GridWise® Architecture Council

Transactive Energy Systems Tutorial Part 2

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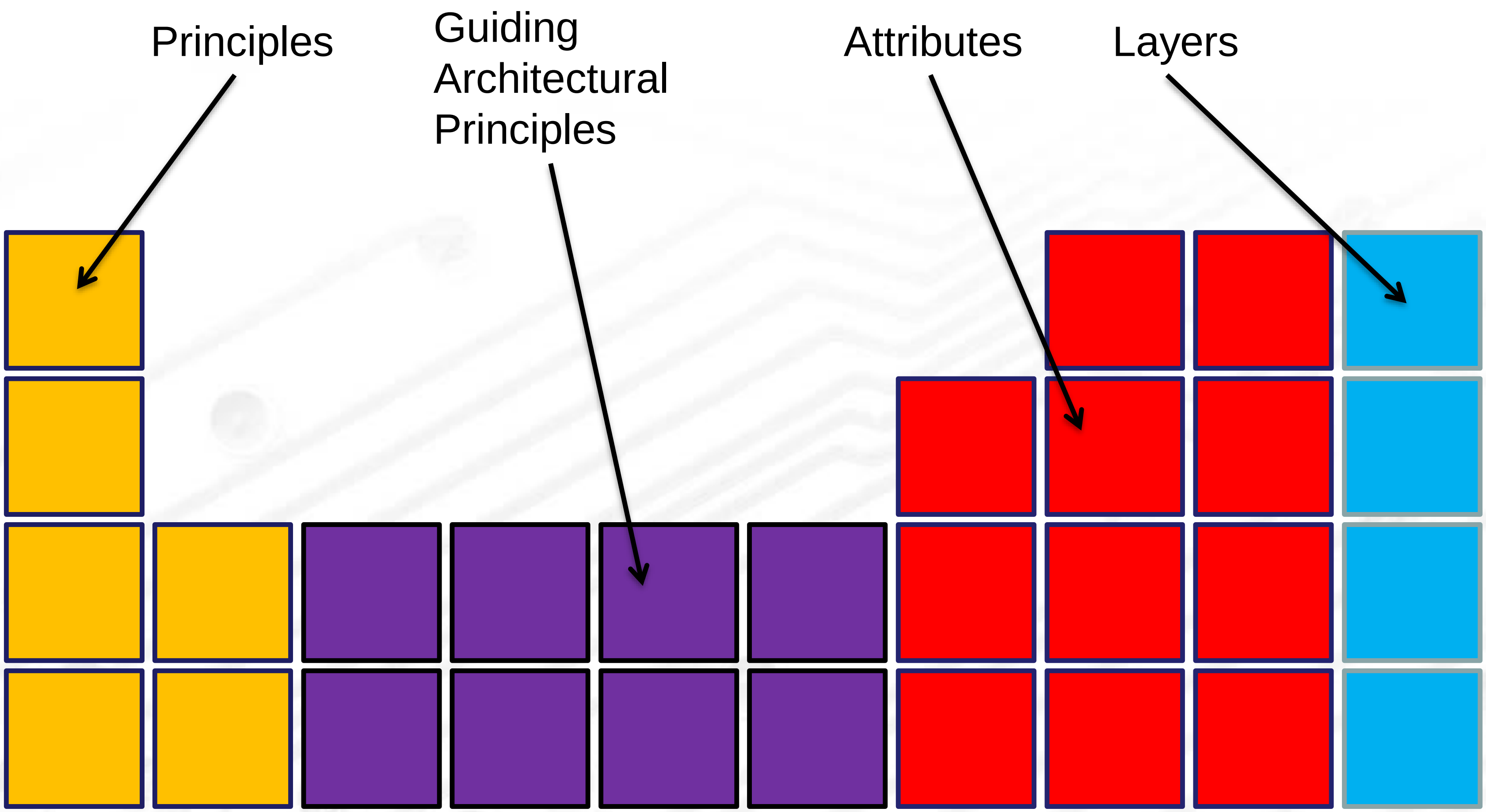
The Periodic Table of TE



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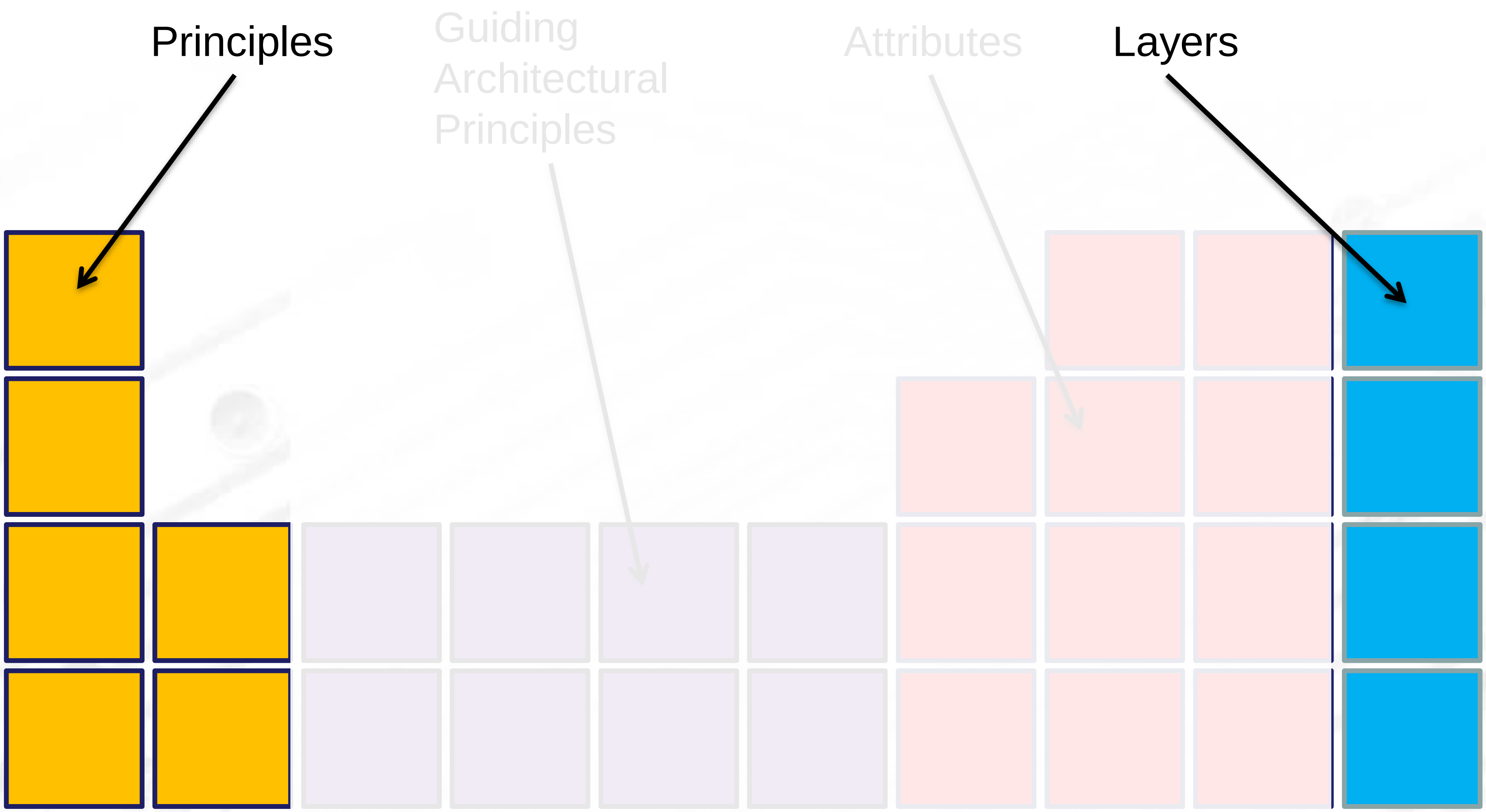


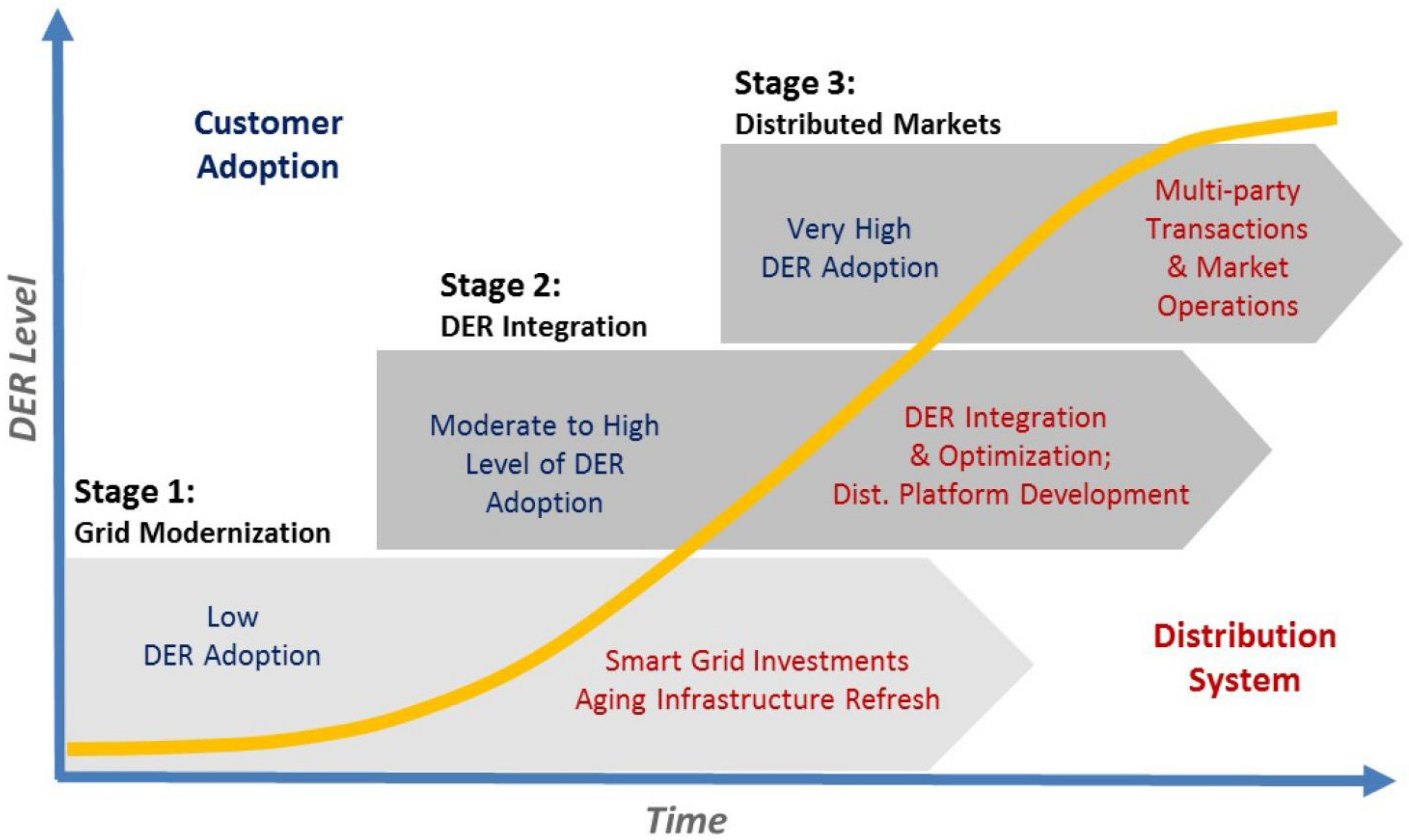
Principles

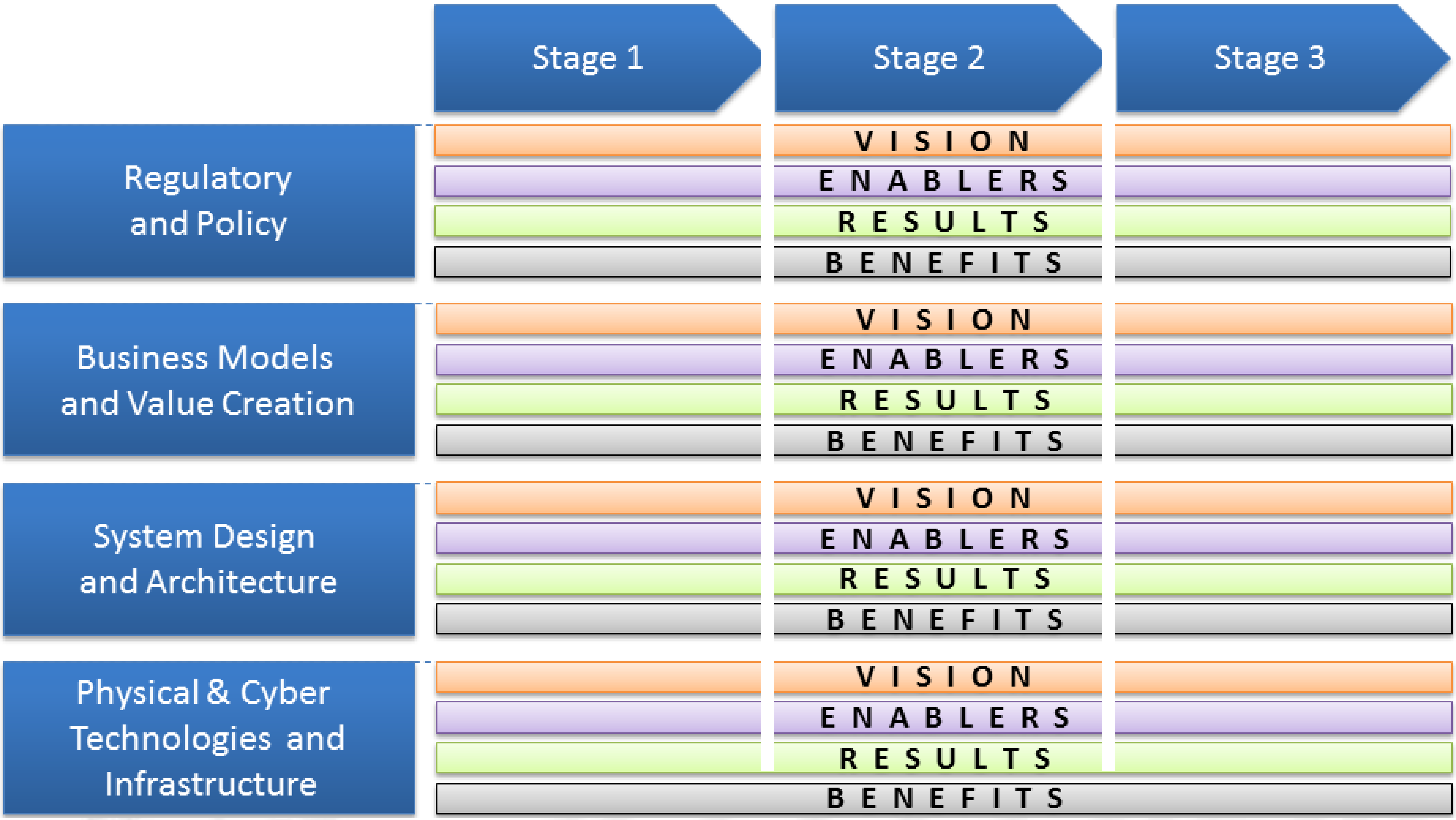
- During the February 2014 GWAC workshop held at PJM in Philadelphia, the participants agreed on the need for a set of high-level principles that apply to TE systems.
- Such principles are, in effect, ***statements of high-level requirements*** for such systems.

TE Layers (TE Roadmap Tracks)

- Applying the set of principles and framework described in GWAC's "Interoperability Context-setting Framework" to transactive energy we are identifying the ***interoperability challenges to be considered for TE***.
  - Regulatory and Policy
  - Business Models and Value Realization
  - System Design and Architecture
  - Physical and Cyber Technologies and Infrastructure
- The roadmap captures potential changes over time (***Stages***) and organizes them by business and technical ***Tracks***. Within each Track it also groups potential changes into ***Swim Lanes*** that identify what it is that we hope to see (*vision*), what it takes for this to occur (*enablers*), what we see as a result (*results*), and what these features do to add value (*benefits*).

TE Roadmap Stages




Stage 1
Stage 2
Stage 3
Regulatory and Policy
VISION
ENABLERS
RESULTS
BENEFITS
Business Models and Value Creation
VISION
ENABLERS
RESULTS
BENEFITS
System Design and Architecture
VISION
ENABLERS
RESULTS
BENEFITS
Physical & Cyber Technologies and Infrastructure
VISION
ENABLERS
RESULTS
BENEFITS

Core Concepts

- Each roadmap section includes core concepts expressed in as timeless (stage-free) a manner as possible for each track of the roadmap.
- Note: items in bolded italics represent condensed encapsulations of the TE principles described in Section 3.3 of the TE Framework document
- The core concepts provide a means to check for gaps (where a concept has not been invoked) or duplication (where a concept has been used multiple times).

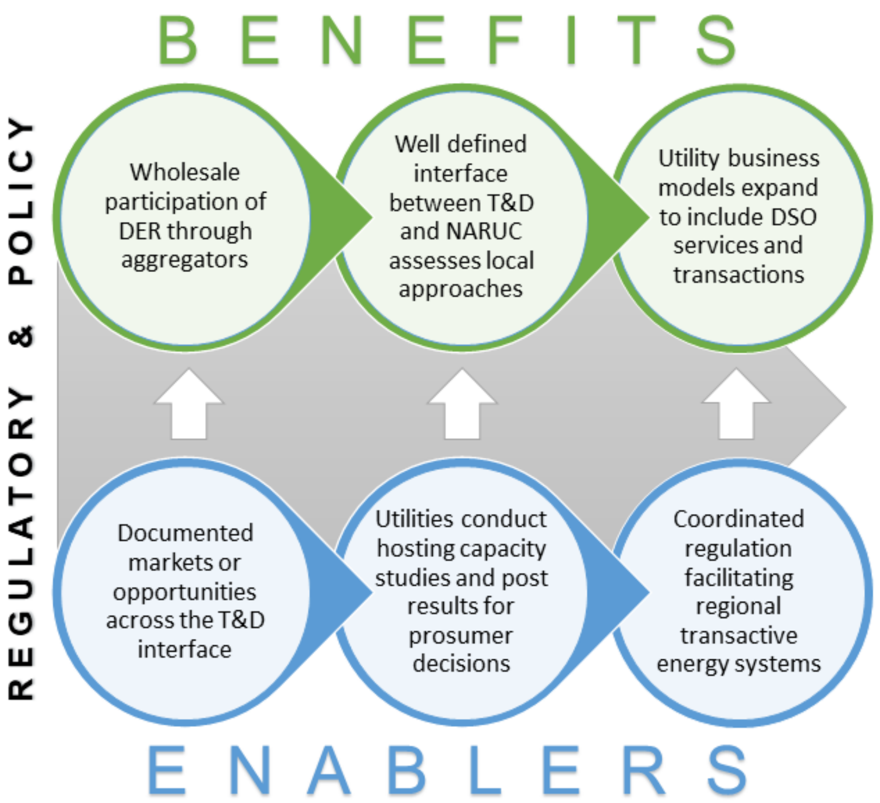
Core Concepts Example

- BM1 - Incentives and opportunities exist for all stakeholders with all ***parties accountable for standards of performance***
- BM2 - A means exists to optimally assign value when comparing alternatives (for example wires and non-wires alternatives)
- BM3 - Business models align values across the participating entities in an ***observable and auditable*** manner
- BM4 - Opportunities exist for value creation (services) across multiple streams

Principles of TE

- Transactive energy systems implement some form of highly coordinated self-optimization
- Transactive energy systems should maintain system reliability and control while enabling optimal integration of renewable and distributed energy resource
- Transactive energy systems should provide for non-discriminatory participation by qualified participants
- Transactive energy systems should be scalable, adaptable, and extensible across a number of devices, participants, and geographic extent
- ***Transactive energy systems should be observable and auditable at interfaces***
- ***Transacting parties are accountable for standards of performance***

Regulatory and Policy Example and Concepts



- **RP1** - Support for retail power markets with ***non-discriminatory participation***
- **RP2** - Consistency of regulation/minimum requirements from state to state
- **RP3** - Dynamic exchange of information and value (including real-time retail tariffs) between wholesale and retail markets across the T&D interface
- **RP4** - Intra- and inter-jurisdictional market monitoring and oversight functions are described in policy (and regulation)

Regulatory and Policy Vision

Reference	Stage 1 *Persistently Demonstrated*	Stage 2 *Broadly Applied*	Stage 3 *At Scale*
RPV01	Wholesale market transactive interactions of DR, where allowed, mainly through aggregators with no change in legacy market products and services developed for the capabilities of conventional bulk generation / system operation resources	The existence of a well-defined T&D interface from a regulatory and market perspective that allows both a distribution level market for individual participants and participation in the wholesale market for qualifying participants.	Enhancement of bulk power /wholesale market rules to align system operational needs with market-based incentives
RPV02	Questions from policy makers regarding when and how to create transactive retail markets	Several states creating regulatory support for retail energy (and derivative) markets. Analysis of regulatory differences from state to state by NARUC.	Most states have retail transactive energy market regulations with (mostly) consistent requirements and terminology.
RPV03	Transactive Exchanges available in bulk power bilateral and centralized wholesale markets, stopping at the T&D interface, with exceptions.	Evolution of new bulk power / wholesale products and services (flexibility reserves, ramping, primary frequency response, synthetic inertia) along with provisions for DER assets to provide such services	DER transactive participation in bulk power and wholesale markets based on bids and offers
RPV04	Limited use of transactive energy in distribution except for pilots and proofs of concept.	Geographic footprints of TE trades expand over larger areas of the country, creating opportunity for wide-scale power purchase agreements	End-to-end Transactive exchanges among prosumers within different layers within the distribution system as well as across the T&D interface

Regulatory and Policy Enablers

Reference	**Stage 1** *Persistently Demonstrated*	**Stage 2** *Broadly Applied*	**Stage 3** *At Scale*
RPE01	Understand what cyber needs will be and determine cost of policies to correct equity or barrier to access issues.	Balanced need for big data and more sophisticated grid edge data analysis with consumer privacy concerns and security	Security, privacy and non-discriminatory participation are addressed in policy at all levels.
RPE02	Analysis of steps required to enable T&D integration through rate making policy	Prioritized list of inter-jurisdictional regulatory barriers to address between distribution markets.	Common DSO approaches allow consistent T&D integration.
RPE03	Documented opportunities and value proposition of markets each side of the T&D interface.	Opportunities and value proposition for markets across the T&D interface.	Minimum standards identified to allow for basic consistency of market rules between states.
RPE04	Minimal regulatory changes, but increased focus of attention.	Active regulatory involvement, and new regulations to enable TE.	Coordinated regulatory involvement opening the way for regional TE systems.
RPE05	Insights into operational cost inform how charge, billing and rate structure can cover the overhead transaction costs and identify incentives, regulations, and dynamic rate definitions.	Identify how cost and benefits are being created and distributed, and how to police bad actors where necessary; possibly through software defined rates and smart contracts.	Obligation to serve redefined for TE markets.

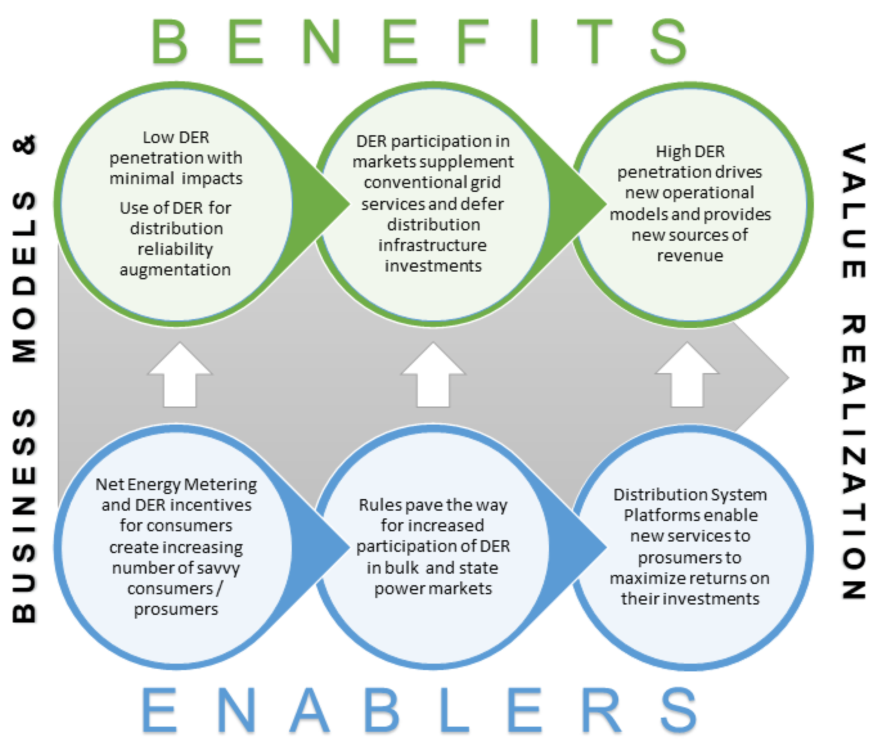
Regulatory and Policy Outcomes

Reference	Stage 1 *Persistently Demonstrated*	Stage 2 *Broadly Applied*	Stage 3 *At Scale*
RPR01	Lack of consumer guidelines for participation in TE systems.	Interest in development of consumer guidelines for participation in services offered by DSOs.	Consumer guidelines for participation in energy and ancillary services markets.
RPR02	Limited awareness but growing interest in TE from policymakers.	Active support from some states by allowing recovery of some approved utility costs to encourage TE.	Emergence and persistence of retail transactive energy markets.
RPR03	Rule changes to permit demand side participation in wholesale markets.	Growth of customer participation in grid management through ancillary services and reliability coordination.	Dynamic trading between DSOs and ISOs to support markets and reliability.
RPR04	Utility business models largely unchanged.	Utility business models expand to include DSO transactions and services.	DSO role is fully distinct/disaggregated from the utility role, with some DSO's merging to perform regional services.
RPR05	Quantification of cost of policies to correct equity or barrier to access issues.	Regulatory requirements for consumer privacy and security.	Common security, privacy and non-discriminatory participation policies for all DSO markets.

Regulatory and Policy Benefits

Reference	Stage 1 ***Persistently Demonstrated***	Stage 2 ***Broadly Applied***	Stage 3 ***At Scale***
RPB01	Policymakers recognize the need to address DER integration with regulatory changes.	DER provide opportunities for distribution level revenue generation through provision of grid services.	Changes to the regulatory process by some states provides tangible foundations for more change.
RPB02	Understanding of equity or barrier to access costs allows policy making to develop new models.	Regulatory definition of consumer privacy and security requirements create opportunities for service providers.	Sharing of best practices and common policies for DSO markets create opportunities for shared services and service provider growth.
RPB03	The benefit/need for demand side resources to participate in grid services is recognized.	Consumer awareness into the complications of grid operation and the benefits of participation.	Enhanced flexibility to support reliability.
RPB04	Provides confidence in TE as a viable/integration solution with potential for customer benefits.	Provides the capability to regulate (and deliver) the same grid services either side of, and across, the T&D interface.	Enables energy trading and service provision though common services and rules.
RPB05	Creates the perception of electricity as a service with value, as opposed to just “being there”.	Valuation of electricity as a service creates a foundation for innovation.	Optimizes value at a personal, community and distribution system level for specific needs.
RPB06	Messaging developed in each relevant sphere for how to prepare the public and stakeholders for impact of DER, how and why to tolerate in stages 2 and 3	Benefits of TE Systems well understood in general by policy makers with respect to creating more flexibility and value	Benefits of TE Systems well understood in general by consumers with respect to creating more flexibility and value.

Business Models Example and Concepts



- **BM1** - Incentives and opportunities exist for all stakeholders with all ***parties accountable for standards of performance***
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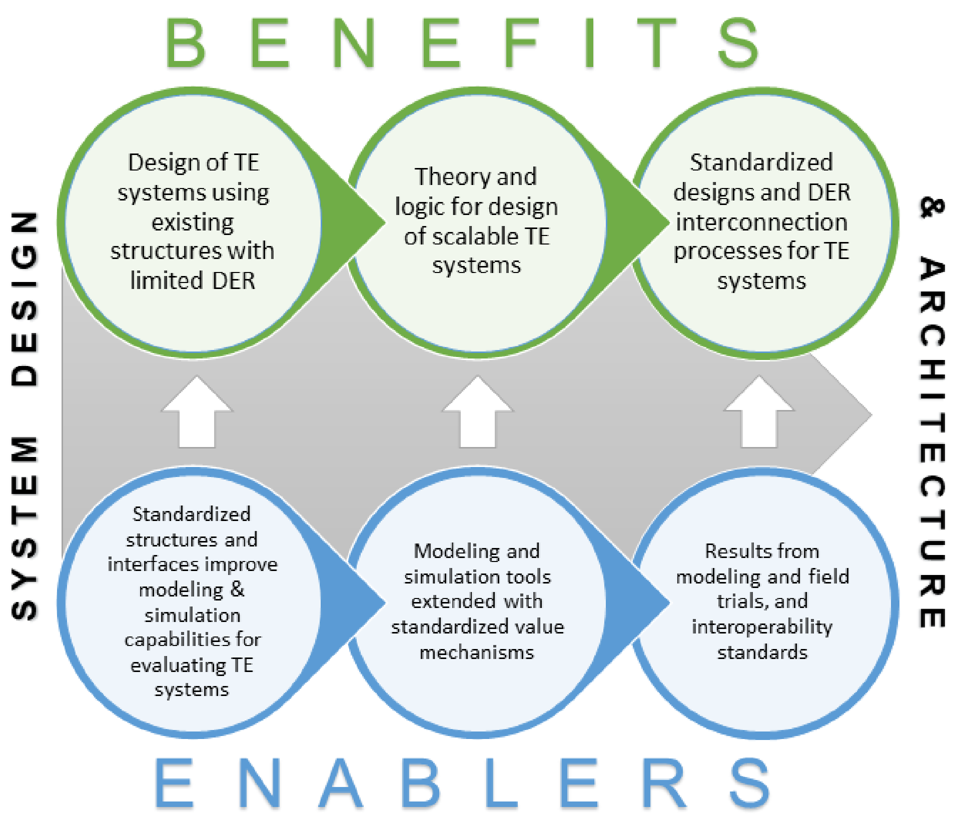
Business Models Vision

Reference	Stage 1 *Persistently Demonstrated*	Stage 2 *Broadly Applied*	Stage 3 *At Scale*
BMV01	Limited use of DR for distribution capacity relief – utility DR programs	DER transactive participation based on capacity auctions primarily to defer infrastructure upgrade	Proliferation of bilateral peer-to-peer forward transactive exchanges among prosumers, including microgrids, Building Energy Management Systems (BEMS), etc.
BMV02	Main economic use of DER for load shifting or peak shaving using aggregators and direct control	Evolution of distribution level products and services that optimize value for incentivized stakeholders (phase balancing, distribution constraint relief services, etc.)	Distributed ledgers and smart contracts offer the opportunity to build new models on top of the existing infrastructure
BMV03	DER are used for local generation and reliability augmentation without use of transactive systems	Transactive exchanges across the T&D interface, mainly for large consumers/prosumers, and through intermediaries such as aggregators for smaller prosumers.	Evolution of DSOs into pseudo-balancing entities at the T&D interface while accommodating peer-to-peer bilateral exchanges across the distribution system.
BMV04	The need to develop business model simulation and valuation techniques is recognized.	Business model simulation and valuation techniques begin to be developed for TES and DER	Tools are available to model value flow to support business model simulation and valuation from different stakeholder perspectives

System Design & Architecture Example and Concepts



- **DA1** - A standard set of definitions and structure develops for interface structure for X2G operations at all levels
- **DA2** - Transition from centralized to decentralized based on ***highly coordinated self-optimization***
- **DA3** - ***Reliability and control*** are assigned value when integrated into all TE systems that interact with the grid
- **DA4** - Buildings and facility-grids feature more prominently over time
- **DA5** - Modeling and simulation solutions for TES produce consistent results with each other and can exchange data

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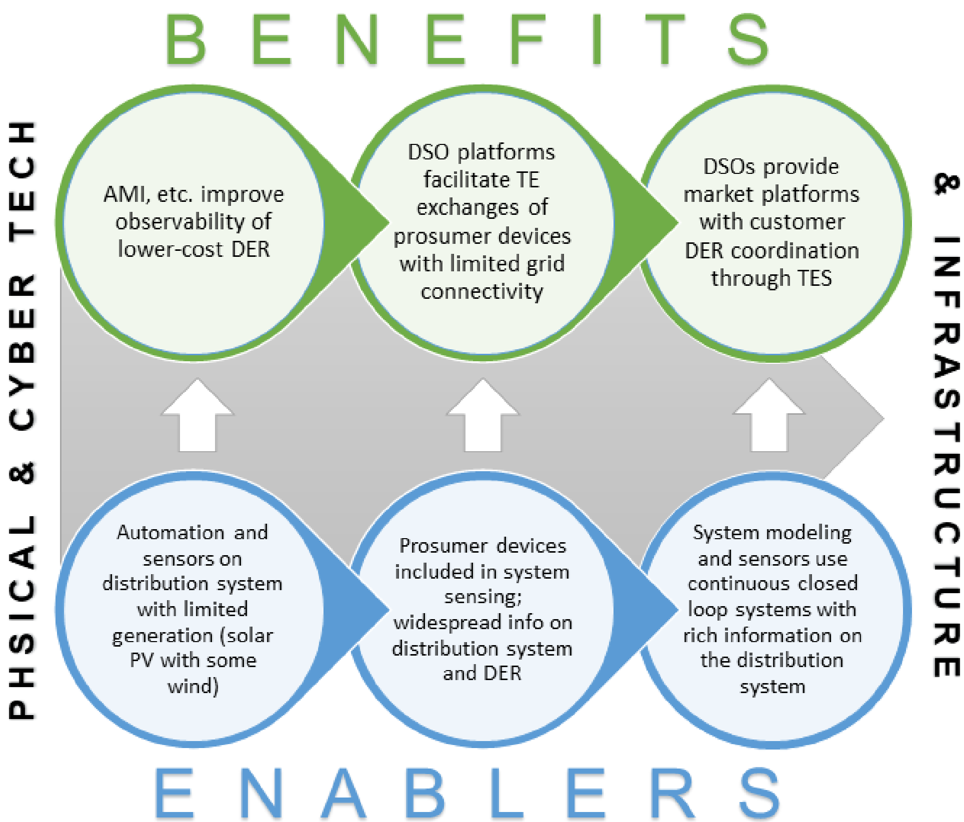
System Design & Architecture Vision

Reference	Stage 1 *Persistently Demonstrated*	Stage 2 *Broadly Applied*	Stage 3 *At Scale*
DAV01	The grid consists of transmission and distribution with interfaces driven by local interconnection requirements.	The grid consists of a collection of independent or semi-independent systems operating in a coordinated way.	Standardized interfaces create reusability of applications at all levels within the grid.
DAV02	Characterized by centralized distribution control by utilities	Mix of centralized and distributed control still largely using centralized optimization across service territory with utility beginning to act as DSO	Distributed system operations and controls coordinated via DSO with all stakeholders across the region.
DAV03	Local management of transactive systems used to optimize behind the meter buildings, campus, and microgrid value.	DER at connected buildings interact with the grid, enabled by transactive energy systems	Distributed optimization of buildings and other DER facilities support reliability and resilience.
DAV04	Local devices respond to grid events on a deterministic basis.	Local device behavior is a mix of deterministic and stochastic requiring modeling and simulation	Stochastic optimization is employed as a means of more accurately accounting for uncertainties in interactions (and simulations) across a large number of devices and participants

Physical and Cyber Technologies and Infrastructure Example and Concepts



- **PC1** - Improved measurement, verification, and situational awareness
- **PC2** - Affordability of devices and communications enables ***scalable, adaptable, and extensible*** deployment
- **PC3** - Distributed devices securely integrated into control schemes
- **PC4** - Ability for consumer devices to support sub-cycle to long term activities (markets/operations)
- **PC5** – Explicit, well-defined, trust models that define identity, authentication, service level agreements, and privacy need to be built into all TE systems.
- Items in ***bolded italics*** represent condensed encapsulations of the TE principles described in Section 3.3 of the TE Framework

Physical and Cyber Technologies and Infrastructure Vision

Reference	Stage 1 *Persistently Demonstrated*	Stage 2 *Broadly Applied*	Stage 3 *At Scale*
PCV01	Proliferation of Advanced Metering Infrastructure (AMI) or other measures to improve distribution system operator observability into DER	Evolution of DSOs with distributed system platforms primarily utilizing DERMS and ADMS, and facilitating new transactive exchanges	DSO construct realized at scale with distribution market platforms and broad awareness of impacts across the T&D interface
PCV02	Deployment of DMS and ADMS systems by most utilities. Limited circuit switching capability.	Enhancement and evolution of DMS/ADMS for better situational awareness and control. Automated switching for more distribution circuits.	Distribution state estimators and phasor measurement systems in use for distribution systems and used in transactive energy system optimization
PCV03	Cost of smart devices for use by utilities continues to drop, driving broad deployment	Proliferation of low cost prosumer devices leading to improved local control systems and limited connectivity to grid systems	Customer and facility devices and control systems coordinate with utilities and DSOs through transactive energy systems

Workshop Question #2:

- Share an example of a project where some of the TE principles discussed are being applied today:
  - Who is taking the lead?
  - What are the objectives?
  - What are the observed benefits?
  - What are the lessons learned?