Theme -A: Session -2

Evolving Architecture of The Net Zero Power System

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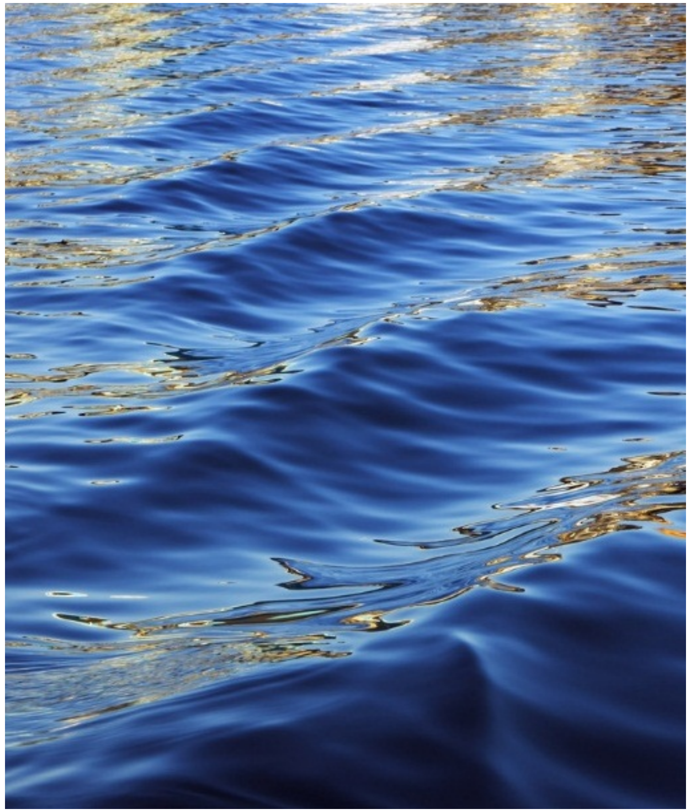

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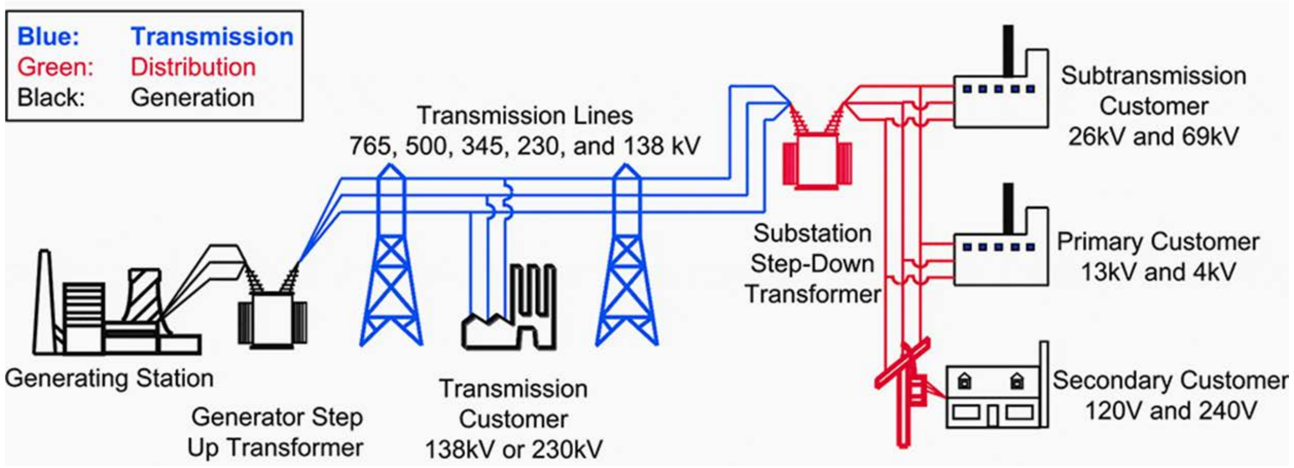
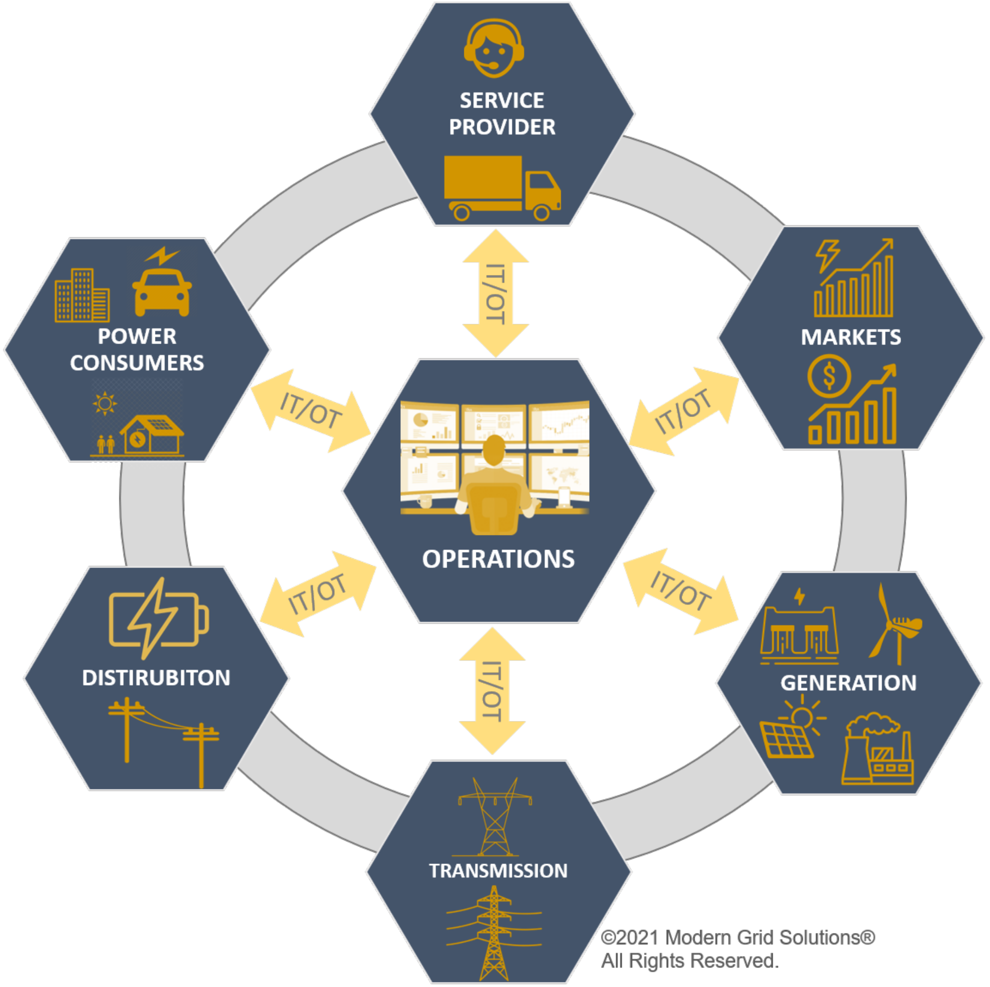
Making Smart Grids Business As Usual

Power Delivery Mechanism is changing





From **To**

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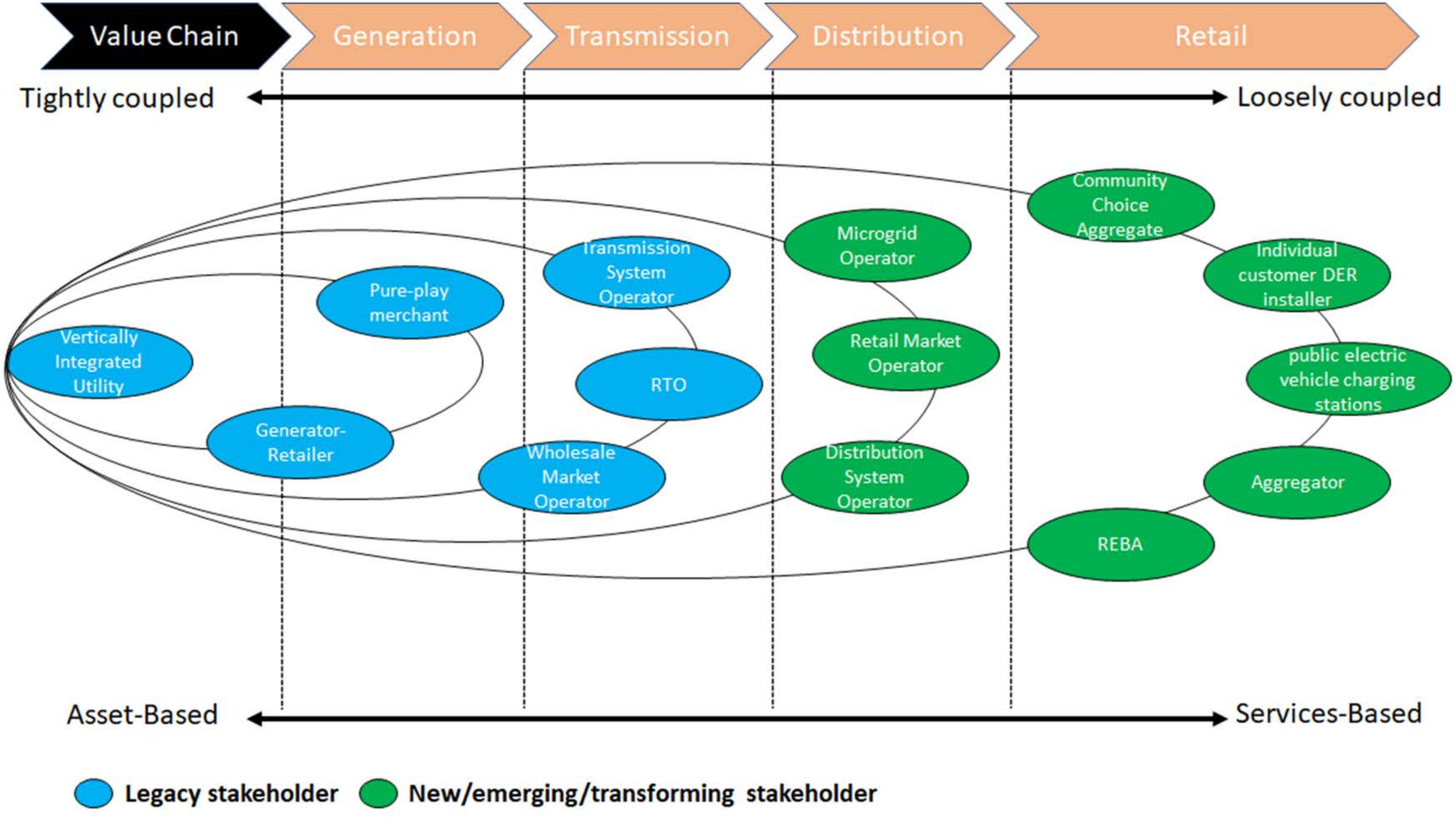
Changes along the energy value chain

New participants, new business models, new interactions, and new impacts to the system operations



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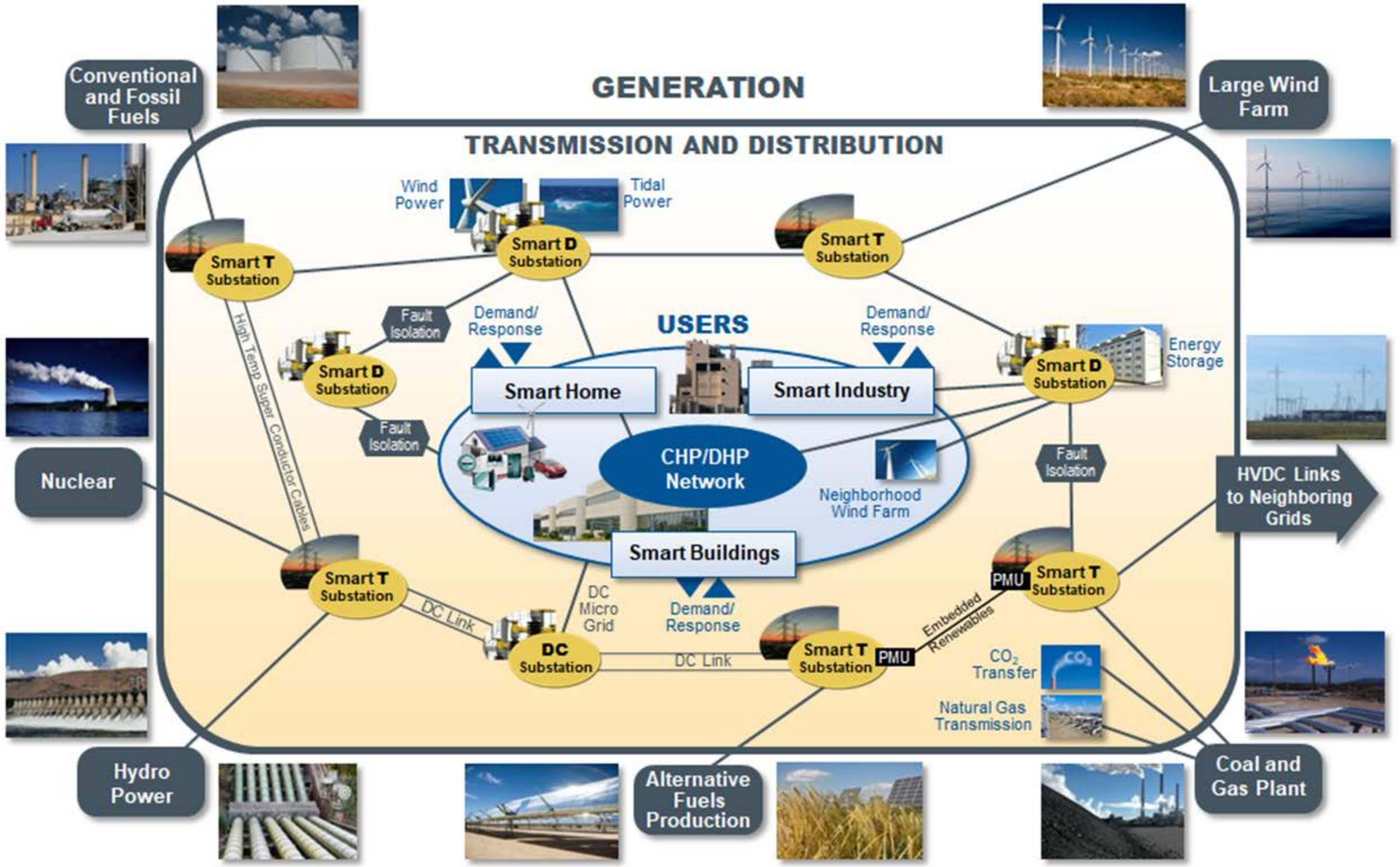
State of operational architectures and systems –



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- ❑ Core Systems
  - ❑ GIS
  - ❑ SCADA
  - ❑ ADMS
  - ❑ EMS
  - ❑ DER/Renewable Management and Optimization
  - ❑ AMI
  - ❑ CIS
- ❑ Non-Core Systems
  - ❑ Microgrid Operations
  - ❑ Grid-Edge Systems
  - ❑ In-Home and in-Building Systems
  - ❑ Demand Response
  - ❑ EV – Charging and V2G
  - ❑ IoT
  - ❑ BESS

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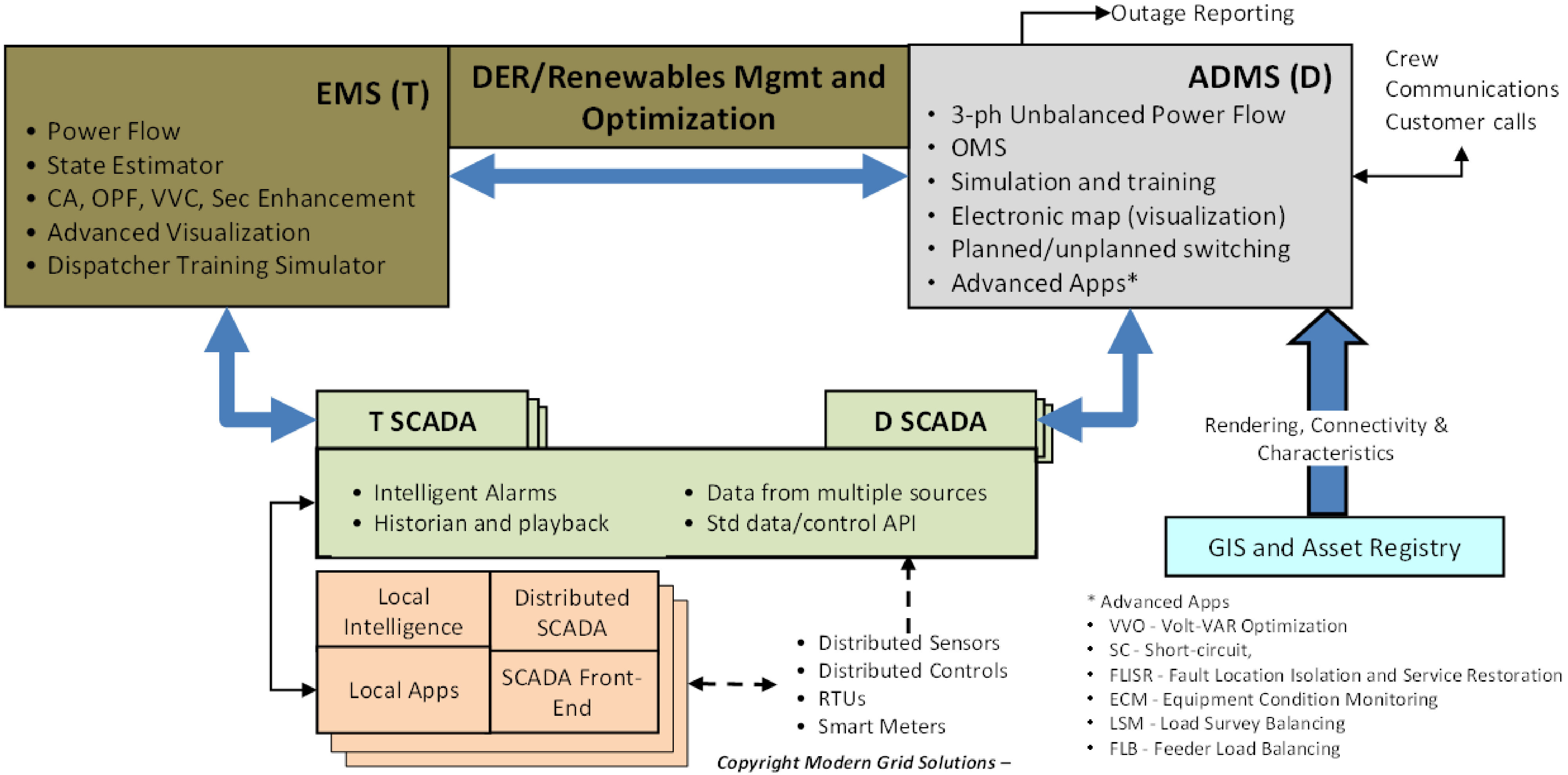
The continued need for integration –

The operational environment includes a set of systems, some legacy and still evolving, and others that are still new and on their way to maturity. They are also different architecturally and functionally. They need to work together seamlessly to enable the utility to functions as an entity delivering reliable power to its customers.



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Key characteristics of grid architecture of the future

- Two new types of buses: The IT/Data bus and the OT/Control bus
  - The **IT/Data bus** is responsible for carrying all the non-operational models and information necessary to drive utility decisions
  - The **OT/Control bus** is responsible for carrying all the operational data and control actions taken at the local level, centralized level, or other levels in-between, should they exist.
- Standardized and open interfaces: Implementing a **standards-driven architecture** allows the entire suite of solutions to become more flexible, nimbler, and capable of changing faster while keeping up with the industry's changing needs.
- Standardized tools and APIs: **Standardized utilities/tools/functions** are the crux to making the next generation of architecture work
- Standards-based and standardized models: Establishing and utilizing a standard allows for **modeling the various components** to be done in a structured manner using a common approach
- Self-registration of devices, applications and systems: The electric grid is like a computer network in that computer, automation, and power system devices and components are continuously added and removed from the grid's network. Today, these changes are manually managed and maintained. The ability of these devices to **"self-register" and advertise their existence** and associated connection points on the grid is essential

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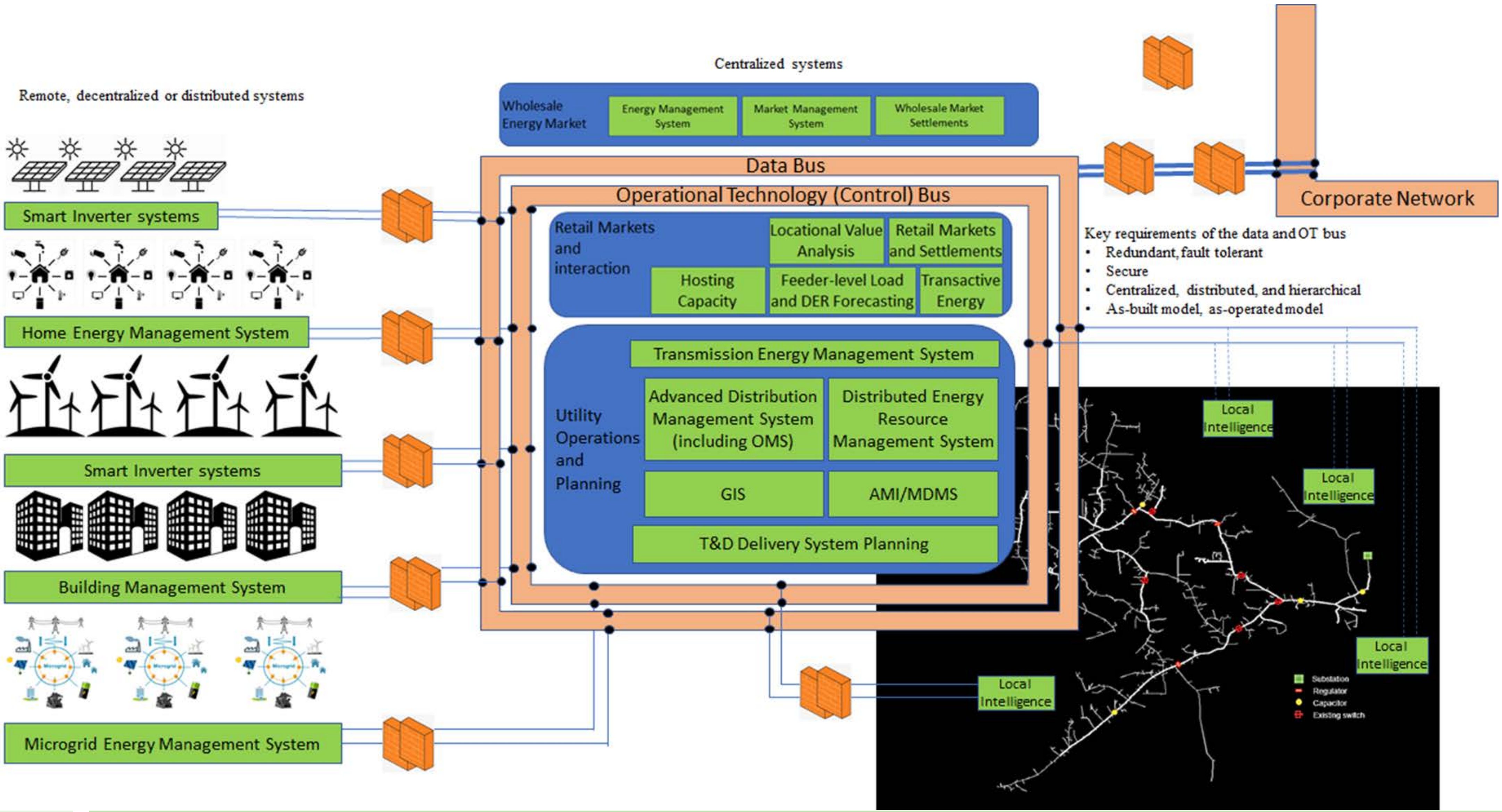
A Logical Architectural Construct of the Future Grid



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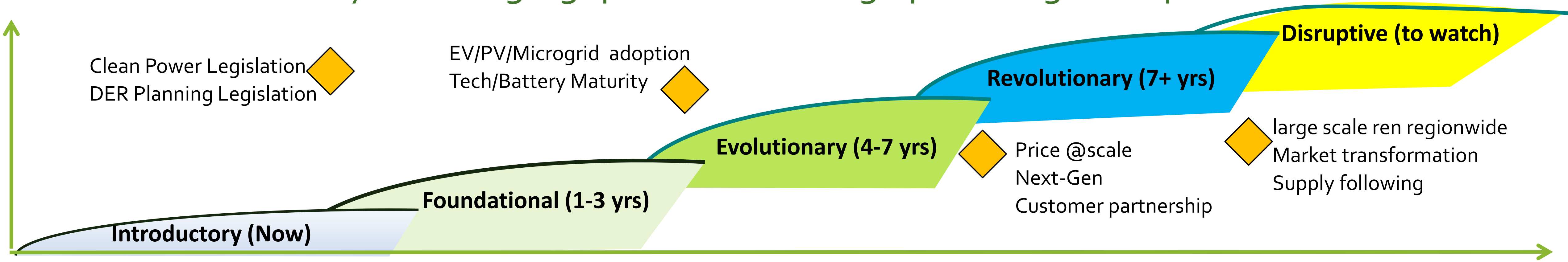
So – how do we get there – We build a roadmap

We start by watching signposts and setting up Guiding Principles



Guiding Principles

1. Align pace with customers' aspirations, and affordability.
2. Track/influence policy & regulatory changes – state and federal.
3. Spend prudently – spending customer's money
4. Watching technology trends and signposts to determine when / if need to act.
5. Keep an eye on the distance for disruptive technologies that might come to bear.
6. Learn from (pilots, Living lab, customer insights, etc.) – even if from other utilities experiences.
7. Focus on (1) Visibility insights and control, (2) Reliability, resiliency and grid optimization, (3) Distributed energy, resources integration, and (4) Customer empowerment and stakeholder engagement.

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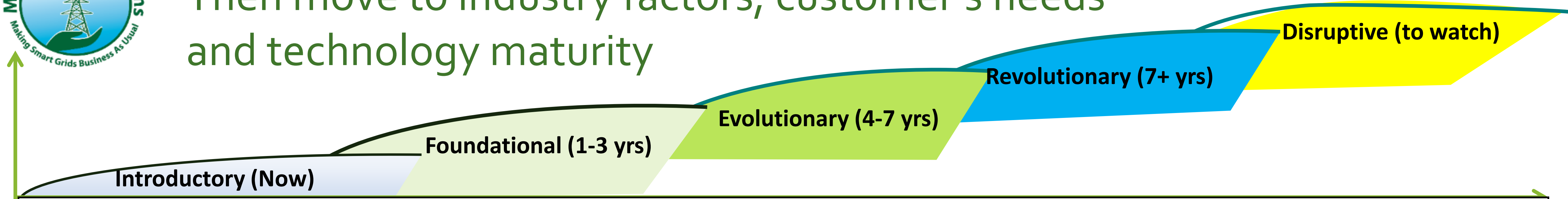
Then move to industry factors, customer's needs and technology maturity



As Industry Factors and Customer Needs Evolve (assumptions)				
Per utility • DER/DR/NWAs % penetration: Low • EV Penetration: Low, rising • Microgrids coming of age • Storage maturing	Per utility • DERs: 20 ckts, 100 MW rooftop PV • DR/NWA still opportunistic in use • EV Penetration. 75K – 100K • 3-5 microgrids • Targeted Storage implementations	Per utility • Planning: More NWA (+storage) • DR: increased use as an alternative • Transactive DR under consideration • DERs: 50 ckts, 500 MW rooftop PV • EV Penetration> 200K. • Microgrids in 10-15% utility territory	Per utility • DR: more prevalent as an alternative • Transactive DR getting common • NWA becoming more common • 20-25% microgrids in utility • EV/HV/ST 35-45% transport • DERs: 200 ckts and growing • Storage/NWA – commonplace	Per utility • DER/DR/NWA commonplace • Vehicle-to-Grid (V2G), >50% EVs • CCAs commonplace • 100% renewable; Cold fusion • Full rate unbundling
and Technology Matures (Assumptions)				
• AMI Mature, Comm still slow • 1st gen PV mature / inexpensive • 1st gen storage emerging • 1st gen EV gaining acceptance • 1st gen Microgrid – pilot mode • 5G communication emerging	• ADMS/AMI – Mature. DA/Grid-Edge automation emerging • 1st gen PV continuing price/perf imp • 1st gen storage maturing • 1st gen EV gaining critical mass • 1st gen microgrid evolving • 5G communication prevalent	• DA/Grid-Edge automation increasing • Solid-state PS components emerging • 2nd gen PV (+ storage) emerging • 2nd gen storage emerging • 1st gen EV (>20% penetration). Bigger impact in fleet. • Microgrid capability maturing. Commercially justifiable • Comm bandwidth and latency imp	• Real-time AMI introduction. • DA/Grid-Edge automation mature – intelligence embedded. • Solid state PS components evolving • Early 2nd gen PV (+ storage) • 2nd gen Storage – enhanced capacity / duration • 2nd gen EV emerging (V2G) • Microgrids at scale • Comm bandwidth and latency imp	• AMI//DA/Grid-Edge tech evolution • Solid state PS components common – complete w/remote intelligence • Ubiquitous Solar PV • Storage/DERs/ NWAs Pricing signals • Carbon sequestration • D grid conglomeration of microgrids • Nuclear fusion(?) • Comm bandwidth and latency imp

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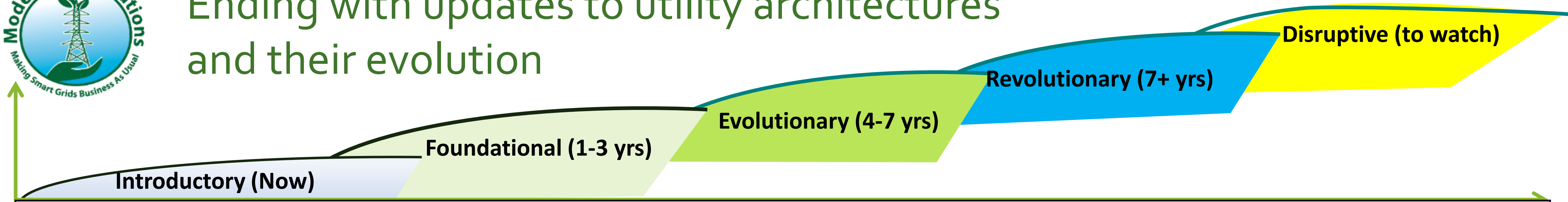
Ending with updates to utility architectures and their evolution



And utilities continue their focus on improvements in reliability, resiliency, safety, risks and new customer options (assumptions)				

• Initial Grid-Edge visibility for safety
• Beginnings of
  • Reliability at a lower cost
  • Operational flexibility
  • Early DER int for imp cust choice
	• Complete grid edge visibility
	• Targeted peak load shifting
	• Reliability at lower cost - Initial CBM
	• Alt cust DER partnership opportunities
	• Imp power quality in specific feeders
		• Early edge of grid control and dispatch
		• Expanded load shifting during peak
		• CBM for all high-risk equipment
		• Integrated Grid Planning is prevalent
		• Customer collaboration solidified
			• Edge of grid control/dispatch at scale
			• Carbon impact at 70% reduction
			• Consumer prosumers: customer as energy operations partners
				• Significant transmission investments
				• Retail markets transformation and CCA
				• Carbon neutrality – 100%

Driving a need for updates to utility architectures – Technology architecture evolution (Projection based on assumptions)				
• Cloud installations - awareness • Primary decision-making central • Limited to no intelligence at edge – basically independent devices • Data and OT bus just a concept • As-Operated state knowledge central • AI/ML in operations – awareness • Microgrid integration – manual • Open source S/W – awareness	• Cloud considered by small utilities • Primary decision-making central • Grid-edge intelligence emerging – still basically independent devices • Data and OT bus still a concept • As-Operated state knowledge central • AI/ML in operations – investigating / advisory • Microgrid integration – still manual • Open Source S/W – Still awareness	• More cloud apps – Small utilities (some large) • Primary decision-making still central • But grid-edge intelligence evolving – some coordination among devices • Data and OT bus emerging • As-Operated state knowledge central – but some knowledge at edge • AI/ML in operations – advisory / pilots. Aug reality introduced in field • Microgrid integration – increased awareness • Open source S/W – inc acceptance	• Cloud apps norm • Decision-making divided between centralized and grid-edge. • Grid-Edge intelligence mature – full PS state knowledge + coordination • Data and OT bus evolving • As-Operated state knowledge central – but full knowledge at edge • AI/ML in operations – evolving. Aug reality norm in field • Microgrid – Full integration • Open source S/W – Inc acceptance	• Next-gen app dev env emerging • More decision-making moving from centralized to grid-edge. • Grid-Edge intelligence normal –full PS state knowledge + coordination • Data and OT bus standard • As-Operated state knowledge central – but full knowledge at edge • AI/ML in operations – commonplace and in closed-loop operation. • Microgrid – internal to D Operations • Open source S/W – Inc acceptance

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Roadmap – Bringing it all together

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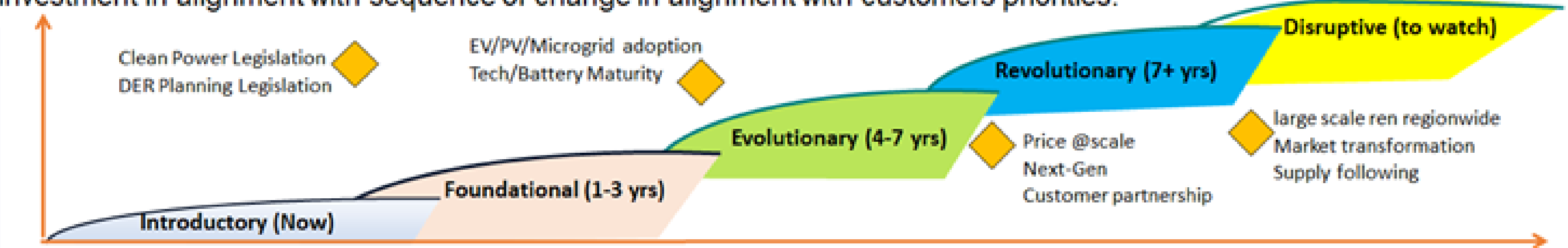
A roadmap defines investment in alignment with sequence of change in alignment with customers priorities.

Guiding Principles

1. *Align pace with customers' aspirations, and affordability.*
2. *Track/influence policy & regulatory changes – state and federal.*
3. *Spend prudently – spending customer's money*
4. *Watching technology trends and signposts to determine when / if need to act.*
5. *Keep an eye on the distance for disruptive technologies that might come to bear.*
6. *Learn from (pilots, Living lab, customer insights, etc.) – even if from other utilities experiences.*
7. *Assumptions informing immediate tactical tangible action plans in the short term.*
   - *Visibility insights and control*
   - *Reliability, resiliency and grid optimization.*
   - *Distributed energy, resources integration.*
   - *Customer empowerment and stakeholder engagement.*



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Conclusions:

"How should the transmission and distribution grid and their IT/OT architectures be redesigned to make it ready for the various new drivers?"

- Grid ecosystems and architectures must also evolve to lower the needed capital deployments as utilities deliver the "green" value to customers and stakeholders.
- The future holds integration and reliance on customer owned behind the meter assets, furthering the need for a robust and secure grid architecture.
- External transparency into processes has become more important than ever as these complex decisions are made in **designing**, **forecasting**, **dispatching**, and **settling**.
- The utility industry is moving toward a data-rich environment where a tremendous amount of information is coming from sensors in the grid and beyond (grid-edge and BTM).

We are not providing a specific architectural solution to the utility industry. Instead, our analysis offers a set of characteristics that need to be considered during the period of significant change so that utility operations can continue to provide the best levels of reliability and resilience at the lowest cost.

The intent here is to provide a context for vendors, utilities, and their service providers to review and understand the changes that are coming and get ready for them. Each vendor and utility may approach the journey in their own ways to stay competitive and ahead of the others.

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Next Steps – Industry-led and DOE-enabled

We need to start with a roadmap

The roadmap requires an analysis of situations very unlike what operators have seen in the last 100 years. The analysis needs to take both planning and operations into consideration mainly because one feeds the other. The roadmap should consider:

- **Business constructs:** With every new entrant, the system operator will need to evolve their systems and business processes to interact with the 3rd party's systems and processes.
- **Technological considerations:** The two buses introduced will need to be standardized and formalized over time. Interactions with these buses will need to be defined and documented.
- **Cybersecurity will become extremely critical** with the entrance of third party (non-utility) players who will bring their systems into the utility operational equation. The concepts of trust as a specific attribute will become more important to define the kinds of interactions between components in the field with specific systems responsible for maintaining the reliable operations of the grid.
- **OT technologies:** OT technologies can be divided into several classes of components and include evolution of sensors and controls mechanisms, and power system components such as solid-state transformers, circuit breakers and so on. They also need to consider evolution of existing sources of generation and the introduction of new and innovative sources such as generation from hydrogen and nuclear fusion/fission.
- **IT technologies:** IT technologies are evolving at a tremendous pace. However, given the criticality of the nation's power system, they cannot be introduced into system operations architectures right away. They need to be assessed carefully and introduced when ready. This includes items such as the advent of the cloud in system operations, communications, and new analytical mechanisms such as AI/ML.
- **Timing of these changes:** Determining which of these technologies is expected to come to fruition for utility use and when.

This cannot be a theoretical exercise and needs to consider the realities of utility-funding constraints, pace and cost of such changes. It also needs to consider the pace of regulatory processes both for transmission and distribution.

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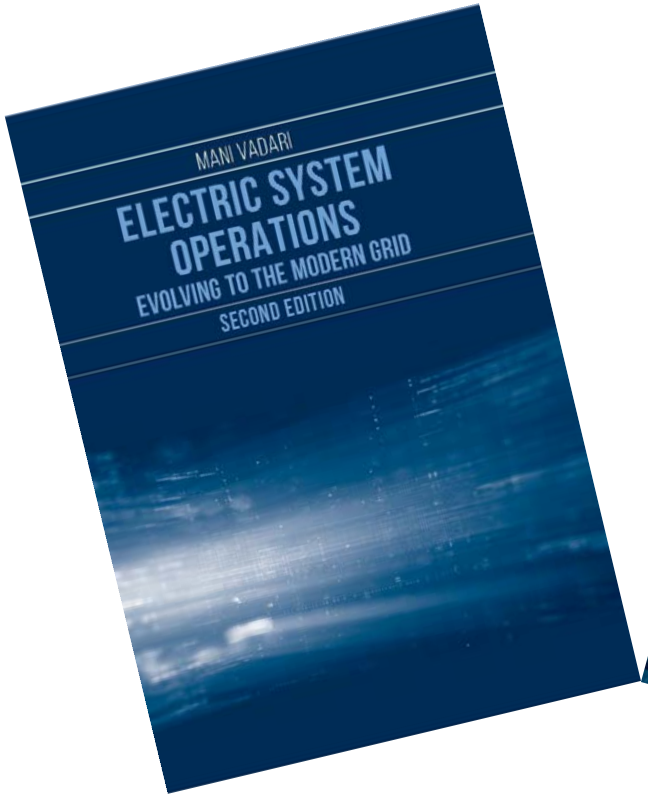

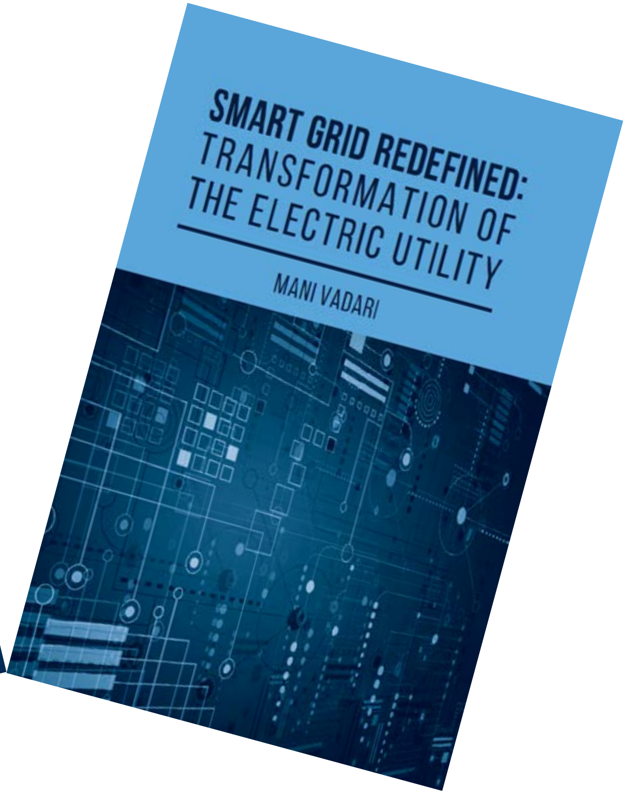

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Dr. Mani Vadari is an electric industry leader and visionary, with over 30 years of experience delivering business and technical solutions for transmission, distribution, and generation operations, wholesale markets, Smart Grid, and Smart Cities. Mani has a multi-year track record of delivering value on a wide range of technology and business solutions.

Dr. Mani Vadari leads a team of experts to deliver complex and innovative technology, business, regulatory, and finance solutions. Mani brings over 35 years of experience delivering business and technical solutions. Mani is also an Affiliate Professor at the University of Washington, and an Adjunct Professor at Washington State University. Mani has published two popular books, "Smart Grid Redefined: Transformation of the Electric Utility" and "Electric System Operations – Evolving to the Modern Grid, 2nd edition", and has authored over 100 industry papers, articles and blogs.

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PNNL/DOE White Paper: **"Evolving Architectures and Considerations to address DERs and NWAs: – The Emergence of the OT/Control Bus",** Mani Vadari, August 6th, 2021

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