Grid Tech.
The decade of deployment.

Market and Submarket Introduction
2023 Outlook

This introductory report frames the rapidly growing Grid Tech market.

Thousands of vendors across hundreds of solutions are competing to help power companies reduce costs, increase profitability and decarbonize. Learn more about our Members Intelligence Center.

Learn More

indigoadvisorygroup.com/research

Indigo
ADVISORY

Table of Contents

Market Introduction

Grid Tech Market Background

Indigo ADVISORY

Market Introduction - Section Brief

- Buoyed by recent federal funding, a private capital boon, and a favorable regulatory landscape, the Grid Tech market is forecasted to be worth $640 billion by 2030, with a CAGR of over 19.60%.
- A vibrant market of software solutions, industrial robotics, and intelligent automation is transforming how electrons are delivered on today's grid, with rapid changes taking place across 6 key Grid Tech submarkets: Flexibility, Core Systems, eMobility, Digital Asset Management, Optimization Technologies, and Robotics & Connected Worker.
- This global marketplace includes thousands of vendors that serve the sector's evolving needs. As Grid Tech matures, we are seeing a mix of conglomerates and startups emerging as the market's Top 150 most promising vendors.

Deploy. Digitize. Decarbonize.

Market Introduction

Grid Tech is a rapidly growing and evolving market. The decarbonization, economic and customer benefits derived from applying sensors, communications and software on power networks are enormous. The market is comprised of several stakeholders. On the one hand, you have a broad set of utilities, with various ownership structures and other buyers who have experienced decades of changing physical grid requirements and evolving regulatory frameworks. On the other hand, suppliers ranging from conglomerates, specialized mid-sized companies and startups are innovating and integrating sophisticated solutions into new and existing product sets. This is all underpinned by a rapidly growing climate VC market, substantial amounts of public money and the mergence of new business models.

Defining and Valuing the Grid Tech Market

In terms of value, our initial analysis of submarkets and a refreshing older smart grid models suggest the Grid Tech market is forecasted to be worth $640 billion by 2030, with a CAGR of over 19%. The market is comprised of primarily software related solutions, sensors, and applications. The constituent submarkets are generation source agonistic and focus on grid performance and utility innovation. These submarkets enable new sources of generation both centrally and at the grid edge. Across these markets, a range of vendors, use cases and deployments exist in the power industry and at various levels of maturity.

The Grid Tech market is comprised of sensors, communications technology, software and new ways of working for power companies. Across these enabling technologies, hundreds of use cases can be deployed to operate the grid in a clean, reliable and cost-effective manner.

Grid Tech By The Numbers

Funding & Valuation

1 

$640b

Grid Tech Market Value by 2030

2 

$23b

$23b invested in startups, M&A activity and SPACs in 2 years

3 

$350b

Billions available in Federal Funding & Credits

Decarbonization & Cost Imperative

4 

7,700 MtCO2

7,700 MtCO2 enabled by Grid Tech by 2030

5 

500 MtCO2

500 MtCO2 Direct by Grid Tech by 2030

6 

1.7 kWh

Infrastructure cost increase in 10 years to 4.3 cents per kWh

Markets & Activity

7 

10

High Focused Grid Tech VCs

8 

1864

Grid Modernization Actions Taken by States in Past 5 years

9 

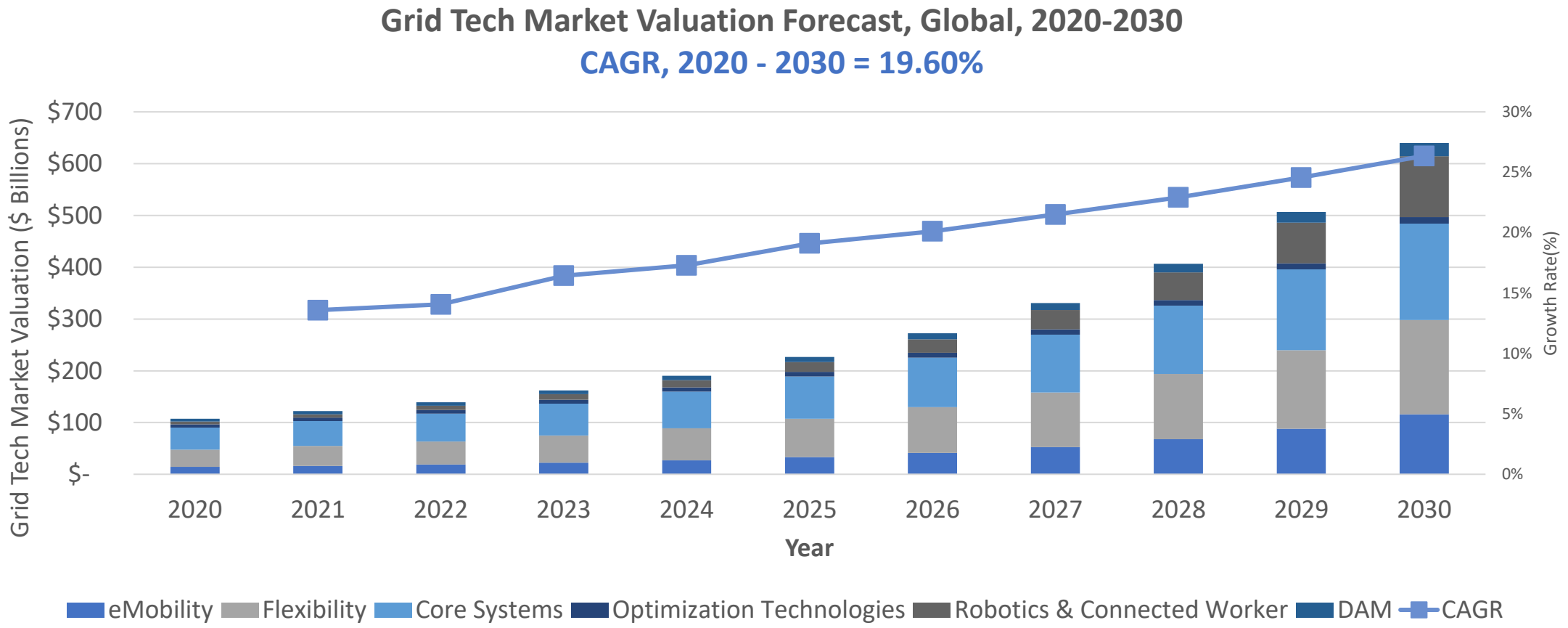
382

Patents filed by Utilities in the US in the Past 20 years

Indigo ADVISORY

Grid Tech - The Decade of Deployment

The Global Grid Tech market is forecasted to be worth $640 billion by 2030, with a CAGR of 19.60%



Indigo Advisory Group Meta Analysis 2022, , Initial analysis of submarkets refreshing older smart grid models

Grid Tech – Submarkets and Applications

There are 6 major submarkets that comprise the overall Grid Tech market, all heavily dominated by software solutions.

Illustrative Applications

Core Systems

- DMS / ADMS
- Cyber Systems
- AMI
- GIS
- CIS
- SCADA

Digital Asset Management

- Asset Monitoring & Control
- APM Software
- Digital Twins
- Climate Risk Analysis of Infrastructure

Robotics & Connected Worker

- Connected Worker
- Industrial Robotics
- Extended Reality (XR) for Safety and Training
- UAS for Image-based Inspection

Optimization Technologies

- Power Flow Controllers
- Topology Optimization
- Dynamic Line Rating (DLR)

Flexibility

- DERMS & VPP
- Battery Management System
- BEMS & HEMS
- Demand Response
- Microgrids

eMobility

- EV Charging
- Fleet Electrification & Inspection
- Vehicle-to-Grid (V2G)

Indigo ADVISORY

Applications and Adoption Across the Value Chain

Across the energy value chain, power companies are investing in new technology-enables use cases

Illustrative

Power Generation

- Asset Performance Management
- Risk and price forecasts for the day-ahead and real-time markets
- Real-time Ops & Maintenance
- Work Prioritization & Scheduling

Transmission & Distribution

- Advanced Distribution Management Systems (ADMS)
- Fault Location Isolation and Service Restoration (FLISR)
- Real-time System Operations
- Veg Management & Optimization
- Optimization Technologies

Customer

- Decarbonization Advisory
- Meter to Cash Integrations and Automation
- Outage Experience
- Remote Energy Audits
- New Journeys (e.g., charge EVs)
- New Products and Services

Korean Southern Power Co. | Steam Turbine High Vibration Diagnostics

Dominion Energy | Image-Based Inspection for Grid Infrastructure

Capital Power | *Historical Data Ingestion*

Enel | Demand and Supply Forecasting for Wholesale Markets

AES Indiana | Asset Performance Management (APM) Platform

Delaware Electric Cooperative | Vegetation Management

Xcel Energy | Dynamic Line Rating (DLR)

Alabama Power | Fault Isolation and Service Restoration (FISR)

PGE | Distributed Energy Resource Management System (DERMS)

Georgia Power | Outage Management System (OMS)

NYS Electric & Gas | Smart Thermostat & DR Bundle

Green Mountain Power | Community Solar & Energy Marketplace

Consumers Energy | Utility Marketplace

AES Indiana | Digital Customer Activation

OPERATIONS CROSS CUTTING

- Connected Digital Worker (e.g., mobile apps)
- Long-term Forecasting and System Planning
- Distributed Energy Resource Management System (DERMS)
- Predictive Maintenance
- Capital Management Efficiency
- Safety Risk Management Software

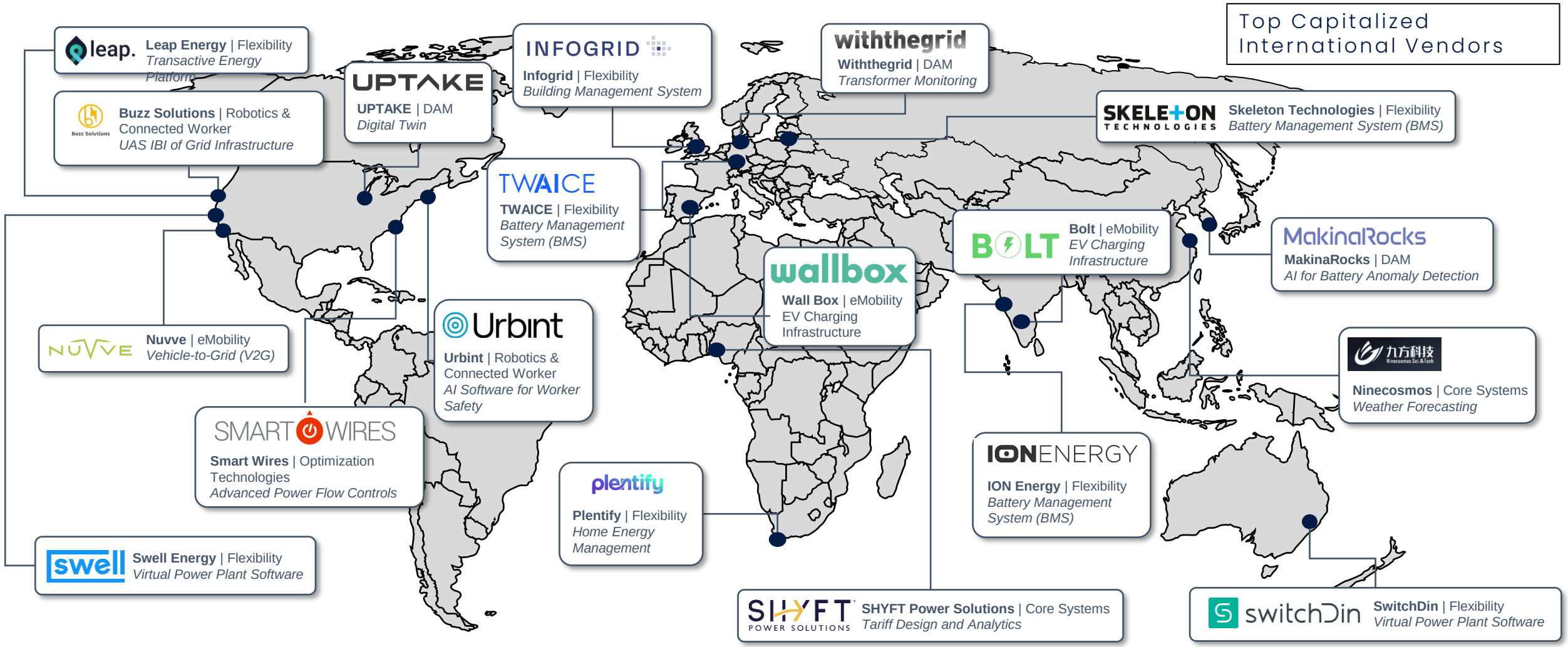
CUSTOMER CROSS CUTTING

- Distributed Intelligence
- Customer Analytics and Information Accessibility
- Automated M&V
- Marketplaces
- AI-enabled Customer Care (chatbots)
- Digital Engagement Channels

10

Grid Tech Global Markets

As local utilities tend to buy local vendors, innovative startups have emerged across the globe to satisfy local utility demands



Indigo ADVISORY

Grid Tech Market Map

Outlining 150+ top vendors

Market Introduction

Flexibility

RenewaFi, piclo, enspired, LevelTen Energy, leap., Palmetto, voltus, FLUENCE, Origami

Market Platforms for Trading

energyX, buildingsIOT, INFOGRID, Grid Edge, LOGICAL BUILDINGS, CORTEX, ENCYCLE, enerbrain

Building Management System

swell, sympower, GRIDPOINT, GENERAC, AutoGrid, Virtual Peaker, Lumenaza, switchDin

Virtual Power Plant Software (VPP)

Utilidata, CAMUS, allumia, reactive technologies

Distribution Management System (DMS)

ACCURE, TITAN, Form energy, CABAN SYSTEMS, RENEWANCE, ENERGY VAULT, POWIN, ION ENERGY, TWAICE, HYDROSTOR, SKELETON TECHNOLOGIES, novo, BattGenie., moixa

Battery Management Systems

GridBeyond, 75F, ELECTRIC POWER, LANCIUM, kiwipower, Arcadia, EnergyHub, energyworx, OhmConnect, Gridwiz, copper, ENGIE

Demand Response Management System

60 HERTZ SCALE

Microgrids

Heila, AMMP, SPARKMETER

DERMS

DAM

withthegrid, MakinaRocks, GE, Schneider Electric, terabase, WindESCo, LOSENERGY, EMERSON, ABB, UBIQUITI, REsurety, clir, SIEMENS

Asset Performance Analytics

eMobility

whip around, FREEWIRE, chargepoint, CHARGELAB, CHARGEUP, BOLT, wallbox, Inspiration, SWTCH, AMPLY POWER, ELECTRA EV, WiTricity, ATOM POWER, Wirelane, CHARGENET, JET CHARGE, CHARGE AMPS, IONITY, ev.energy, WeaveGrid, volta, BONNET, ZEST, AddENERGIE, FORUM MOBILITY, MONTA, ROCSYS

EV Charging Infrastructure

Grid Tech 150

Robotics & Connected Worker

PETRA, Perceptual Robotics

Robotics

Urbint

Safety Risk Management Software

Buzz Solutions, Skydio, CrowdAI, SenseHawk, DroneDeploy, PRECISIONHAWK

Unmanned Aircraft Systems (UAS)

magic leap, LIBRESTREAM, GILYTICS, realwear

Extended Reality (XR)

Optimization Technologies

menlomicro, SPAN, TS

Innovative Hardware

Ampacimon, Heimdall Power, LINEVISION

Dynamic Line Rating

Core Systems

kevala, aurora, urbio, bidgely

Energy Infrastructure Planning

Gridware, AIDASH

Wildfire and Vegetation Management

AMPERON, SHYFT POWER SOLUTIONS, uplight, bidgely, GridX, Gridcognition

Tariff Design and Analytics

mysti.ai, gaiascope

Energy Market Forecasting

tomorrow.io, Climavision

Weather Forecasting

Aclara, Itron, Landis+Gyr

Advanced Metering Infrastructure (AMI)

OATI, ERICSSON, Johnson Controls, S&C

Distribution Management Systems (DMS)

bodhi, ostrom, Colossus

Customer Renewable Notification System

Capital Inflows

Public and Private Investment Data

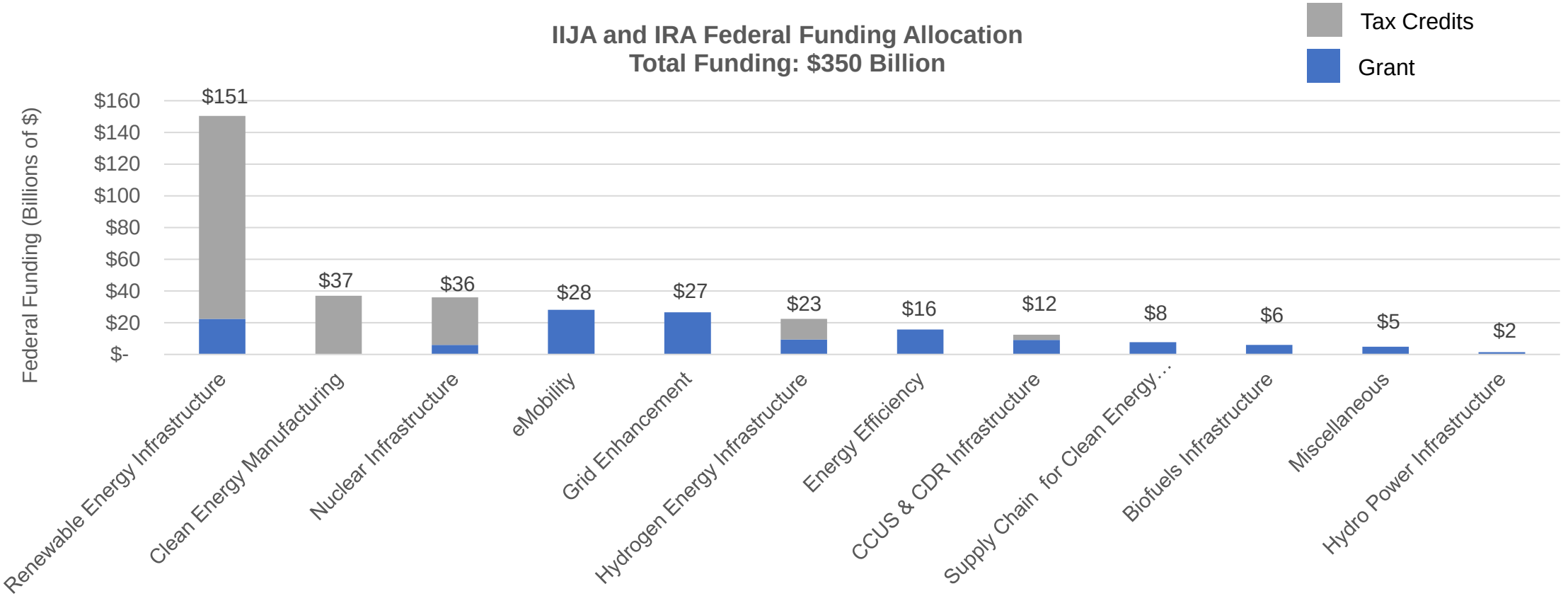
Indigo ADVISORY

Growing Investment - Section Brief

- Between the Infrastructure Investment and Jobs Act (IIJA) and the Inflation Reduction Act (IRA), there is approximately $350 billion dollars in public funding allocated towards Grid Tech and related markets.
- Administered through DOE's new Grid Deployment Office, the Grid Resilience and Innovation Partnership Program is funded by the Bipartisan Infrastructure Bill, and will enhance grid flexibility and improve the resilience of the power system against growing threats of extreme weather and climate change
- There has been approximately $23.2 billion invested in startups, M&A activity, and SPACs in the past 2 years with eMobility and Flexibility forming the largest markets.

Grid Tech Related Federal Funding is Ramping Up

Between the Infrastructure Investment and Jobs Act (IIJA) and the Inflation Reduction Act (IRA), there is approximately $350 billion dollars in public funding allocated towards Grid Tech and related markets



IIJA, BBB Congressional Documents

Indigo ADVISORY

The DOE's Grid Deployment Office (GDO)

Administered through DOE's new Grid Deployment Office, the Grid Resilience and Innovation Partnership Program is funded by the Bipartisan Infrastructure Bill and will enhance grid flexibility and improve the resilience of the power system against growing threats of extreme weather and climate change.

- **Grid Resilience Grants ($2.5 billion)** support activities that will modernize the electric grid to reduce impacts due to extreme weather and natural disasters. This program will fund comprehensive transformational transmission and distribution technology solutions that will mitigate multiple hazards across a region or within a community, including wildfires, floods, hurricanes, extreme heat, extreme cold, storms, and any other event that can cause a disruption to the power system. This program provides grants to electric grid operators, electricity storage operators, electricity generators, transmission owners or operators, distribution providers, and fuel suppliers.
- **Smart Grid Grants ($3 billion)** increase the flexibility, efficiency, and reliability of the electric power system, with particular focus on increasing capacity of the transmission system, preventing faults that may lead to wildfires or other system disturbances, integrating renewable energy at the transmission and distribution levels, and facilitating the integration of increasing electrified vehicles, buildings, and other grid-edge devices. Smart grid technologies funded and deployed at scale under this program will demonstrate a pathway to wider market adoption. This grant program has broad eligibility, open to domestic entities including institutions of higher education; for-profit entities; non-profit entities; and state and local governmental entities, and tribal nations.
- **Grid Innovation Program ($5 billion)** provides financial assistance to one or multiple states, Tribes, local governments, and public utility commissions to collaborate with electric sector owners and operators to deploy projects that use innovative approaches to transmission, storage, and distribution infrastructure to enhance grid resilience and reliability. Broad project applications are of interest including interregional transmission projects, investments that accelerate interconnection of clean energy generation, utilization of distribution grid assets to provide backup power and reduce transmission requirements, and more. Innovative approaches can range from use of advanced technologies to innovative partnerships to the deployment of projects identified by innovative planning processes to many others.

IIJA, BBB Congressional Documents

Indigo ADVISORY

Aligning Grid Tech to DOE Grid Modernization Initiative (GMI) Strategy

Capital Inflows

Goal - ***Achieve a carbon-free electricity sector by 2035 | Equitably transition America to net-zero greenhouse gas emissions by 2050***

1. DOE Goals

- **Decarbonization**
- **Infrastructure Modernization**
- **Equity and Energy Justice**
- **Climate Adaptation and Mitigation**

2. Power System Objectives

- Clean Energy Integration
- Grid Infrastructure Expansion
- Managing Electrification
- Reliability, Resilience, & Security
- Affordability

3. Pillars

- Devices & Integrated Systems
- Operations
- Planning
- Markets, Policies, and Regulations
- Resilient and Secure Systems
- Flexible Generation & Load

4. Research Areas

- HVDC/Optimization Technologies
- Storage
- Inverters/DER Interconnection
- Cables and Conductors
- Transformers
- Codes & Standards

- T&D Integration
- Flexible Management
- Sensing and Measurement
- Data Analysis
- Controls
- Protection

- Climate Adaptation and Mitigation
- Data Science and Forecasting
- Power System Modeling Tools
- Economic Modeling
- Interdependent Infrastructures
- Multi-Model Integration
- Behavioral Science

- Policies and Regulations
- Market Design
- Economic Valuation
- Energy Justice

- Cybersecurity
- Microgrids
- Inter-and Intra-System Risk Assessment

- Flexible Generation
- Flexible Load
- Hybrid Systems/Integrated Energy Systems

5. Program Types

R&D | **Testing and Validation** | **Simulation** | **Demonstrations** | **Technical Assistance** | **Analysis**

6. Indigo Submarkets

- **Core Systems**
- **Digital Asset Management**
- **Robotics & Connected Worker**
- **eMobility**
- **Optimization Technologies**
- **Flexibility**

The DOE maintains that the smart grid gross domestic product (GDP) multiplier is higher than many forms of government investment. For every $1 million of direct spending, which included both government ARRA funds and private-sector matching, the GDP increased by $2.5 million

Grid Tech - The Decade of Deployment

Monitoring Grid Tech Capital Inflows

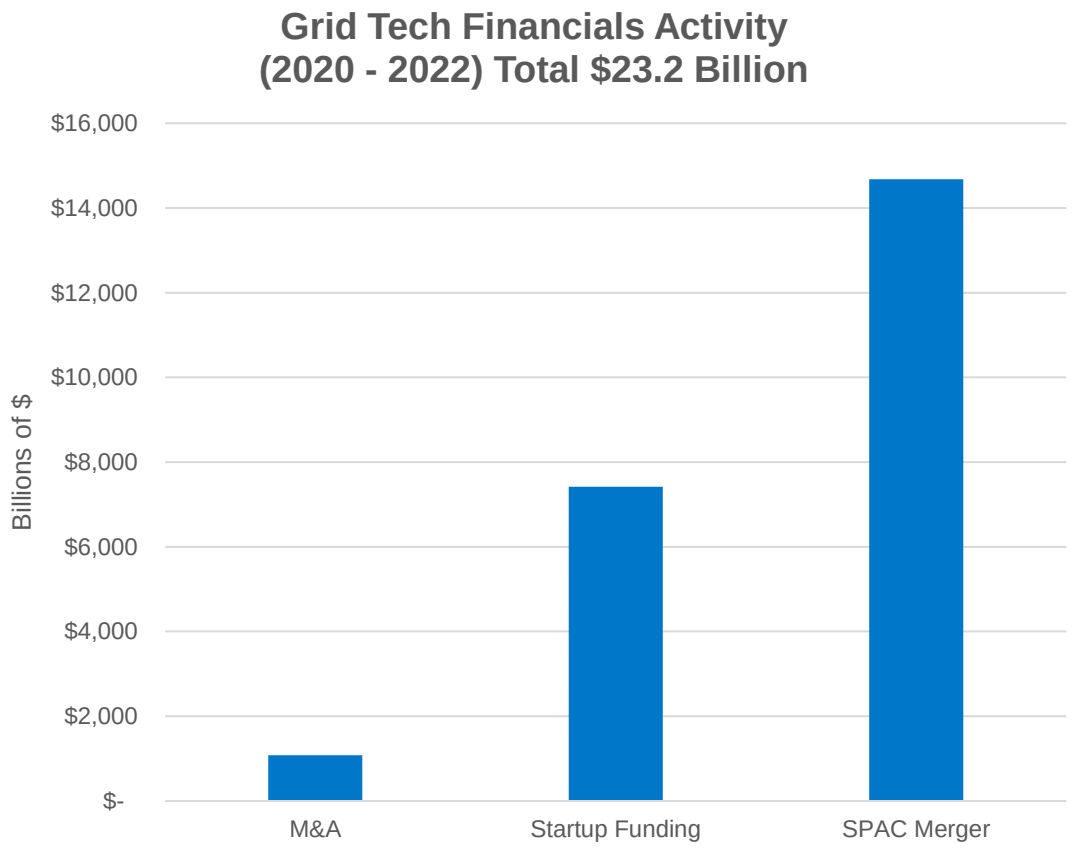
Traditionally, public investment in the grid has yielded positive outcomes. In 2009, the DOE maintained that the smart grid gross domestic product (GDP) multiplier is higher than many forms of government investment. For every $1 million of direct spending, which included both government ARRA funds and private-sector matching, the GDP increased by $2.5 million to $2.6 million, which compares favorably against other potential government investments and infrastructure.

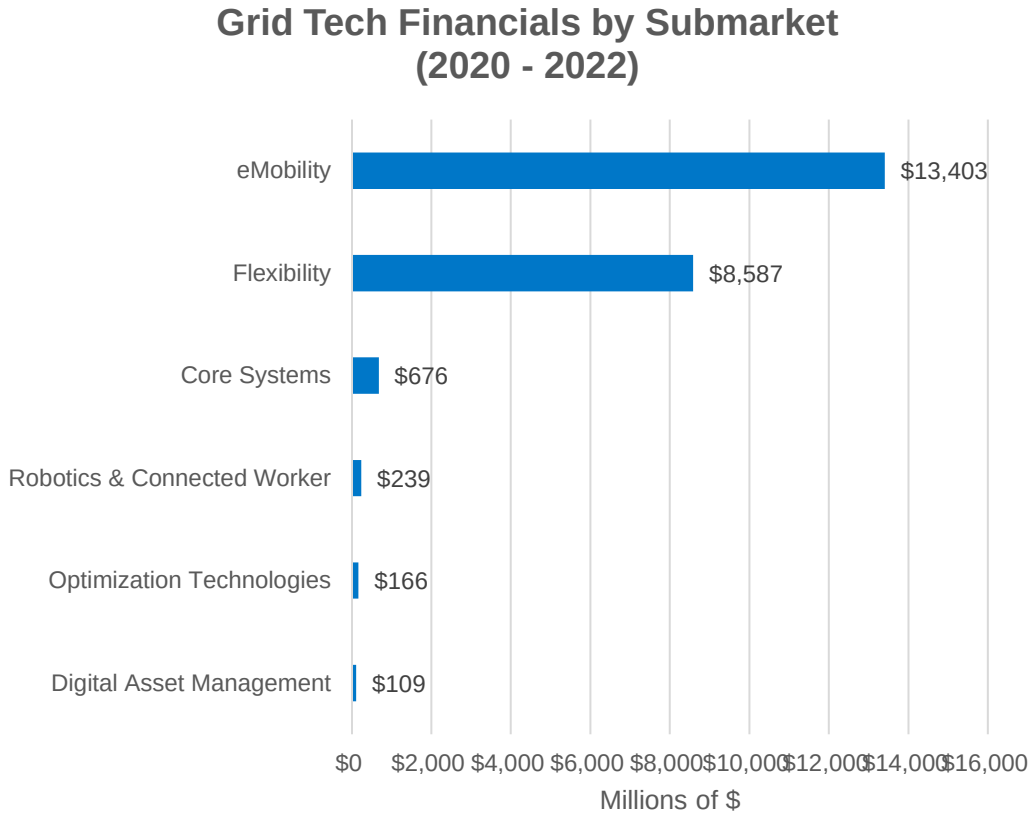
As a result, the recent swath of announcements between the Inflation Reduction Act (IRA), Infrastructure Investment and Jobs Act (IIJA), Build Back Better Act (BBB), and DOE's Build a Better Grid Initiative, equate to over $350 billion dollars in public funding allocated towards Grid Tech. This is no surprise given that current national goals of 100% carbon-free electricity by 2035 will require new technologies, upgrades, and markets.

In terms of private investment, recent activity in funds established to focus on 'Climate Tech' have also seen a steady focus on purely grid related technologies. Our analysis reveals that in the past 2 years, there has been over $23 billion invested in startups, M&A activity and SPACs. The most active investors by count in the market include Energy Impact Partners, Bluebear Capital, and National Grid Partners, with the Flexibility and the eMobility submarkets are seeing the lions share of capital

Startup funding, SPACS & M&A

There has been approximately $23.2 billion invested in startups, M&A activity and SPACs in the past 2 years.





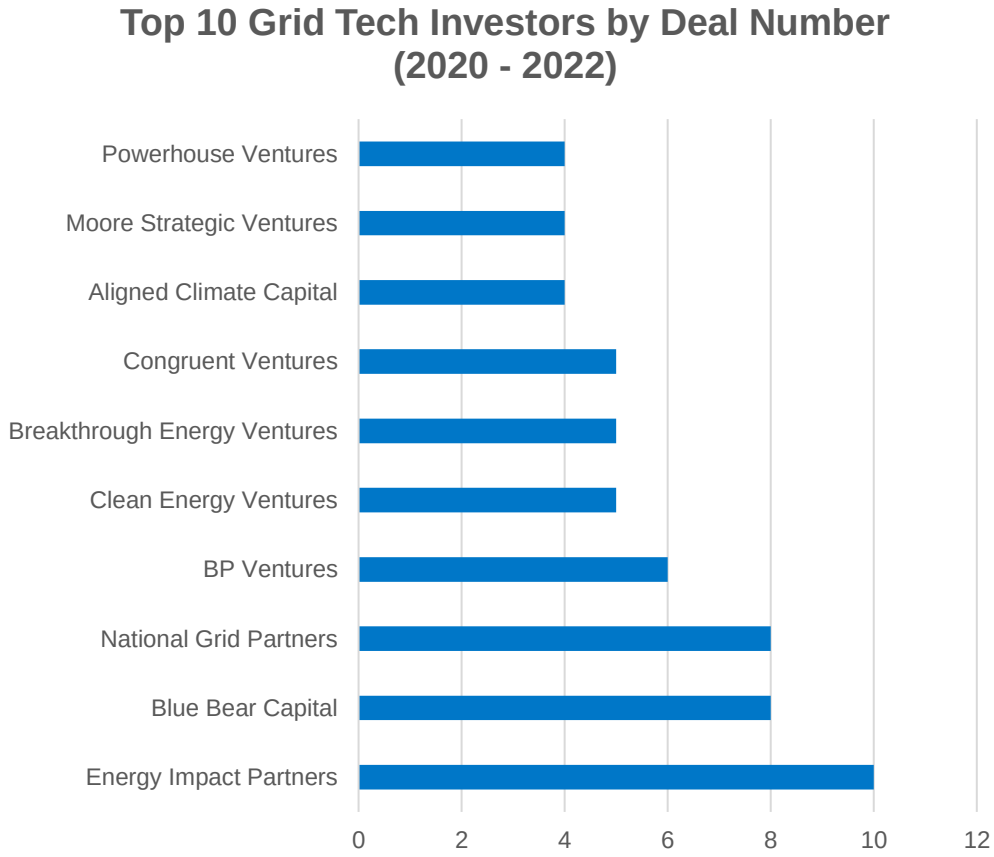
Indigo Advisory Group Research Team

Largest Investors and Largest M&A Deals Since 2020

Investing in the Grid Tech market requires multi-disciplinary skills. Although still a burgeoning market, there has been consolidation particularly within the eMobility space as well as significant investor activity from large players.

Largest M&A Deals

Announced	Company	Submarket	Amount	Description
January 2021	EVgo	eMobility	$2,600 million	EVgo goes public in SPAC merger with SPAC Climate Change Crisis Real Impact.
February 2021	volta	eMobility	$2,000 million	Volta Industries goes public in SPAC merger with SPAC Tortise Acquisition II.
August 2021	chargepoint	eMobility	$88 million	ChargePoint acquires Viricity to enhance optimization of fleet electrification.
April 2022	blink	eMobility	$23.4 million	Blink Charging acquires EB Charging to include new commercial and home charging offerings.



Indigo Advisory Group 2022

Indigo ADVISORY

Grid Tech – 20 Most Capitalized US Startups (’20 –’22)

Over $7 billion has been invested since 2020 in companies developing innovative grid technologies.

1. Core Systems

Climavision
Utilidata
bidgely
tomorrow.io

2. Digital Asset Management

AIDASH
UPTAKE
UBIQUITI NETWORKS

3. Robotics & Digital Worker

Urbint
magic leap
Skydio
Buzz Solutions

4. eMobility

otonomo
NUVVE
FERMATA ENERGY

5. Flexibility

leap.
swell
GRIDPOINT
AutoGrid

6. Optimization Technologies

SMART WIRES
SYNTIANT

Indigo Advisory Group 2022

Indigo ADVISORY

Market Drivers

Performance, Cost and Decarbonization Goals

Indigo ADVISORY

Grid Tech Drivers - Section Brief

- The costs of the infrastructure needed to deliver power rose from 2.6 cents per kilowatt-hour in 2010 to 4.3 cents per kWh in 2020 — nearly equal to the cost of generating the power itself according to the DOE.
- Grid Tech has both an enabling and direct impact on carbon abatement. To achieve net-zero in 2050, the Electricity & Heat sector must decarbonize by 7,700 MMT of CO2 by 2030.
- Grid Modernization Actions by states over the past 5 years have increased with New York, California, Hawaii, Minnesota and Massachusetts the being most active states.

Exploring the Grid Tech Market Drivers

Measuring the Grid Tech Market Impact

The reason for substantial capital flows becomes apparent when key metrics are applied to the defined marketplace, namely the cost of power delivery, decarbonization objectives, and the need to manage new business models requiring more complex grid management.

Firstly, as the cost of delivering power is increasing, utilities can leverage Grid Tech to defer high fixed costs and improve grid efficiency. The cost of the infrastructure needed to deliver power rose from 2.6 cents per kilowatt-hour in 2010 to 4.3 cents per kWh in 2020 — nearly equal to the cost of generating the power itself according to the DOE. Power Delivery includes maintaining, replacing and building new transmission and distribution grids, plus the management of other equipment like transformers and meters. As we enter a new decade, keeping this cost increase in line will require a sophisticated and targeted investment. Indeed, utilities and equipment manufacturers have reported to NIST that their costs for integrating non-interoperable equipment and systems range from $140 million to $1 billion per year per firm.

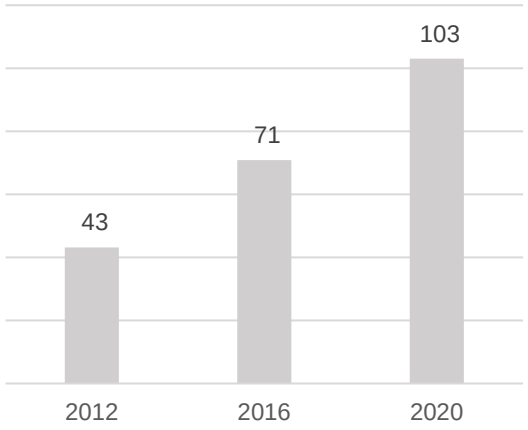
Secondly, Grid Tech has both an enabling and direct impact on carbon abatement. To achieve net-zero in 2050, according to the IEA, the Electricity & Heat sector must decarbonize by 7,700 MMT of CO2 by 2030. This emission abatement schedule cannot occur without investment in Grid Tech solutions. For example, the grid suffers from technical losses each year which require utilities to produce more power to make up for inefficiencies. Investment in Grid Tech can solve these inefficiencies and directly avoid 500 MMT of CO2 emissions, approximately 6.5% of the total decarbonization effort needed for the Electricity & Heat sector by 2030 according to ARS Technia. To provide perspective, the direct carbon reduction potential of Grid Tech is 12.5x more than the amount of carbon reduced by CCUS in 2020. In other words, the amount of carbon abated by CCUS in 2020 is about 8% of the direct carbon reduction potential of Grid Tech.

Thirdly, Grid Tech is a critical market to enable new business models across the power industry landscape. Creating the often-simplified vision of the “grid as a platform ”, requires huge investment in situational awareness and visibility technologies to enable grid edge markets. Across many verticals, from meters, to DERs, to eMobility assets, grid technologies are a critical and central investment point to enable deployment.

Emerging Complexity and Assets at the Grid Edge

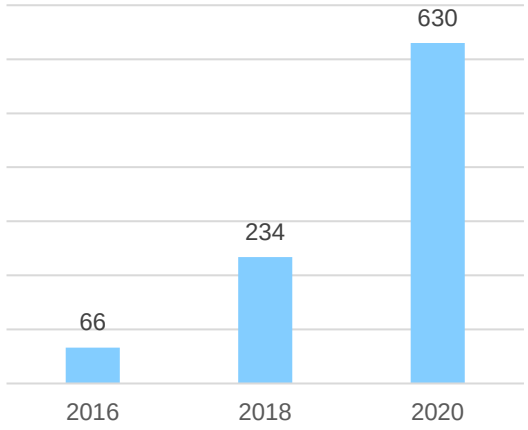
Surging Grid Edge activity in the last number of years is necessitating utilities to invest in flexibility management technologies.

AMI Deployment
(U.S. meters, millions)



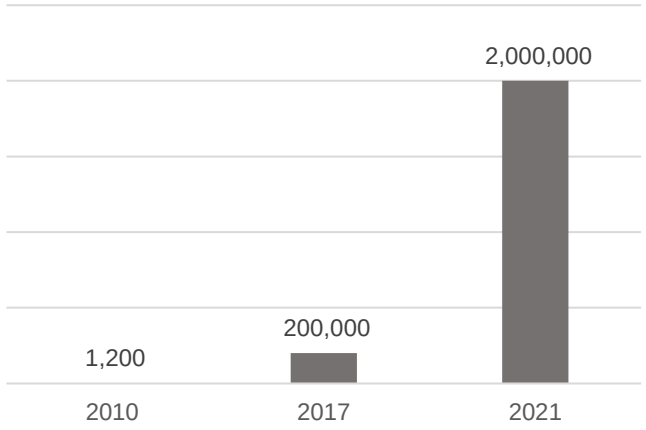
EIA Annual Electric Power Industry Report (2012 – 2020)

Distributed Storage
(U.S. capacity, MW)



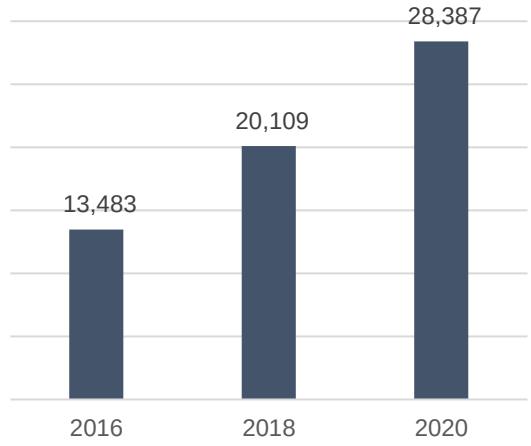
EIA Annual Electric Power Industry Report (2012 – 2020)

Electric Vehicle Sales
(U.S. sales)



IEA Global EV Data Explorer (2012 – 2021)

Distributed PV
(U.S. capacity, MW)



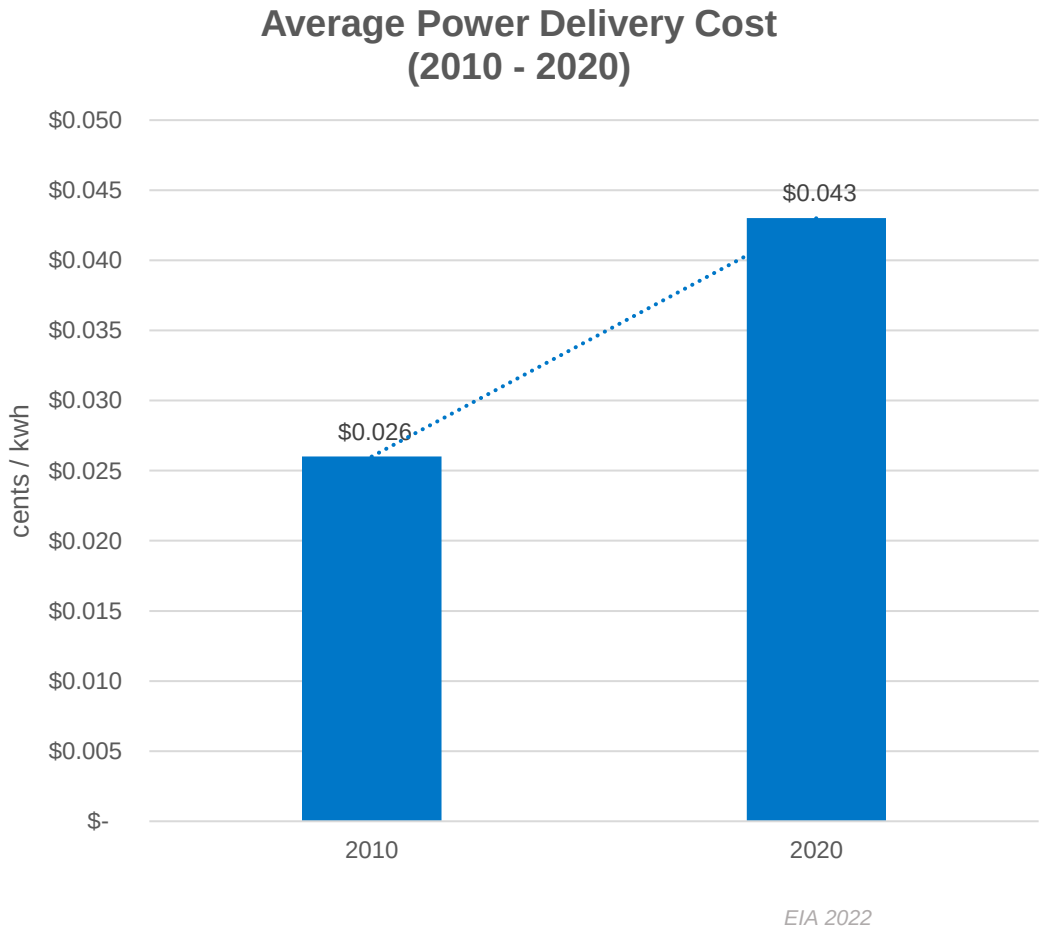
EIA Annual Electric Power Industry Report (2012 – 2020)

Indigo ADVISORY

Grid Tech – The Cost Imperative

As the cost of delivering power is increasing, utilities can leverage Grid Tech to defray high fixed costs and improve grid efficiency.

- The costs of the infrastructure needed to deliver power rose from 2.6 cents per kilowatt-hour in 2010 to 4.3 cents per kWh in 2020 — nearly equal to the cost of generating the power itself according to the EIA.
- Power Delivery includes maintaining, replacing and building new transmission and distribution grids, plus the management of other equipment like transformers and meters.
- As we enter a new decade, keeping this cost increase in line will serve a multitude of stakeholders well. Indeed, utilities and equipment manufacturers have reported to NIST that their costs for integrating non-interoperable equipment and systems ranges from $140 million to $1 billion per year per firm.



EIA 2022

Indigo ADVISORY

Carbon Abatement Impact – Tackling Technical Losses

Grid Tech has both an enabling and direct impact on carbon abatement.

Indirect Emission Enabled by Grid Tech

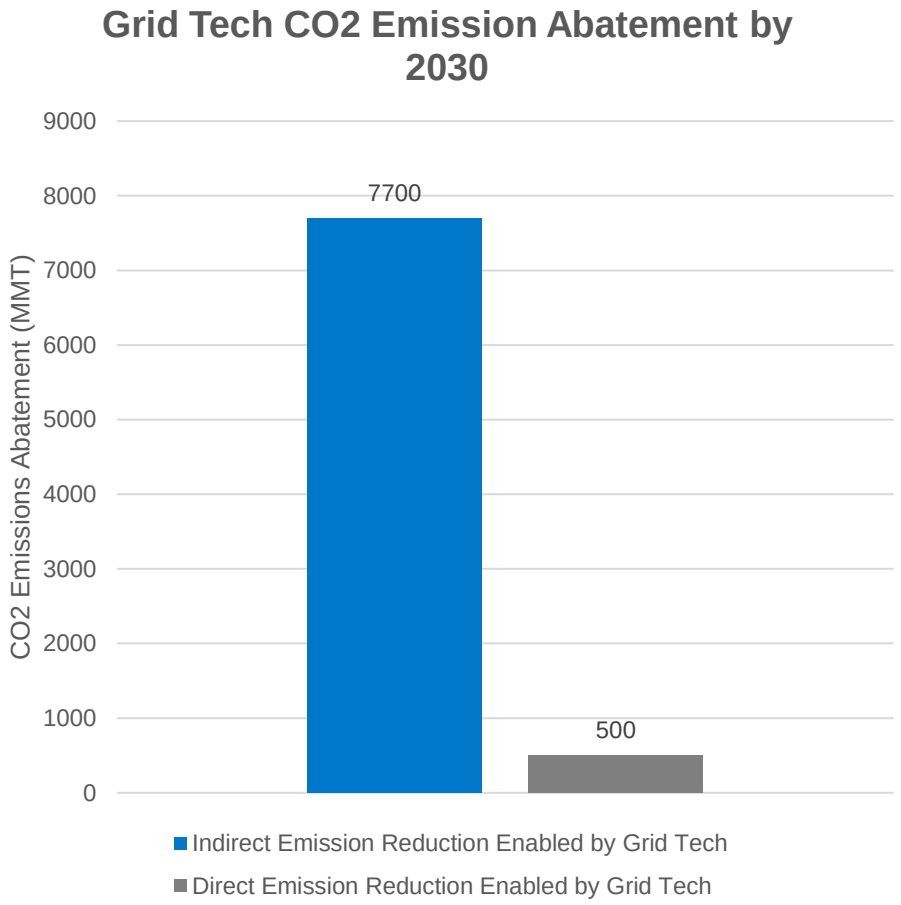
- To achieve net-zero in 2050, the Electricity & Heat sector must decarbonize by **7,700 MMT of CO2** by 2030 according to the EIA
- This emission abatement schedule cannot occur without investment in Grid Tech solutions.

Direct Emission Enabled by Grid Tech

- The grid suffers from technical losses each year which require utilities to produce more power to make up for inefficiencies.
- Investment in Grid Tech can solve these inefficiencies and directly avoid **500 MMT of CO2 emissions**
- That is approximately **6.5%** of the total decarbonization effort needed for the Electricity & Heat sector by 2030.

Comparison Analysis

- The direct carbon reduction potential of Grid Tech is **12.5x more** than the amount of carbon reduced by CCUS in 2020.
- The amount of carbon abated by CCUS in 2020 is about **8%** of the direct carbon reduction potential of Grid Tech.



International Energy Agency (IEA) & ARS Technica

Indigo ADVISORY

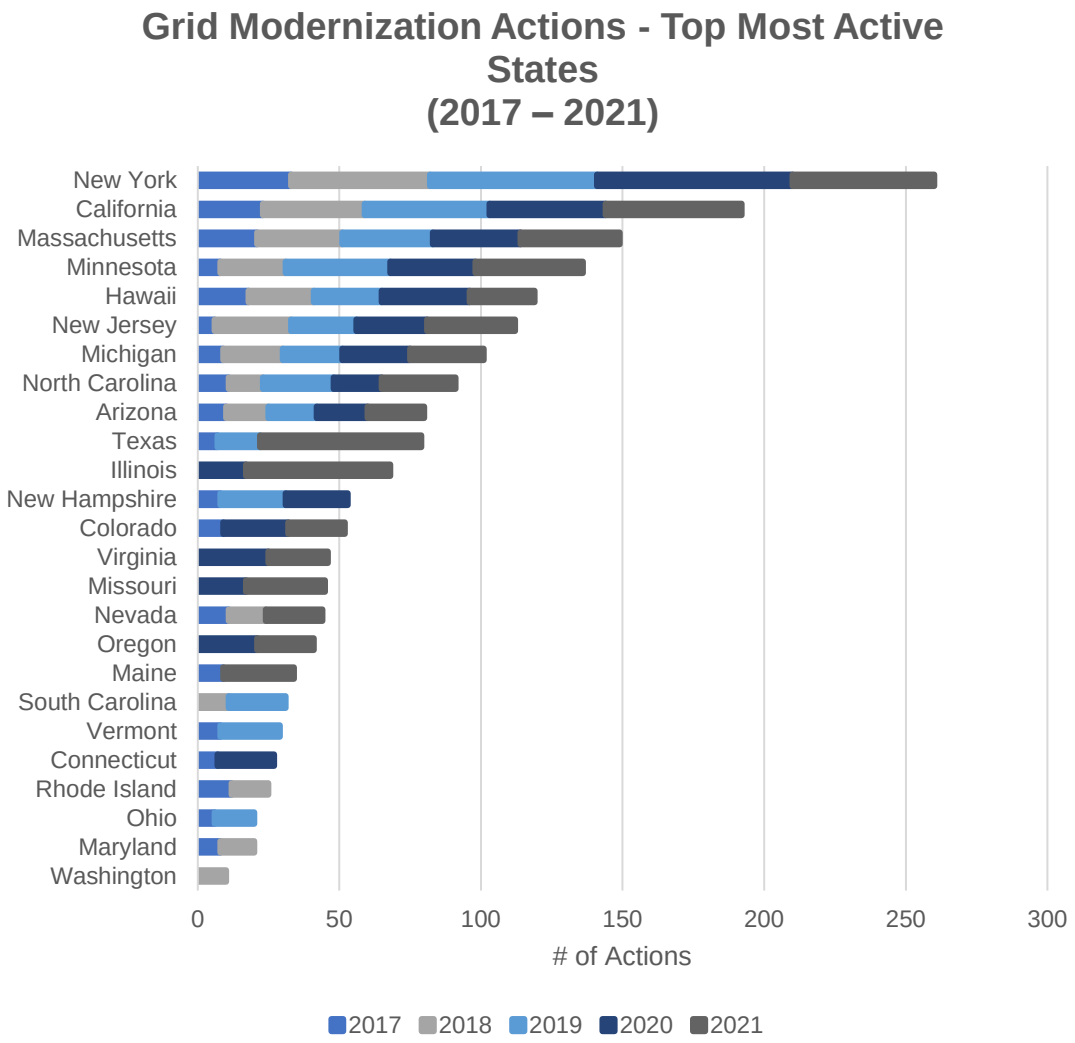
How the Regulatory Environment Drives Deployments

The Regulatory Imperative

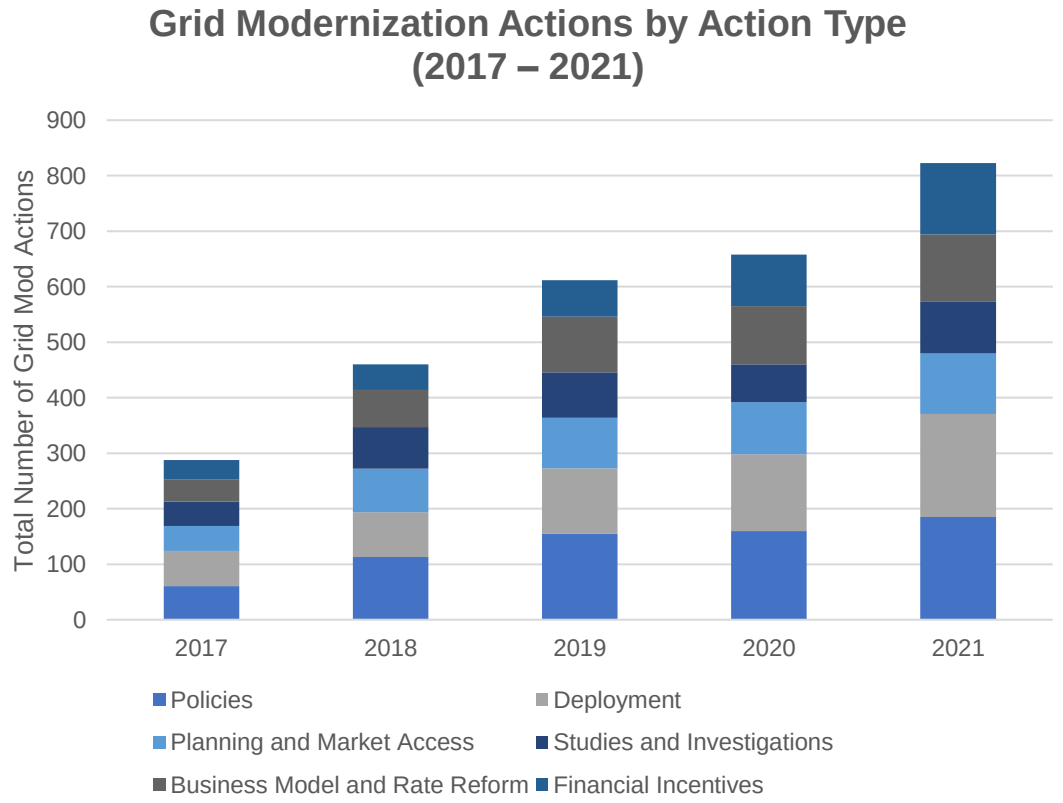
Central to the growth of the Grid Tech market is a conducive regulatory environment. In the US, State legislatures and utility commissions play an important role in modernizing the grid and through years of coordinated modernization plans, utilities, in the main, have the technical foundations in place adopt new solutions. Indeed, the regulatory approach to Grid Tech is changing. While several states require utilities to submit integrated resource plans (IRPs) for approval by state regulators, there is a trend to expand this concept to integrated distribution system planning with the overarching goal to establish a process that will allow the system to adopt new technologies more seamlessly. In addition, several states are adopting Next Generation Distribution System Platform (DSPx), using DOE grid architecture principles to develop holistic plans that can guide grid modernization efforts. The goal is to help plan and facilitate grid modernization decision processes, so they better align the expectations of regulators, utilities, and technology developers. These efforts have been initiated by state public utility commissions in several states, including California, Hawaii, Minnesota, New York, and Ohio. What is evident across these areas is a significant imperative to devise a more comprehensive understanding of Grid Tech innovation and how to best integrate market developments from a product and service perspective.

In terms of empirical activity, analysis of NC Clean Energy Technology Center who track Grid Modernization Actions by State annually suggests that, nationally, the pace and focus of regulatory actions are significantly increasing year over year for power companies. Indeed, States such as New York and California have seen over 150 actions each over the past 5 years. In addition, new regulatory models are emerging that are accelerating the pace of change in the industry. Traditional regulation has often involved rate basing technology investment over long periods of time and as such allowing for accounting certainty and stable customer costs. However, with new investment in, for example, cloud-based technologies (over three quarter of utilities use cloud-based solutions) this paradigm is changing as grid tech accounting matures. For example, Pennsylvanian regulators allowed Duquesne Light to treat cloud implementation costs as a regulatory asset, New York regulators allowed utilities to prepay for cloud services and treat that expense as part of their rate of return, and Alabama Power PUC established a regulatory asset to amortize and earn a regulated rate of return on software investments that include the cloud.

Grid Modernization Actions - Most Active States



Various states are taking steps to modernize their grid through increasing Grid Modernization filings over the past 5 years.



NC Clean Energy Technology Center

Submarket Analysis

Market Definition and Trend Analysis

Indigo ADVISORY

Submarket and Application Trends - Section Brief

- There are 6 discrete submarkets that comprise Grid Tech with approximately 175 use cases served by 1000’s of vendors both incumbent and startup. Use cases span the utility value chain and employ a variety of frontier technologies.

- The constituent submarkets are as follows from largest to smallest in valuation: Core Systems ($53.68 Bn), Flexibility ($44.75 Bn), eMobility ($18.81 Bn), Robotics & Connected Worker ($8.14 Bn), Optimization Technologies ($7.25 Bn) , and Digital Asset Management ($6.72 Bn).

- In terms of vendor activity, we expect to see consolidation in the eMobilty and Flexibility submarkets as they mature and a select number of vendors continue to gain market share.

1. Core Systems

Market Overview

In recent years, as innovations in software have proliferated throughout the power sector, utilities have been opting for more agile, integrated systems of management. The Core Systems submarket encompasses new and existing functionality that utilities are deploying to either supplement or supplant legacy systems. These applications include Advanced Distribution Management Systems (ADMS), Customer Information Systems (CIS) and Customer Relationship Management (CRM), Geographic Information Systems (GIS) and Weather Forecasting Systems, and others. Utilities can leverage these software solutions to enable customer digital activation through utility marketplaces, access more grid control and visibility through tools like volt-Var optimization (VVO) and facilitate adoption of DERs through accurate weather forecasting.

Illustrative Applications

- Fault Location Isolation & Service Restoration (FLISR)
- Demand & Supply Forecasting
- Geographic Information Systems (GIS)
- Wildfire Detection
- Weather Forecasting
- Advanced Distribution Management Systems (ADMS)
- Tariff Design and Analytics

Trends We're Watching

- **Supercharge Old Systems** – As new ideas and tech permeate the power sector, legacy applications such as Distribution Manage Systems (DMS), Outage Management System (OMS), Geographic Information Systems, etc., are experiencing significant refreshes.
- **Improved Energy Production Predictions** – There are a variety of channels that utilities can leverage to increase their control over the grid, including ADMS and GIS systems where necessary; however, as waves of DERs come online, gid management will become more reliant on predicting the production capacity of these weather dependent resources. Vendors such as Climavision and Tomorrow.ai use AI-based weather forecasting algorithms to accurately project incoming weather patterns that might affect load on the grid. This increased visibility will enable utilities to better manage their overall energy production.
- **Customer Digital Activation** – The electrical end-use landscape will change drastically in the near future. The EIA forecasts that over 8% of total electricity generation will come from either residential, commercial, or industrial onsite solar PV systems by 2050. Consumers are no longer passive homeowners, but have transformed into *prosumers*, customers that both consume and produce energy via the grid. Vendors such as Uplight have solutions to boost digital customer engagement, empower customers with home energy reports, and build a utility marketplace for trusted energy-related products.

2. Digital Asset Management

Market Overview

Although it is a mature market, Digital Asset Management has been elevated by AI/ML fueled software solutions and the emergence of the one-stop-shop Asset Performance Management (APM) platform. Utilities have at their disposal algorithms to make sense of the data deluge that is stored in historians and maximize their assets' potential. With the adoption of a robust digital asset management strategy, utilities can reduce unplanned outages and unnecessary planned work, opting for predictive forecasting and financially optimized maintenance.

Illustrative Applications

- Remote Transformer Temperature Monitoring
- Predictive Vegetation Management
- Rotor Flux Monitoring System
- Autonomous Wind Turbine Inspections
- Blade Tip Health Monitoring
- Fiber Optic Temperature Monitoring
- Hydroelectric Turbine Monitoring
- Climate Risk Analysis of Infrastructure

Trends We're Watching

- **Asset Performance Management Platform – Utility** Asset Performance Management strategies (APM) can vary in maturity and digital development. However, as incumbents absorb software-based startups, the submarket has transitioned from majority point applications to platforms. Vendors advertise one-stop-shop software solutions for utilities to aggregate operational data, analyze trends, and co-optimize across enterprise assets.
- **Preventative vs. Predictive** – It is important for utilities to make distinctions between solutions that are preventative and predictive. Common forms of APM are preventative; that is, they monitor real-time data to detect anomalies in performance before there is a failure. This approach can alleviate expensive failures and increase overall reliability of service, but it is not the most advanced approach to asset management. There are various types of predictive maintenance, such as Reliability Centered-Maintenance, statistical/regression-based methods, or machine learning. Unlike preventative maintenance, predictive maintenance provides utilities with a more comprehensive set of insights ranging from expected asset lifetime, rate of failure, correlating failure factors, and others.
- **Digital Twins** – As the DAM submarket matures, there has been an emergence of solutions that provide utilities with 3D digital representations of assets known as digital twins. While they can come in different packaging, digital twins allow for the utilities to monitor asset performance real-time, visualize meaningful operational insights, and toggle asset parameters to simulate various events.

3. Robotics & Digital Worker

Market Overview

Robotics & Connected Worker delivers empowerment and productivity where worker meets asset. Unlike other submarkets, Robotics & Connected Worker solutions integrate existing hardware like worker wearables and Unmanned Aircraft Systems (UAS) with Extended Reality (XR) and AI-based software to modernize antiquated utility workforce processes and management systems. Technology such as smart helmets and Virtual Reality goggles improve safety conditions for workers through locational tracking, real-time digital assistance, and virtual simulation for difficult and dangerous scenarios. Other use cases expedite maintenance and repair jobs, ultimately slashing utility O&M costs and boosting worker productivity. As such, a robust Robotics & Connected Worker initiative is essential for any utility's digitization plan.

Illustrative Applications

- UAS Image-Based Inspection (IBI) for Grid Infrastructure and Renewables
- AR Software and Wearables for Real-time Asset Maintenance
- XR Software for Safety and Training Simulations
- Additive Manufacturing (3D Printing) for Operational Equipment
- Digital Work Force Management System (WFMS) for Job Execution

Trends We're Watching

- **Transfer Knowledge –** according to the U.S. Bureau of Labor Statistics, approximately 50% of P&U sector employees are age 45 and above. In order to replace the imminent wave of retirement of valuable workers, utilities can find ways to formalize their responsibilities and expertise through deployment of knowledge retention and automation technologies.
- **Prioritize Safety** – electric utilities are at high risk for serious injuries and fatalities (SIFs) with an exposure rate of 32% according to DEKRA Organizational Safety. Innovative startups such as Urbint and RealWear are leveraging AI-based risk management software and XR wearables to predict high risk locations and provide real-time assistance and visualization tools in the field.
- **Increase Productivity** – as the global skilled worker shortage rises to 85 million in 2030, utilities must equip their workforce with knowledge and capabilities to perform their jobs safer, faster, and more accurately. Currently, the sector should increase deployments of innovative technologies such as XR and smart wearables to boost worker efficiency on-site to address changes in the labor market.
- **Leverage Frontier Technology** – new startups such as Buzz Solutions are challenging aging utility systems by developing AI/ML-based software solutions to conduct routine grid infrastructure inspections and maintenance with Unmanned Aircraft Systems (UAS). These technologies are currently on the market and have the potential to immediately reduce O&M costs for utilities once deployed.

4. Optimization Technologies

Market Overview

As constructing new transmission assets is costly and oftentimes inefficient, utilities need alternative solutions to satisfy the accelerating demands on the grid. Optimization Technologies offer the opportunity to implement frontier software and hardware developments to retrofit the grid and maximize the investment in existing transmission and distribution infrastructure. Innovations such as Grid Enhancing Technologies (GETs), which include Dynamic Line Rating (DLR), Topology Optimization and others, along with hardware refreshes such as the carbon-core conductor, strengthen the capabilities of the grid through increasing overhead line capacity, heightening situational awareness, and buttressing weatherization efforts. Rather than undertake expensive capital projects, utilities can defer high fixed costs though supplemental Optimization Technologies solutions.

Illustrative Applications

- Dynamic Line Rating (DLR)
- Advanced Power Flow Controls
- Topology Optimization
- Various Power Electronics

Trends We're Watching

- **Grid Enhancing Technologies (GETs) –** In order to accommodate rising energy demand and penetration of renewables, utilities must fundamentally reconfigure the grid. An innovative group of technologies known as GETs will be critical in facilitating this transition due to their ability to increase overhead line capacity, ensure safety, and provide much needed situational awareness for grid operators. Groups such as the WATT Coalition, a consortium of GETs vendors and utilities, advocate for the widespread adoption of these technologies due to their significant potential to reshape the grid. The top GETs include Dynamic Line Rating (DLR), Advanced Power Flow Controls (APFC), and Topology Optimization.
- **Innovative Hardware –** Antiquated grid devices are being supplanted by more efficient and reliable pieces of hardware. Vendors such as TS Conductor and CTC Global have developed carbon-core conductors, a significant update to existing steel-based conductors, which increase overhead line capacity and are more resistant to heat and extreme weather. These types of solutions are important for utilities, as transmission assets will become increasingly exposed to climate risks extreme due to frequent extreme weather events.
- **Arming the Grid Edge –** Although smart meters are now widely deployed across the grid, utilities have difficulty deriving optimal value from this hardware. Vendors Utilitdata and NVIDIA have partnered to develop a software-defined smart grid chip which leverages AI to bolster edge computing and facilitate DER integration and resiliency.

5. Flexibility

Market Overview

The power sector is experiencing fundamental market disruptions from digitization to decarbonization. As they navigate this changing ecosystem, utilities should look to grid flexibility as their keystone. At its core, the Flexibility submarket covers types of innovative technology that provide load balancing and resilient energy alternatives in times of uncertainty. Technologies could include microgrids for islanding during outages, demand response systems for peak load curtailment, or battery and building management systems for added flexible capacity. Other solutions such as Distributed Energy Resource Management Systems (DERMS) and Virtual Power Plants (VPPs) unlock residential DERs full value through aggregation and wholesale market access. Utilities should leverage innovative startups to procure new and elastic modes of delivering energy services that do not rely on traditionally restricting systems.

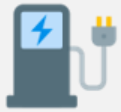
Illustrative Applications

- Demand Response Management Systems
- Virtual Power Plant Software
- Microgrids Control System
- Market Platforms for PPA Trading
- Automated M&V
- Battery Management System
- Distributed Energy Resource Management Systems (DERMS)

Trends We're Watching

- **Drive Deep Decarbonization –** The grid will experience a colossal influx of renewable penetration within the next decade. The Department of energy (DOE) estimates that the U.S. must install an average of 30 GW of solar capacity per year between 2021-2025 and 60 GW per year from 2025-2030 in order to achieve emission abatement goals**.** Flexibility solutions like **DERMS** and **Battery** and **Building Management Systems** will equip operators with the capability to combat the diurnal and seasonal challenges that will arise from deploying a deluge of solar capacity.
- **Provide Resiliency** – According to the IPCC, intensity and frequency of extreme weather events have been on the rise globally. Investing in technologies such as **microgrids**, **V2X**, and **DERMS** will enable a more agile and hardened grid that is high functioning during uncertainty.
- **Access New Markets** – As FERC Order No. 2222 comes online with ISO/RTO compliances, DERs and BTM generating resources are eligible to compete in wholesale markets. Utilities could build aggregation services in-house or through 3rd party VPP/DERMS providers in order to be establish early market share in the wholesale Energy, Capacity, and Ancillary Services markets. Overtime, new prosumer markets will emerge as aggregation technologies develop.
- **Defer Capital Spending** –Unlocking previously inaccessible generational capacity.

6. eMobility



Market Overview

With transport accounting for a quarter of global greenhouse gas emissions, electrification will be key to achieving ambitious environmental goals. As a result, EV adoption is set to grow from about 5% of the fleet today to up to 15% by 2030. While today's grid impact from EV charging infrastructure is modest, demands could change rapidly. Utilities can reduce grid impact by counting on integrated software embedded in EVs and charging locations. Integrated software allows utilities to have remote monitoring and control of EV chargers. Operators can then aggregate and shift EV loads to balance the grid. In addition to home charging, utilities can manage the power needs of the increasing number of public, corridor, and fleet charging sites on the multi-megawatt scale.

Illustrative Applications

- EV Analytics
- Grid Services (V2G, Integrated Volt-Var Optimization, and Transactive energy, load control)
- AI-Powered EV Detection and Estimation
- Passive and Managed Charging
- EV Market Places
- EV Roaming
- EV Billing & Payments

Trends We're Watching

- **eMobility Revolution –** Utilities should build a complete set of capabilities in a step-by-step process in order to have full situational awareness of every EV from the grid control room. Some of the necessary functions include EV charger registration, connection acceptance, modeling, monitoring, scheduling, market interfacing, optimization and control. On a macro level, optimal power distribution and load sharing is vital to ensure that infrastructure is flexible during peak usage. Smart technology and bi-directional charging will help manage challenges by gauging consumers' habits and adjusting in real-time. Improved robustness in current sensing and voltage sensing technology is helping provide connectivity with the grid to optimize energy consumption, similarly to smart thermostats that are sensitive to weather patterns.
- **Communications** - For the utility to interface in a consistent fashion with the myriad of individual and aggregated EV chargers, a standard communication protocol is required: IEEE 2030.5. This protocol is by far the most advanced for DER communications overall and has been well received by the Automotive industry.
- **EV's as Grid Assets** – *Balancing the load with managed smart EV charging* - Offering residential and commercial customers managed smart EV charging services is one way in which utilities can capitalize on the EV revolution while protecting the grid.

Looking Forward

Macro Trends and Outlook

Indigo ADVISORY

Looking Forward - Section Brief

- Tracking technological trends that occur from outside the power sector will serve companies well as very often these innovations find agency across the energy value chain.
- Power companies are not only innovating by partnering with the market over the past number of years, but also increasing their investment in patents for new industry technologies.
- Utilities will be well served by creating capability maturity backed technology roadmaps, scanning and scouting and deploying at scale where commercially available solutions exist.

Frontier Technology Trends we are Watching across all Markets

Artificial Intelligence

- Advances in image and data processing, computer vision and learning are transforming applications across the power sectors by combining various forms of disparate data

Smart cities

- The Coalition for Urban Transitions estimated that cities can cut emissions by about 90% by 2050 using proven technologies and practices.
- Gartner predicts more than 4 billion connected IoT devices in commercial smart buildings by 2028

IoT & Connected Devices

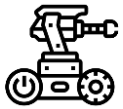
- Due to a vast deployment of IoT sensors and decreased processing costs new use cases are emerging across the value chain
- A key trend to watch here is the combination of AI and distributed intelligence

Digital Twin/Thread

- Increased use of scenario analysis modelling is improving system resiliency
- Overall optimization of asset performance and lifecycle is maturing

Digital Organization

- Scaling solutions from pilots becomes a key market differentiator with evolving focus from Chief Data Officers to Chief Digital Officers



Robotics

- UAVs (Drones), Agile Mobile Robots (Dogs), Autonomous Underwater Vehicles (AUVs/Subs), Wall-Climbing Robots (Climbers) and Specialty Robots
- In many instances, Robotic solutions need to be combined with other IT programs such as data processing, AI etc. to unlock true potential

Cyber Security

- As network architecture grows more complex due to a proliferation of sensor and communications , increased vulnerabilities become apparent
- Further integration of IT-OT architectures and processes are evolving to manage vulnerabilities in a more sophisticated way

AR/VR experiences

- Applications are gaining ground for remote expert use cases and combining real-time overlays for solutions analysis

Indigo ADVISORY

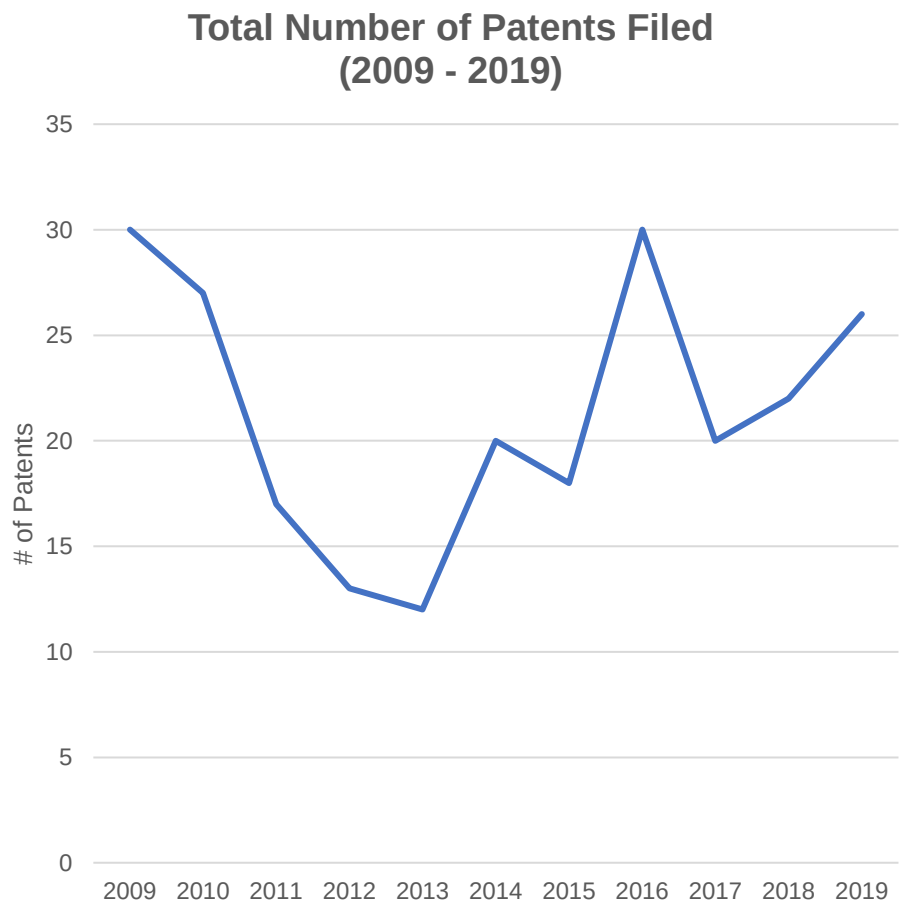
Grid Tech Macro Market Trends

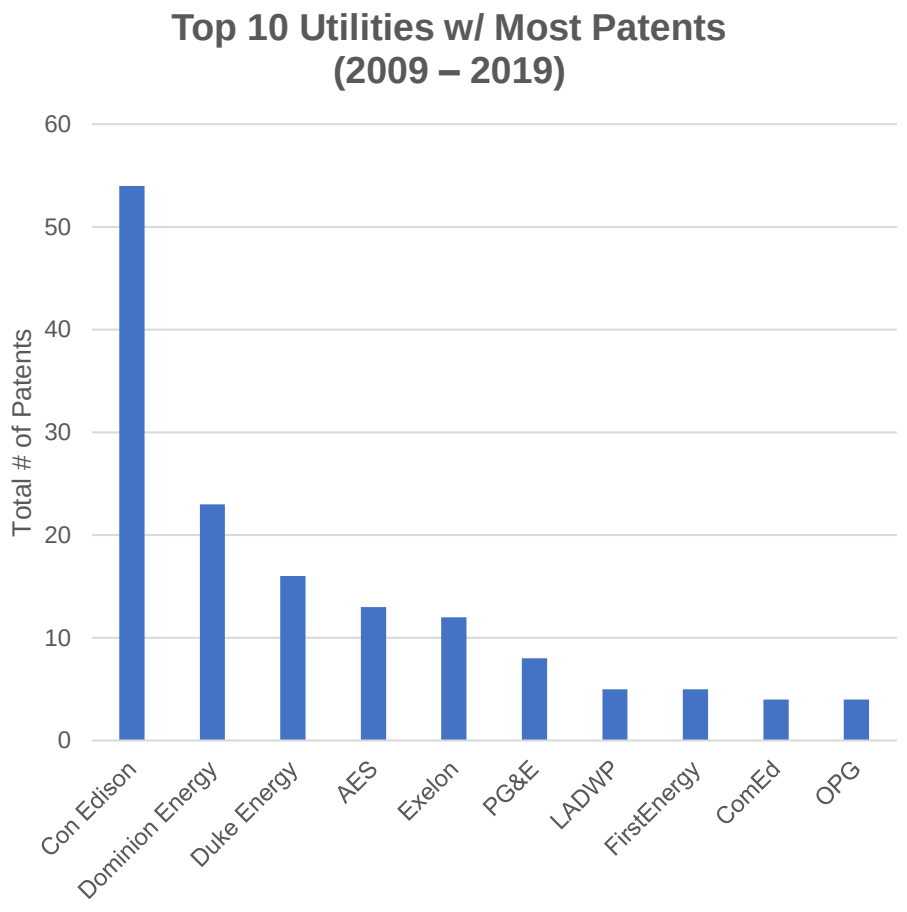
At present, there are multiple trends and technologies impacting the power sector; however, as we are in a period of increased investment, we expect several areas to rapidly evolve in the coming years:

1. **Solution Convergence** – Over the next decade, advancements in AI, distributed intelligence and robotics will impact a variety of sectors. For utilities, these trends combined with the dramatic changes in the energy transition such as distributed energy resources, increased proliferation of sensors on infrastructure, and behind the meter devices and demand management advances will unleash a variety of transformative use cases in the sector. For example, based on our analysis, approximately 10% of our vendors use AI/ML in their solutions.
2. **Robotics** – Robotics applications are gaining importance across the power sector as we move beyond research and development and see real world deployments. Solutions generally sit across 4 areas; UAVs (Drones), Agile Mobile Robots (Dogs), Autonomous Underwater Vehicles (AUVs/Subs), Wall-Climbing Robots (Climbers) and Specialty Robots. Across these solutions, benefits include improving efficiency, reducing labor costs, and, most importantly, avoiding operational risks.
3. **Distributed Intelligence** – The next generation of AMI will purportedly improve upon functionality of AMI 1.0 and accelerate DER penetration through embedding advanced computing power in smart meters at the grid edge.
4. **Intelligent Operations Centers** – As with the last wave of significant investment in the Power Sector, the range and sophistication of solutions available for utility control rooms, monitoring and diagnostics centers, and customer hubs are enabling power companies to build out capability in a cross functional capacity.
5. **Reduced Deployment Timeframes** – As power companies continue their transition to becoming technology companies, the speed to adopt new technologies, enhance systems and integrate innovation is increasing. Compared to a decade ago, we believe that utilities are becoming nimbler when deploying solutions.

Utilities are also Innovating across these Submarkets

Utilities are increasingly drawing on the core competencies in innovation by registering patents





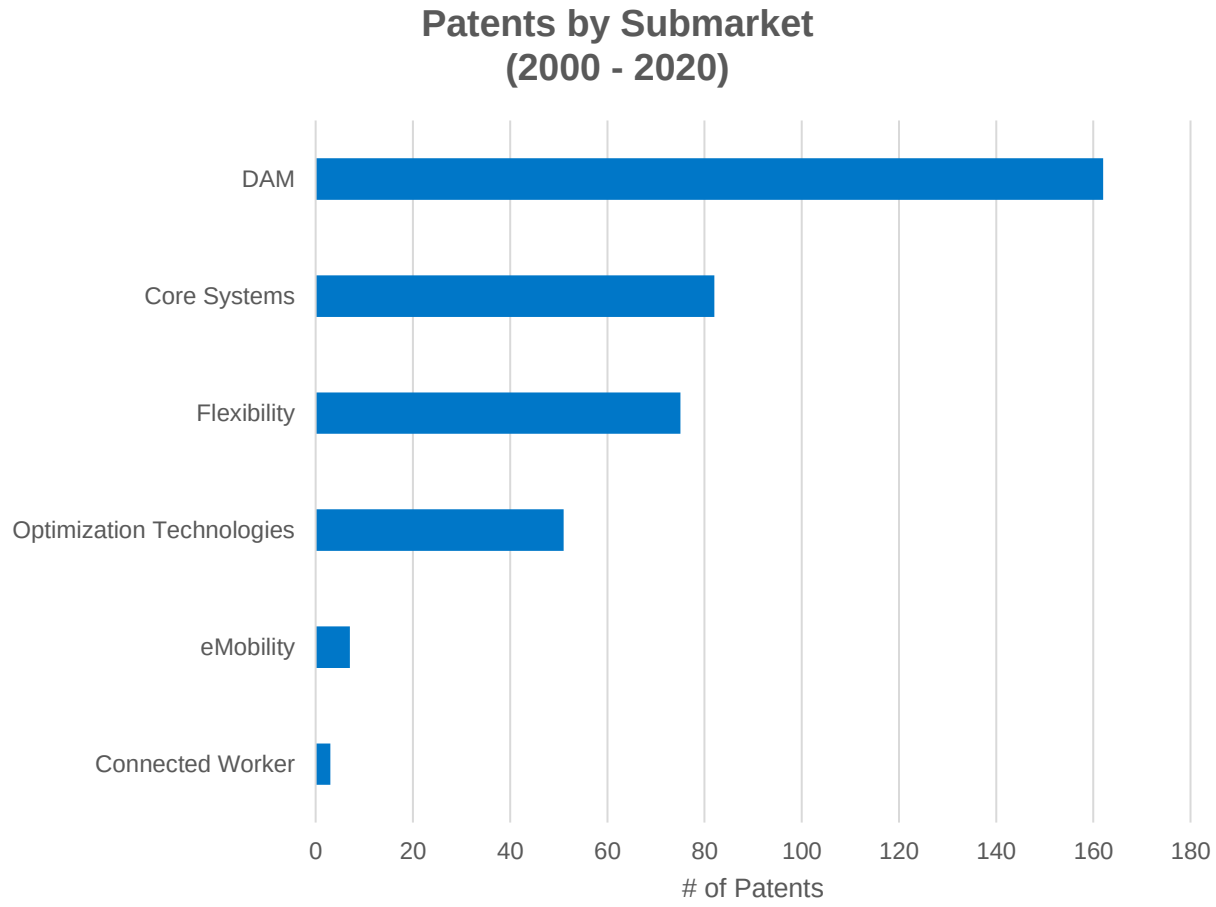
ADL Ventures

Indigo ADVISORY

Utility Patents Types by Submarket

Utilities are seeing opportunities to register innovation patents in select Grid Tech submarkets.

- **Owning Asset Management Solutions** – Rising expectations around reliability and fuel costs have incentivized utilities to find cost reductions through advanced forms of Asset Performance Management (APM). Utilities have graduated from reactive to preventative forms of maintenance and repair, opting for in-house development and control of asset management tools, service equipment, and sensor technology.
- **Grid of the Future** – In preparation for a fully bidirectional, modular grid, utilities have allocated internal resources to build advanced control solutions such as Fault Location Isolation & Service Restoration (FLISR) to better manage power flow and reduce outages.
- **In-house Orchestration** – Proprietary applications like Distributed Energy Resources Management Systems (DERMS) are being patented for improved DER interaction and control. This will boost utilities' autonomy when they scale VPPs or demand response programs as DERs continue to penetrate the grid.

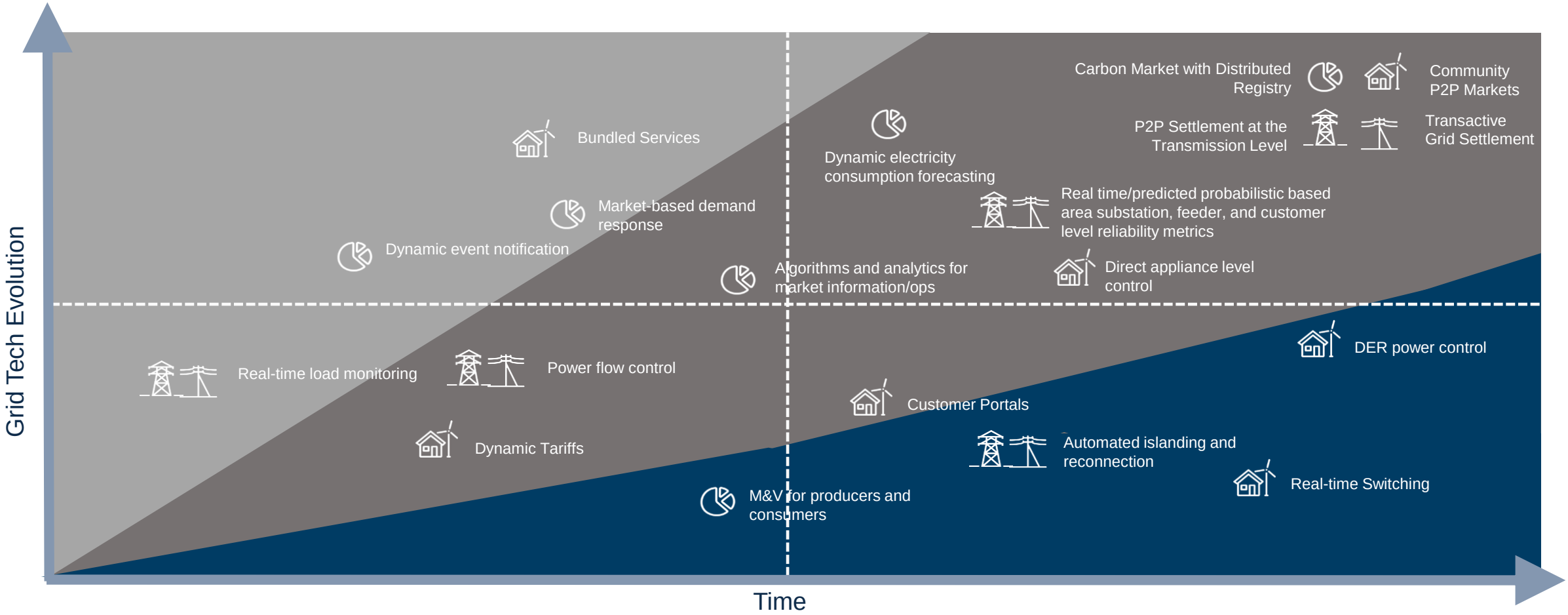


ADL Ventures

A Transactive and Dynamic System is Emerging

Looking Forward

As technologies mature and decarbonization progresses, new applications will emerge across the power sector at various speeds. The key to successfully navigating this transition is understanding the potential of various applications and their impact on the utility business model.



Indigo ADVISORY

Grid Tech – Capability Technology Mapping

Looking Forward

These are the conceptual strategic themes that utilities are pursuing to achieve digital innovation. Core in this journey is to pursue Theme 1 and 2 and monitor 3 as a direction setting objective. Creating a digital blueprint for a utility is key, as very often, various component parts are developing at different speeds albeit to an aligned vision.

1

Grid Tech Digital Foundation

- **Digital Architecture** – System, data and security principles aligned to a 'plug-n-play' digital grid
- **Digital Infrastructure** – Investments in sensors, communications and advanced software
- **Organization and Culture** – Agile, cross-functional and digital culture with a project focus

2

Grid Tech Digital Transformation

- **Digital Design** – Integrated digital and Physical Experience, digital front end processes, moving existing applications to the cloud
- **Value Chain** – Automated back-end processes, automated analytics and intelligence, end-to-end digitization, workforce productivity
- **Digital Hubs** – Building core capability and distributed centers of digital excellence alongside smart operations centers
- **Digital Capability** – Building capability in the integration of bulk and distributed renewables, new system requirements and the ability to integrate new technologies

3

Grid Tech Digital Innovation

- **Convergence** – integrated electric network with water, natural gas, transportation systems and other essential services to create more efficient and resilient infrastructure (e.g., "smart cities")
- **Integrate commercially available solutions** and decrease the time to deploy these innovative technologies. Focus on innovative data use, connectivity, mobility and the use of operational technology
- **Digital Labs and Open Innovation** – Continuous digital improvement on open architecture grids with seamless interoperability and data access
- **Innovative Technologies** – New digital business models and increased use of AI across the organization and grid

Looking Forward

Indigo has complied comprehensive data across the Grid Tech market. We are tracking vendors, use cases, and results. By diving into this market our aim is to highlight innovators, vendors, and solutions that can be commercially deployed at scale.

Post 2008, there was a surge of activity in the Grid Tech market. There are many lessons learned from the allocation of public capital from 2009's ARRA into the utility market and the evolution of utility's ability to acquire technologies from the marketplace. By taking a holistic value chain approach backed by a robust business case and evolving view of the future, utilities can ensure that they future proof digital investments. The greatest transformational potential for utility digitization is the ability to break down boundaries between energy sectors, increasing flexibility and enabling integration across entire systems. One thing is for certain: those utilities that lead in digital transformation will be the ones best placed for future challenges and opportunities.

Plan & Build - Develop robust interoperable Grid Tech Capabilty Aligned Roadmaps and understand that a utility's maturity across a standard methodology is paramount

Scan & Scout - Leverage our analysis of 1000's of Grid Tech Vendors and Use Cases to deploy commercially available solutions

Deploy & Track at Scale - Demonstrate to customers and regulators the enormous value of scaling digital solutions

Indigo ADVISORY

Report Terms and Conditions

Ownership Rights
All reports are owned by Indigo Advisory Group protected by United States Copyright and international copyright/intellectual property laws under applicable treaties and/or conventions. User agrees not to export any report into a country that does not have copyright/intellectual property laws that will protect Indigo Advisory Group's rights therein.

Grant of License Rights
Indigo Advisory Group hereby grants user a personal, non-exclusive, non-refundable, non-transferable license to use the report for research purposes only pursuant to the terms and conditions of this agreement. Indigo Advisory Group retains exclusive and sole ownership of each report disseminated under this agreement. User agrees not to permit any unauthorized use, reproduction, distribution, publication or electronic transmission of any report or the information/forecasts therein without the express written permission of Indigo Advisory Group. Users purchasing this report may make a report available to other persons from their organization at the specific physical site covered by the agreement but are prohibited from distributing the report to people outside the organization, or to other sites within the organization.

Disclaimer of Warranty and Liability
Indigo Advisory Group has used its best efforts in collecting and preparing each report. Indigo Advisory Group, its employees, affiliates, agents, and licensors do not warrant the accuracy, completeness, correctness, non-infringement, merchantability, or fitness for a particular purpose of any reports covered by this agreement. Indigo Advisory Group, its employees, affiliates, agents, or licensors shall not be liable to user or any third party for losses or injury caused in whole or part by our negligence or contingencies beyond Indigo Advisory Group 's control in compiling, preparing or disseminating any report or for any decision made or action taken by user or any third party in reliance on such information or for any consequential, special, indirect or similar damages, even if Indigo Advisory Group was advised of the possibility of the same. User agrees that the liability of Indigo Advisory Group, its employees, affiliates, agents and licensors, if any, arising out of any kind of legal claim (whether in contract, tort or otherwise) in connection with its goods/services under this agreement shall not exceed the amount you paid to Indigo Advisory Group for use of the report in question.

insights@indigoadvisorygroup.com

+1 212 203 6144

www.indigoadvisorygroup.com

@indigoadvisory

linkedin.com/company/indigo-advisory-group

450 Lexington Ave, 4th FL, 10017