


— DSO 101 —

Designing and Comparing DSO Models

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Lorenzo Kristov, PhD, Principal Market Architect
Electric System Policy, Structure, Market Design

A background pattern of a network graph with numerous nodes and connecting lines, rendered in a light beige color against a light blue background.

Disclaimer:
The ideas and perspectives presented here are those of the author alone and do not represent the views of any other person or organization.

Key DSO 101 Takeaways

- **DSO is not a well-defined thing.** "DSO" is a placeholder for the future distribution provider to be designed in Track 2 of this proceeding
- **DSO is not optional.** DER growth is happening. High-DER grid requires upgrading distribution system functions and the system operator
- **Roles & Functions — building blocks of the system — must be defined** independently of the Actors who perform them
- **A DSO Model is an assignment of Roles & Functions to the DSO** and specification of its required interactions with other Actors
- Alternative DSO Models should be **evaluated against specified goals, performance requirements and guiding principles**

What is a DSO, and Why think about it?

The Context: Electricity for the 2020s & Beyond

Electricity systems today must serve **three major societal goals** that were not big issues in the 20th century power system

- **Sustainability** => transition away from damaging energy systems; decarbonize society
 - **Resilience** => continuous electricity service for essential local functions when major disruptions occur
 - **Energy Justice** => equitably distribute benefits & burdens of energy systems; mitigate past inequities for DAC & frontline communities
- ... without compromising traditional reliability, affordability, safety goals.

Customers & many local governments today are adopting DER-based approaches to these goals

Objectives of the High-DER Future OIR

- “... to **prepare the electric grid for a high number of distributed energy resources**, including those specific to transportation electrification and as defined in Assembly Bill 327 and Public Utilities Code Section 769
- “This OIR anticipates a high-penetration DER future and seeks to determine how to **optimize the integration of millions of DERs** within the distribution grid while ensuring affordable rates
- **“This OIR neither seeks to set policy on the overall number of DERs nor does it seek to increase or decrease the desired level of DERs.**
- “This OIR focuses on preparing the grid to accommodate what is expected to be a high DER future and **capture as much value** as possible from DERs as well as **mitigate any unintended negative impacts.**” [emphasis added]

Why we need to talk about a “DSO”

Growth of DER has two major implications for the electricity system:

1. The traditional function of electric distribution — one-way delivery of kWh to consumers — is not adequate for a High-DER Future

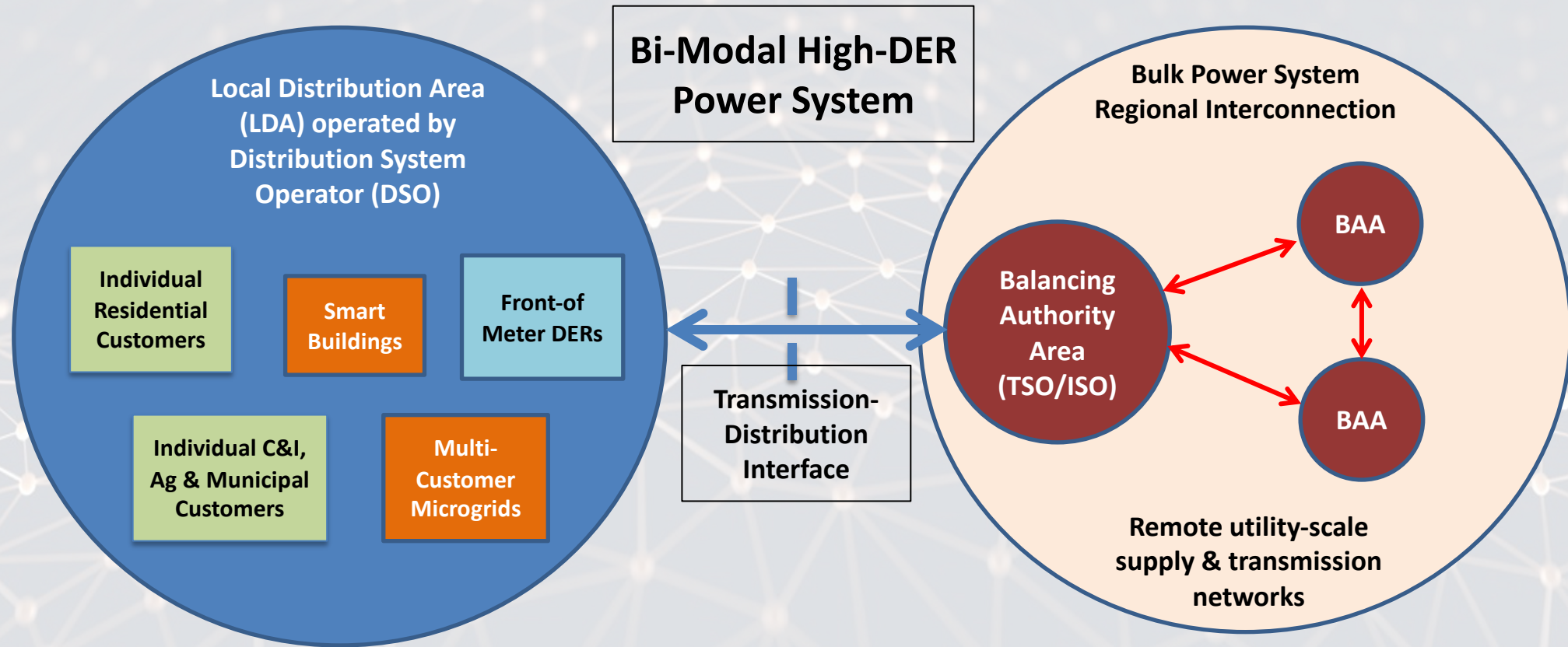
- The distribution system must operate reliably with diverse grid-edge assets, bi-directional energy flows & variable operating conditions

2. DER adoption by customers just for private benefits leaves grid & societal benefits on the table

- Many customers are investing in DER because DER are increasingly cost-effective, customizable and attractive
- DER offer large potential grid benefits (reduced infrastructure, flattening peak demand) and societal benefits (decarbonization, resilience)

=> The grid needs performance upgrades & new regulatory provisions to realize the full benefits of a high-DER future

The High-DER Future Grid: a participatory distribution network complements the bulk system



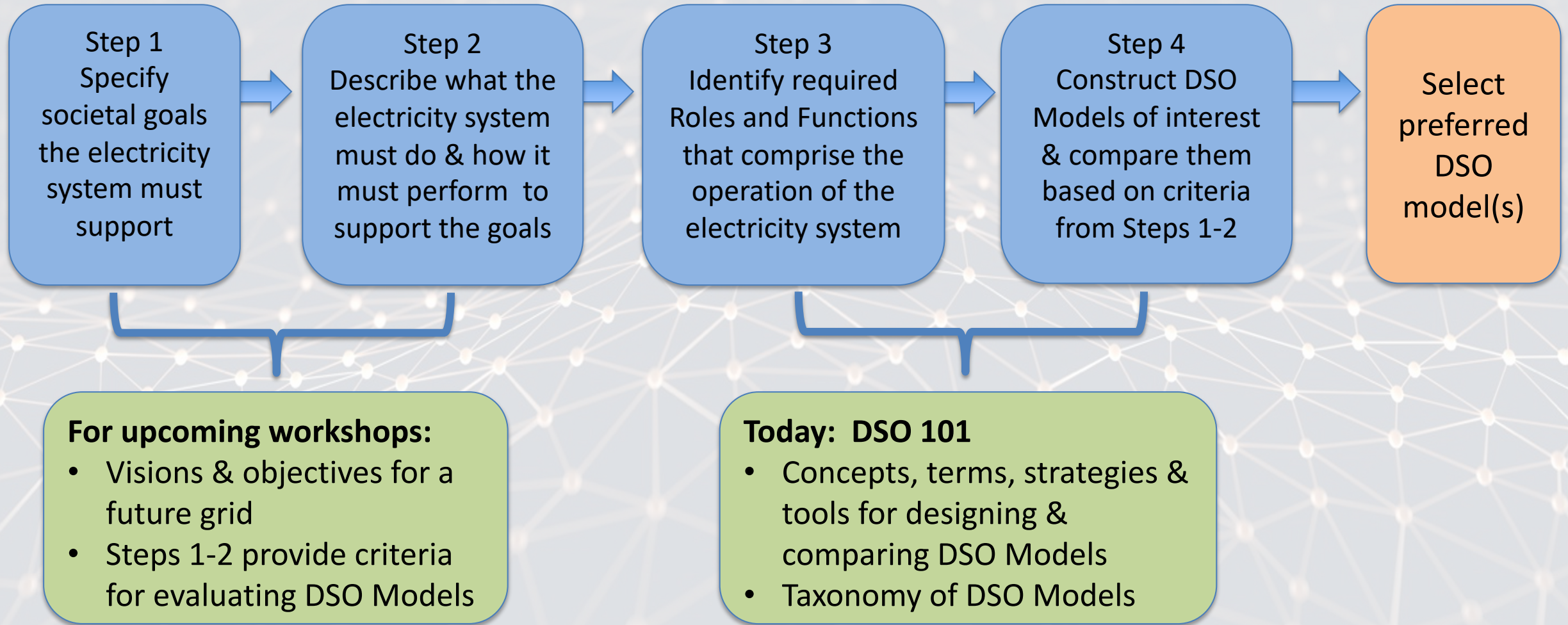
- Distribution network connects all network participants: customers, smart buildings, community resources & microgrids
- **DSO integrates DER cost-effectively to minimize bulk system impacts**
- Local DER can supply a major share of new electrification demand

- **Bulk power system moves renewable energy from production areas to load centers**
- Supplements local production with regional energy diversity & bulk transactions

The question is: What kind of DSO is best for CA?

- **DSO is not one uniquely-defined thing**
 - The term “DSO” is a placeholder for a future evolution — to be designed — of the distribution utility for the High-DER Future
- **DSO is not a yes/no option**
 - The traditional distribution utility must be upgraded with new functional capabilities to meet the needs of the High-DER Future
 - So the question is: **What kind of DSO is best for California?**
- **The DSO must perform at least two primary core functions**
 - A. Provide a reliable, cost-effective, distribution network** for Network Customers
 - B. Coordinate with the bulk transmission system operator** (Balancing Authority, TSO, CAISO) **at the T-D interfaces**

Comparing Alternative DSO Models



A background pattern of a network graph with numerous nodes and connecting lines, rendered in a light beige color on a light blue-grey background.

Key Terms & Concepts

What is a DSO Model?

A “DSO Model” is :

- An assignment of **Functional Roles & Responsibilities** to an entity called the DSO, which is an enhancement of the electric distribution utility for a high-DER future plus
- Specification of the DSO’s **required interactions with other Actors** who comprise the whole electricity system

Note: *The DSO is part of a large complex system*

Each DSO Model has implications for Roles & Responsibilities of other Actors in the system

- E.g., the more the DSO takes responsibility for coordinating DER activities, the less DER coordination the ISO has to do
- E.g., the more the DSO coordinates DER activities to smooth net load profiles & volatility, the less operational impacts on the ISO

Functional Roles & Actors

Functional Roles in a Household

1. Pay
the Bills

2. Earn
Money

3. Buy
Food

4.
Prepare
Meals

5. Wash
Dishes

6. Feed
& Walk
Dog

7.
Maintain
Vehicles

8. Do
Laundry

9.
Vacuum
& Dust

10.
Baby
Sitting

11. Yard
Care

12. Work in
Community
Garden

Actors in a Household

Grandma – 4, 10, 11, 12

Mom – 2, 3, 9, 10, 12

Dad – 1, 4, 5, 7, 8, 10

Brother – 2, 5, 6, 8, 9, 12

Sister – 5, 6, 7, 8, 10, 11

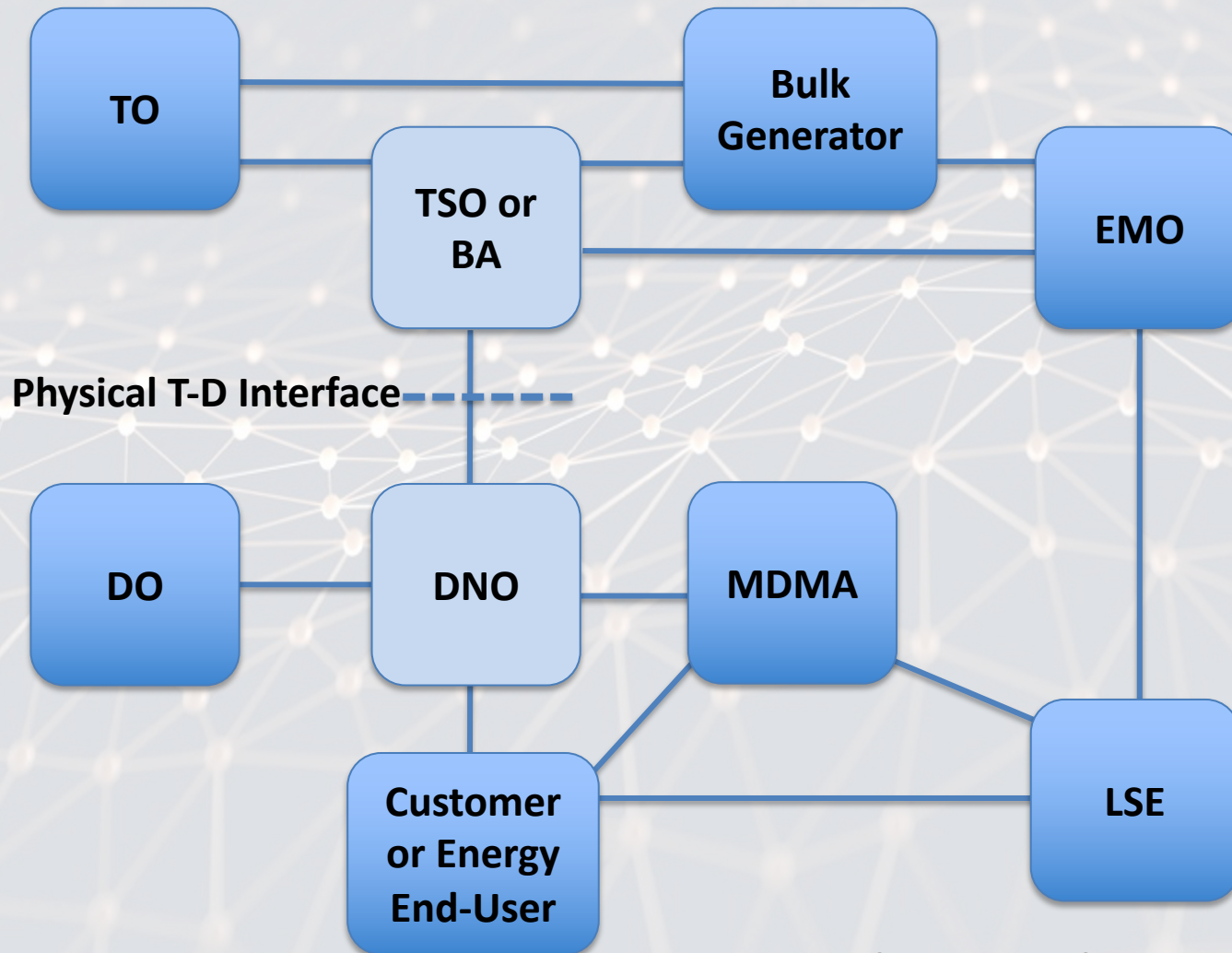
Sparky – 6

Functional Roles in the Electricity System

- **DNO = Distribution Network Operator** => provides network services to Customers & DER & reliably operates the distribution network
- **DMO = Distribution Market Operator** => operates distribution system markets
- **DO = Distribution Owner** => owns, maintains & operates network assets
- **LSE = Load-Serving Entity or Retailer** => aggregates end-use customers for procuring & supplying energy from the grid
- **MDMA = Meter Data Management Authority** => Collects, validates & maintains revenue metering & telemetry data & provides data to eligible parties
- **TSO = Transmission System Operator** => Balancing Authority
- **TO = Transmission Owner** => owns, maintains & operates transmission system assets
- **EMO = Energy Market Operator (wholesale, bulk system)**
- **Customer/DER = Distribution Network User**

Functional Roles & Actors

Functional Roles & Relationships
— a simplified structure diagram



Actors
(California)

IOU (today)
=> DNO + DO + LSE +
MDMA + TO + Gen

CAISO
=> TSO (BA) + bulk
system energy market
operator (EMO)

CCA, ESP => LSE

DSO design =>
which Functional
Roles should the
DSO include?

Functional Roles, Functions, Actors, DSO Models

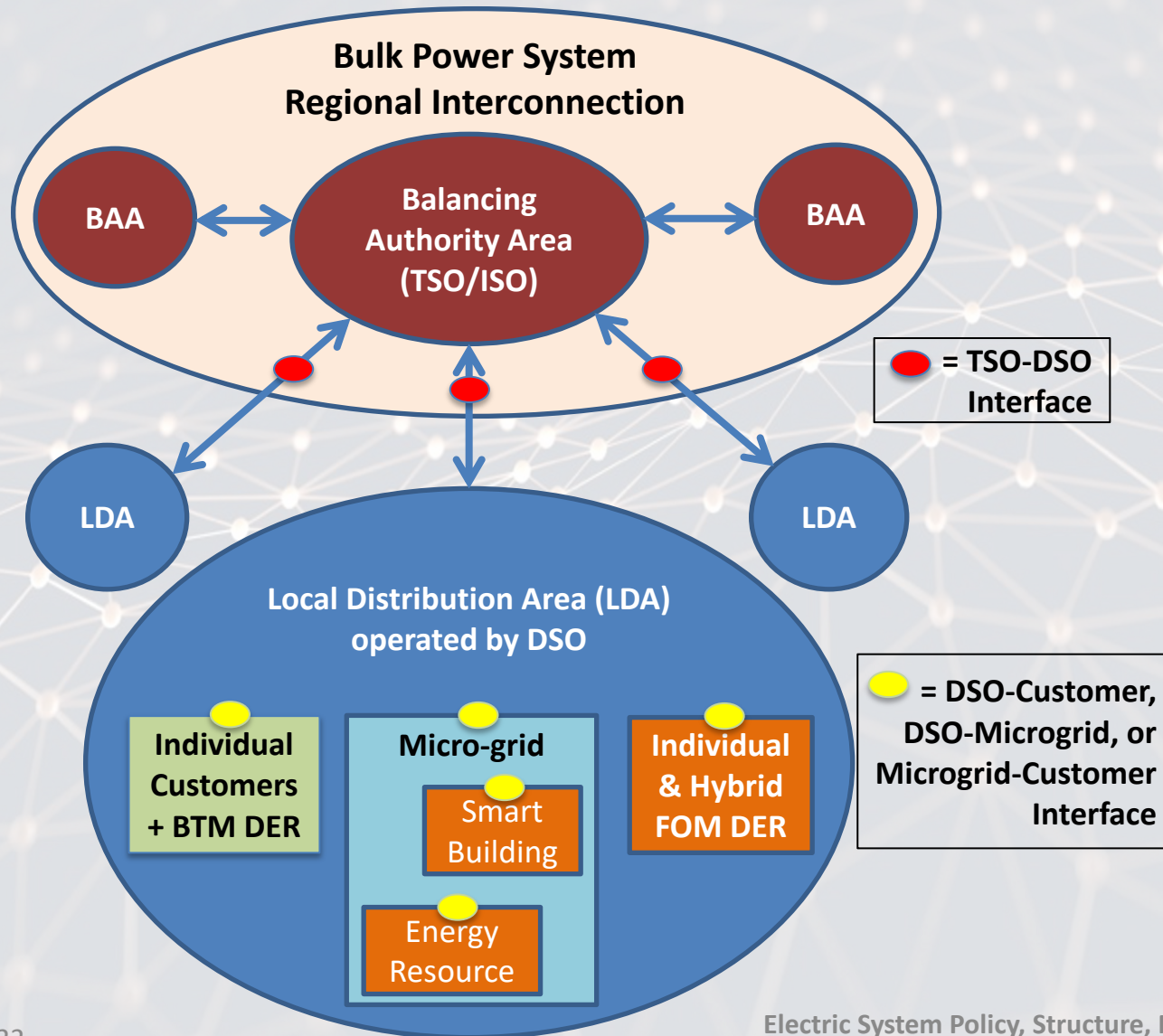
- **Functional Roles = the Building Blocks of the Whole System**
 - Must be described independent of the Entity or Actor that performs each Role
- **Functions [DSO 201] = Specific activities required for the system's performance**
 - Examples: supply-demand balancing, forecasting, interconnection, resource dispatch
 - More granular than Functional Roles
- **Actors = Entities who participate in system performance**
- **Functional Roles and Responsibilities (FRR) = a bundle of Functional Roles & specific Functions to be assigned to a particular Actor**

A DSO Model = an assignment of FRR to the DSO entity, plus specification of its required interactions with other Actors/Roles

- Also called **a System Structure** or **System Architecture** because all Roles in a complex system are inter-related
 - Each DSO Model has implications for the FRR of other Actors

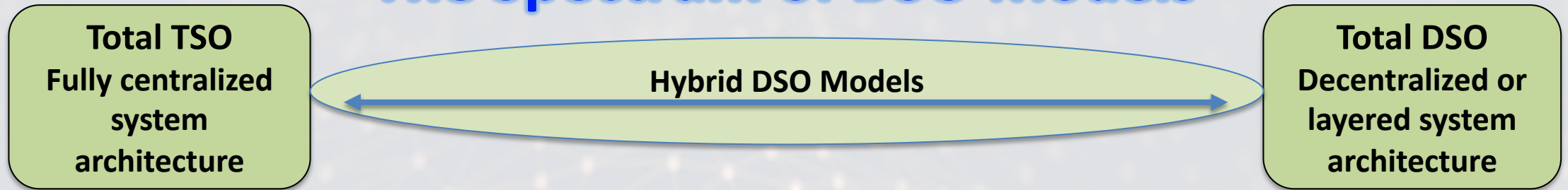
Taxonomy of DSO Models

Layered Architecture: a DSO Model design consideration



- Main layers are Bulk System; Distribution System; Customer/DER
 - Multi-customer microgrid may exist in between Dist. System & Customers
- Unit of analysis is the Local Distribution Area (LDA) associated with a single T-D interface (ISO/RTO pricing node)
- Each layer needs to manage its interfaces with adjacent layers above & below
- Focus on interfaces => Operator of each layer does not need visibility or control of assets within the layer below
- Interfaces allow for bi-directional flows
- Each layer can “island” from layer above at the interface point
- Layering has implications for who is responsible for what

The Spectrum of DSO Models



Total TSO => TSO (CAISO) is responsible for all DER integration

- TSO models & monitors distribution network, sees DER at actual locations, combines DER & Tx-connected resources in optimization accounting for D-grid conditions
- Requires substantial functional enhancements by TSO

Hybrid DSO => TSO & DSO share responsibilities for DER integration

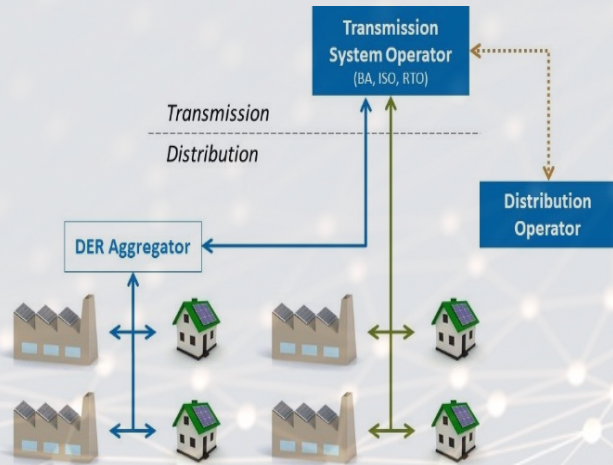
- TSO models DER at T-D interfaces, but dispatches individual DER & DER Aggregations
- DSO manages DER activities on D-system & impacts of/on D-grid conditions
- Most common trajectory of DER integration being considered in US today

Total DSO => DSO is responsible for all DER integration

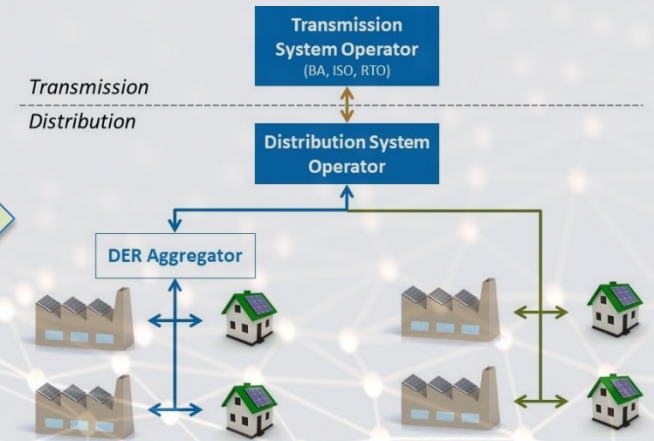
- Total DSO appears to TSO as a single hybrid resource or microgrid at the T-D interface
- TSO issues dispatches to the DSO, then DSO dispatches participating DER
- Requires substantial functional enhancements by DSO

The Spectrum of DSO Models

Total TSO Centralized



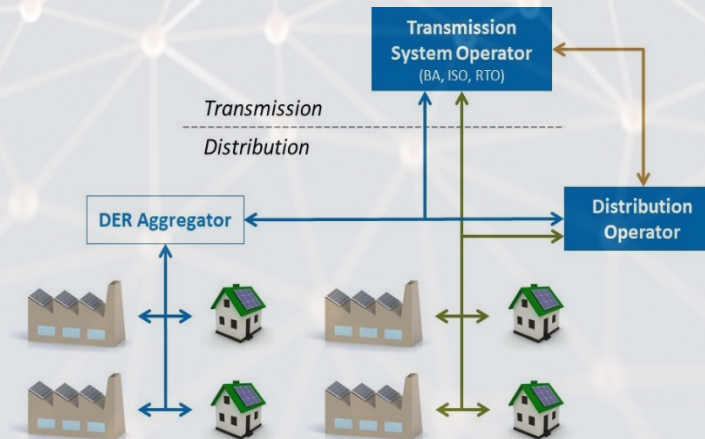
Total DSO Layered



Hybrid DSO Variants

Hybrid DSO

- TSO dispatches DER in the wholesale market
- TSO models DER at T-D interfaces
- TSO has minimal visibility into the distribution system



Hybrid DSO

- DSO dispatches DER for distribution grid needs and services
- DSO coordinates with TSO to ensure reliable DER wholesale transactions

A high-level taxonomy of DSO Models

	Total TSO	Hybrid DSO #1		Hybrid DSO #2		Total DSO	
Roles		Utility	IDSO	Utility	IDSO	Utility	IDSO
DO	DO	DSO	DO	DSO	DO	DSO	DO
DNO	TSO	DSO	DSO	DSO	DSO	DSO	DSO
DMO	TSO	TSO	TSO	DSO + TSO	DSO + TSO	DSO	DSO
Layered						DSO	DSO
Gridworks Models	Total TSO	Hybrid A		Hybrid B	Hybrid C	Total DSO	IDSO

NOTES: (1) Orange boxes indicate which functional roles (DO, DNO, DMO) are included in the DSO Model

(2) “Utility DSO” => DSO includes DO, vs “Independent DSO” (“IDSO”) => DSO is separate from the DO

(3) The MDMA role is not shown: a DSO design consideration is whether the DSO or a different Actor performs the MDMA role

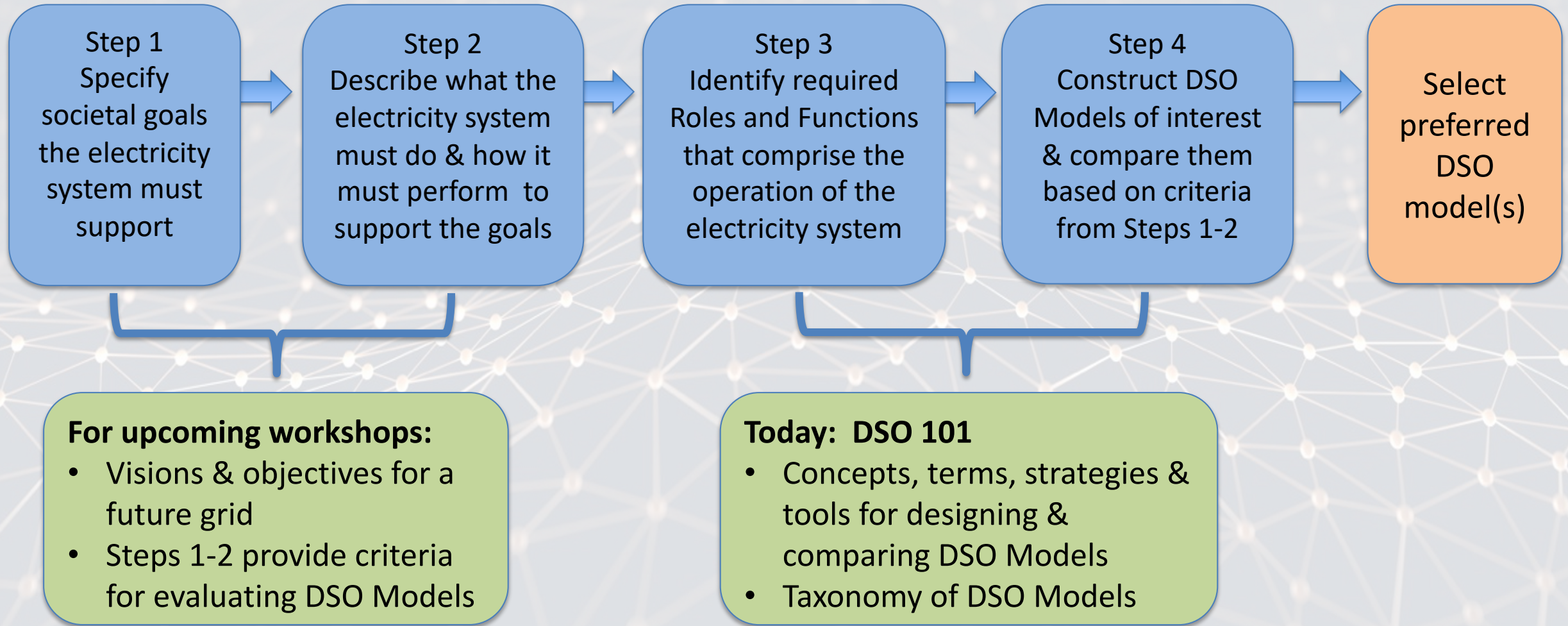
(4) The LSE role is not shown: DSO is likely a natural monopoly Actor, while LSE is a competitive role.

Wrap Up

Key DSO 101 Takeaways

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Comparing Alternative DSO Models



A surreal landscape featuring several power line towers. The towers are shaped like question marks, with the largest one on the right and smaller ones receding into the distance. Power lines stretch across the sky from the towers. In the background, a city skyline is visible on the horizon under a dramatic, cloudy sky at sunset or sunrise. The ground is a dry, scrubby field.

Thank you.

Lorenzo Kristov
LKristov91@gmail.com

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