notable projects

WePower in Estonia

Estonia is doing a nationwide blockchain trial with WePower, which specializes in renewable energy financing and trade; they announced a successful delivery of that pilot. Per CryptoBriefing: "According to WePower's initial results, 26,000 hours and 24TWh of energy consumption data has been successfully uploaded to the blockchain, for a total of 39 billion Smart Energy Tokens." [29]

Power Ledger in Australia

Power Ledger, which has several offerings for P2P trading and electric vehicle charging, received AU$8 million for a smart grid initiative in Fremantle, in Western Australia, to be overseen by Curtin University [30].

Conclusions

Smart grids are proliferating rapidly, and have plenty of change yet to make with the addition of large quantities of distributed renewable energy, electric charging, and smart homes & appliances. Blockchain is well-placed to aid in a number -- if not all -- of the challenges facing them and, indeed, a number of companies are already exploring the space.

Protocol Labs should choose a particular use case they'd like to explore first and run with it, as the space is likely to become quickly saturated.

Glossary

Acronym	Meaning
AMI	Advanced Metering Infrastructure
ADMS	Advanced Distribution Management System
BMS	Building Management System
CBS	Consumer Behavior Study
CVR	Conservation Voltage Reduction
DA/DACR	Distribution Automation (Circuit Reconfiguration)
DER	Distributed Energy Resources
DERMS	Distributed Energy Resource Management System
DLR	Dynamic Line Rating
DR	Demand Response
DRCC	Demand Response Control Center
FLIRS	Fault Location,Isolation, and Restoration System

HAN	Home Area Network
HEMP	Home Energy Management Platform
MDMS	Meter Data Management System
SA	Substation Automation
SCADA	Supervisory Control and Data Acquisition
TOU	Time-of-use
VPP	Virtual Power Plants
VVO	Volt/VAr Optimization

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