# Decentralized Energy Markets and a Path to DSOs: An EU Perspective

## Panel: Flexibility Solutions in Distribution Systems

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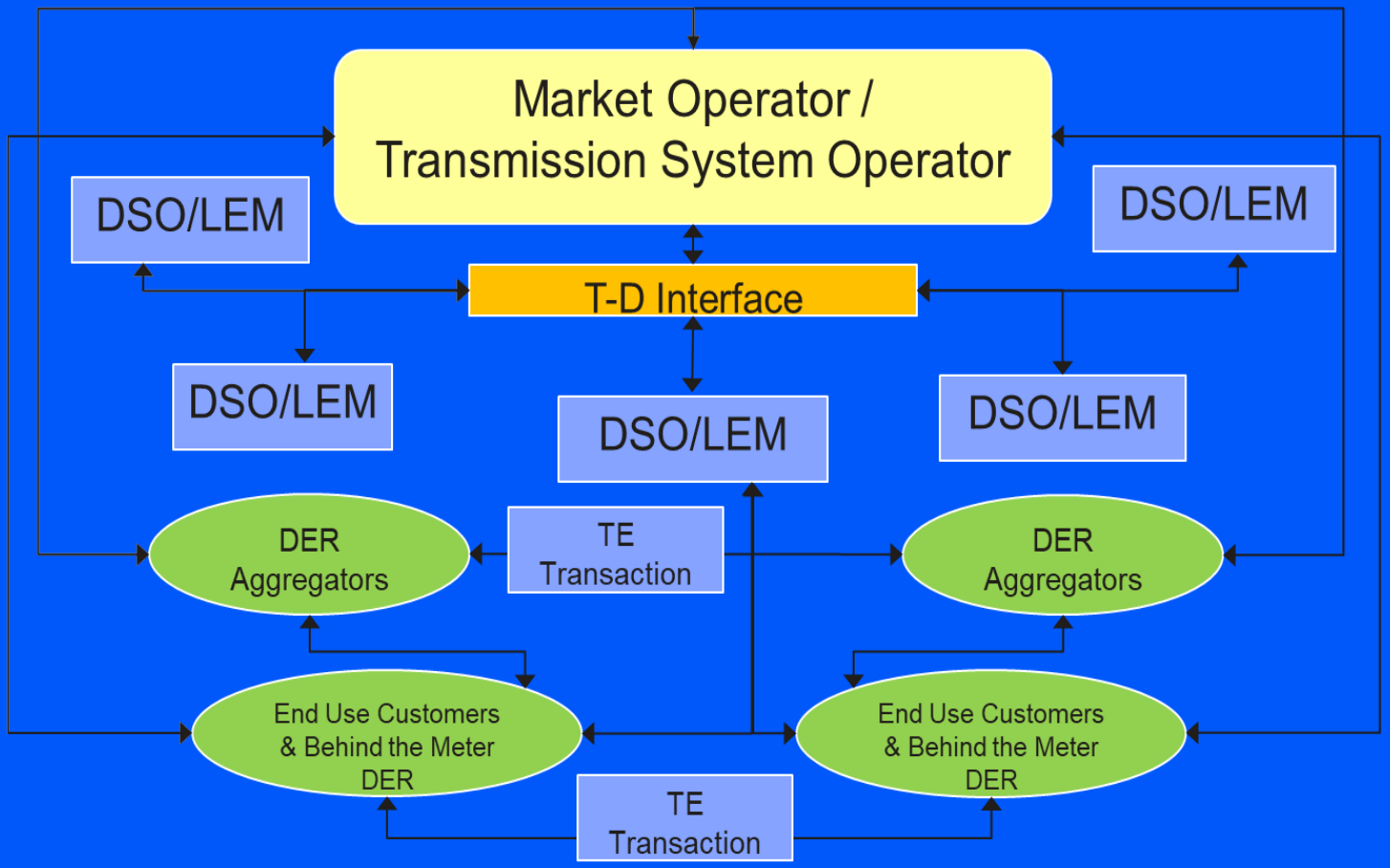
# Outline

- The Decentralized, Hierarchical Energy Model
- UK: The Nodal DLMP DER Market Development
  - Nodal DLMP Market Solution Method
  - Use Cases
- Greece/Poland: The DSO Market Evolution
- EU Horizon 20/20 Project: The Blockchain-based Transactive Energy Development
- Conclusions

# Decentralized Hierarchical Multi-Tier Energy Markets



# What Factors are Driving DER Proliferation?

- **Bottom-up demand & adoption**: customers want them
  - Individual R/C/I customers want more flexibility & control
  - Many customers want to participate in wholesale markets, individually or through DER Aggregators
  - Local resilience is an increasing concern driving microgrid formation
  - Cities & counties explore synergies among municipal services, want to implement climate action plans, and make renewable energy available to renters & underserved communities
- **Top-down policy directives:** policy makers recognize that DERs can support environmental & energy policy goals
- EU performance based regulation
- DER technologies continue to get cheaper & more powerful

# Background

- Traditionally ISOs/TSOs model distribution networks as loads
- DSO, traditionally, regard transmission systems as slack buses with unlimited resources (often modeled as voltage sources)
- Decentralized markets are considered in EU as essential to the energy transition
- Distribution systems are becoming more **active**:
  - Integration of **Distributed Energy Resources** (DERs)
  - Integration of **Information & Communication** Technologies (ICTs)

# The UK Project is a £19m project, funded by Centrica and the European Regional Development Fund (ERDF)

**Summary:**

- Develop a Nodal DLMP platform to facilitate the selling and buying of flexibility on the distribution network
- £13m ERDF and £6m Centrica investment
- DNO is different than the DSO

**Objectives:**

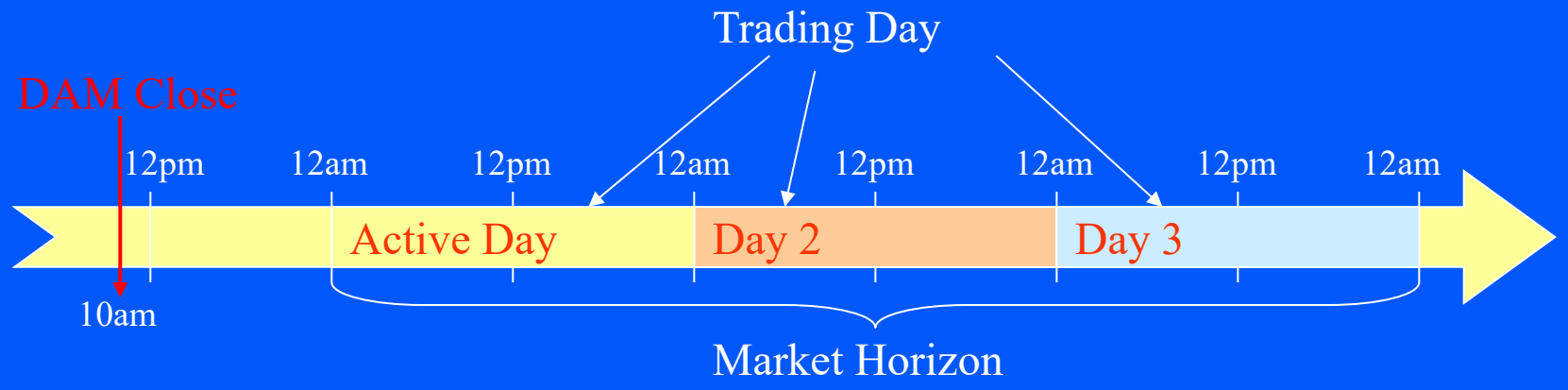
- Learn about the future by doing
- Reduce constraints by increasing flexibility
- Make it easier for consumers to access DSO, ISO/TSO, and wholesale market revenues

**Five key projects**

| | |
|---|---|
| LEM Platform | • Distribution network flexibility services<br>• Single access to multiple markets<br>• Flexibility for constraints management<br>• Avoids/defers network reinforcement |
| Technical Installation | • Install flexible technologies in 60 businesses<br>• Access core DSR revenue streams<br>• Connect to LEM platform<br>• Use assets for constraint management |
| Energy Storage | • 2.75 MW of storage installations<br>• 6 separate applications<br>• Sell flexibility to national grid and LEM |
| Residential | • 100 homes<br>• 100 batteries<br>• Aggregate as one unit |
| Research | • Learnings on regulations, barriers, markets, technology, customer etc.<br>• Insights that inform future policy |

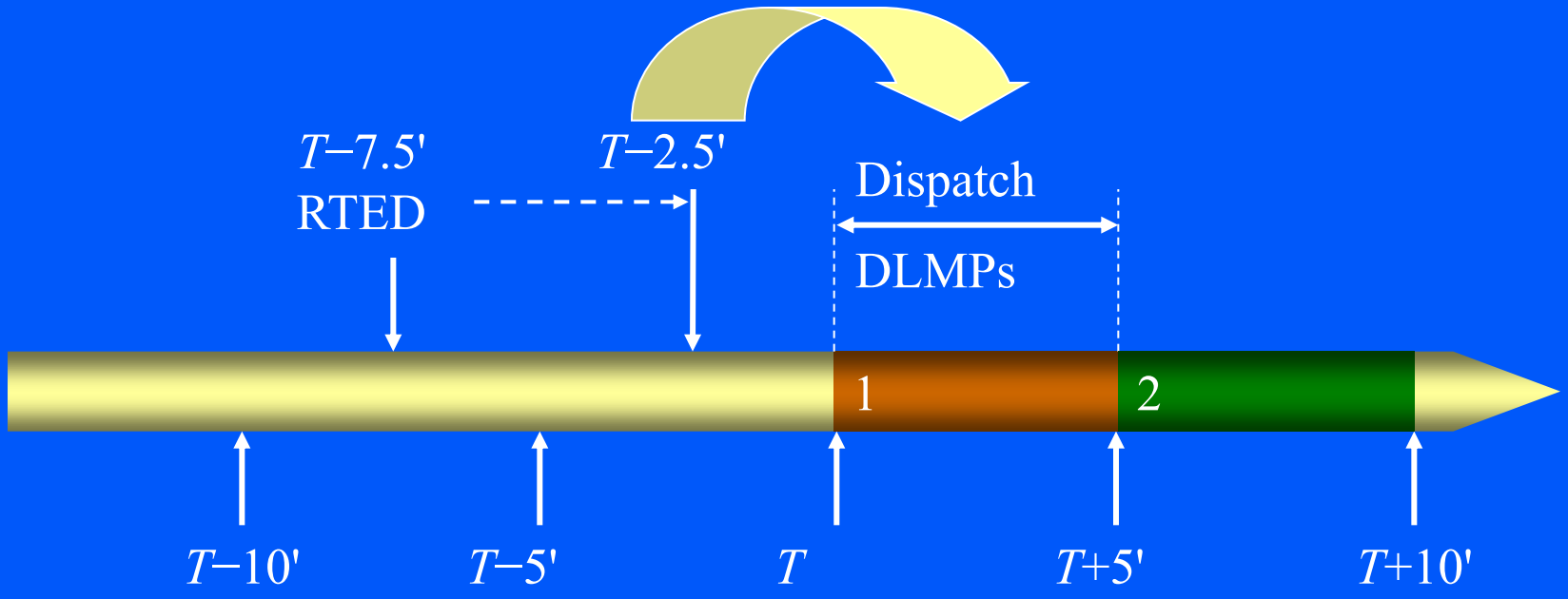
# Nodal DLMP Market Design Elements

# Day-Ahead Market Horizon




- Gate closure at 10 AM
- Time Horizon = 24 hours
- Time intervals = ½ hour

# Real Time Market Timeline




- Gate closure T - 15
- Time Horizon: 1 hour
- Time intervals = 5 minutes

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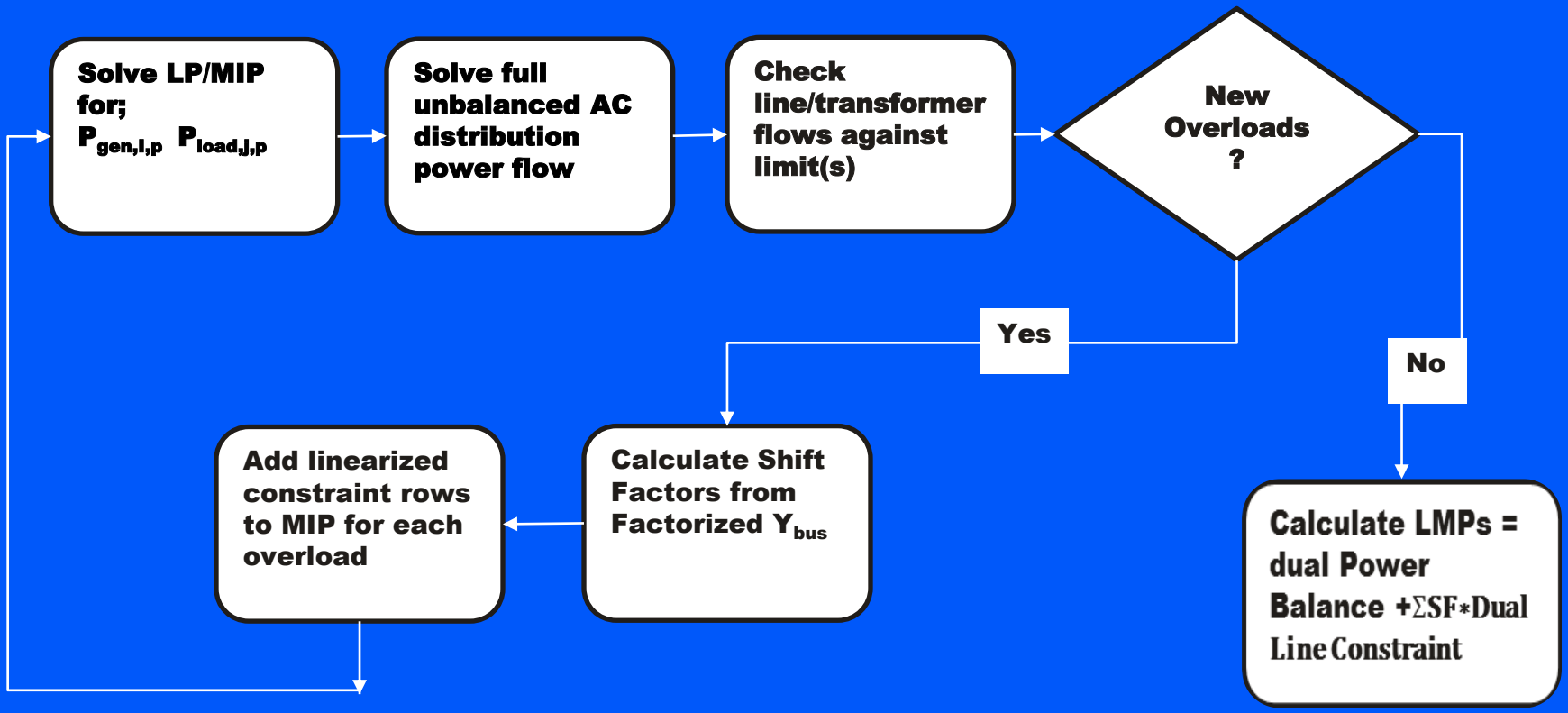
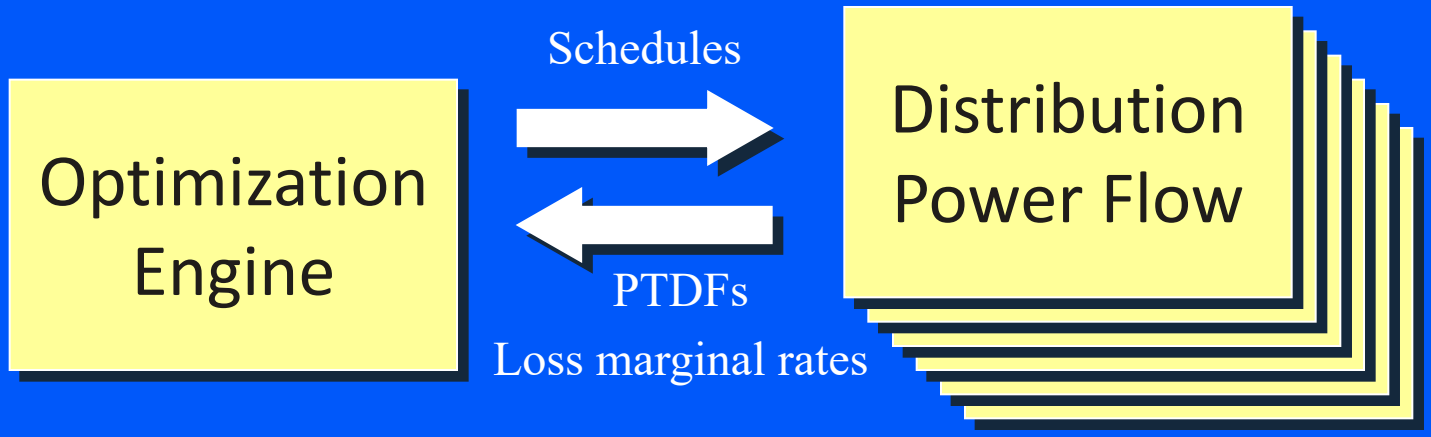
# Nodal DLMP Market Basic Models



# Nodal DLMP Market Solution Method

- Mixed Integer Linear Programming (MILP) or LP
  - Separate distribution power flows for each time interval
  - Iterate with optimization engine that has a single power balance constraint and the active inequality constraints for each time interval



# Nodal DLMP Market Clearing

Minimize $\sum P_{gen,l,p} * C_{gen,l,p} - \sum P_{load,j,p} * C_{load,j}$

Subject to:

$\sum P_{gen} - \sum P_{load} = \sum P_{fixedload}$ (System Power Balance Constraint

Linearized branch constraints

$P_{min,m,n} \leq \sum (P_{gen,l,p} - P_{gen0,l,p}) * SF_{mn,i} - \sum (P_{load,j,p} - P_{load0,j,p}) * SF_{mn,j,p} + P_{mn,0} \leq P_{max,mn}$

# Focus on Three DER Services

| Service | Definition |
|---|---|
| **Distribution Capacity** | The dispatch of power output (MW) of DER assets or DR that reliably reduces net load on desired distribution infrastructure |
| **Voltage Support** | Dynamic voltage management that corrects voltage limit excursions and supports future conservation voltage reduction strategies with utility power control systems |
| **Reliability (back-tie) and Resiliency (micro-grid)** | Load modifying or supply service that improves reliability and/or resiliency by providing a fast reconnection and excess reserves to reduce demand when restoring customers during abnormal configurations<br><br>In addition, resiliency (micro-grid) services for systems with enabling technology that provides power to islanded end use customers when central power is not supplied, reducing the duration of outages |

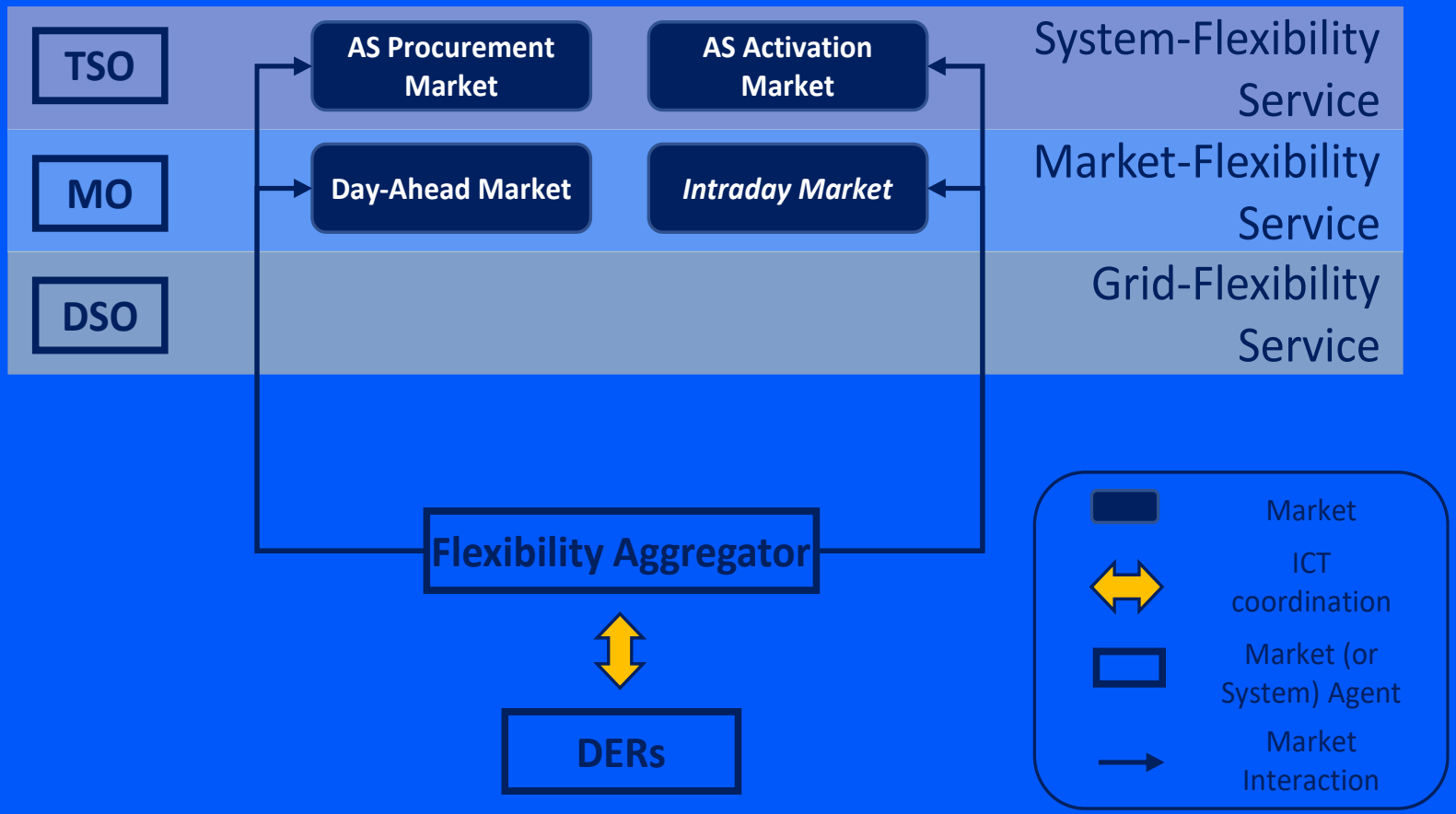
# Challenges to the DLMP DSO Development

- Need data with near real-time 5-15 minute periodicity; most current smart metering rollouts are next day upload, not near real-time
- Availability of network data (GIS/DMS extract)
- Communication challenges, but solvable
- Centralized models with distribution power flows are not scalable and hard to solve
- Convergence issues with AC OPF/UC (nonlinear, nonconvex formulations)
- Difficult to coordinate or co-optimize resources across T&D boundaries
- Behavior of DLMPs, Market Power Issues, Scarcity pricing
- Coordination issues between DSOs/TSOs

# The Greece/Poland Project: DSO Market Evolution

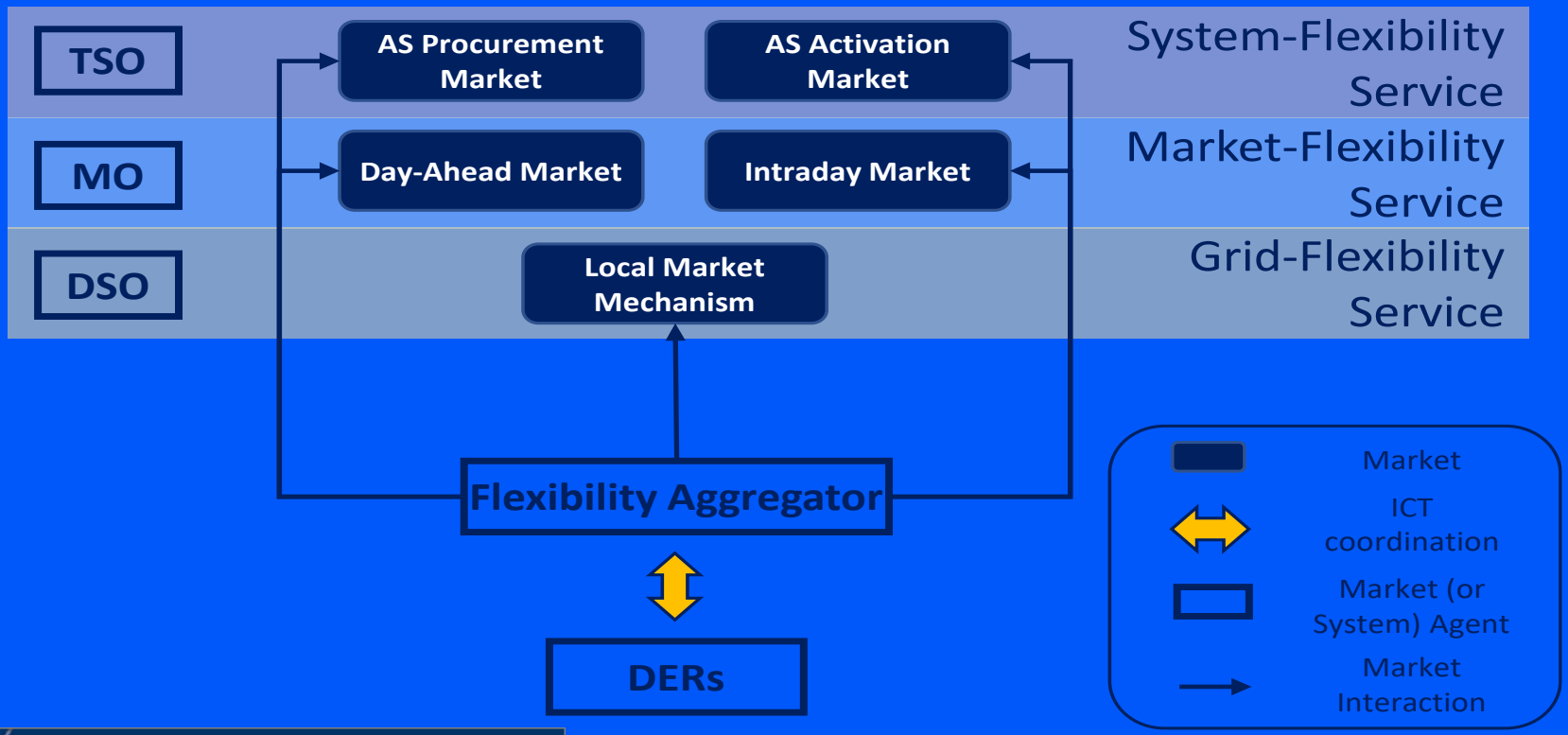
- Stage 1 – DER Aggregator Model with Existing Short-Term Markets (MO/TSO Only)
- Stage 2 – DER Aggregator Model with Short-Term Markets (MO/TSO, DSO)
- Stage 3 – DER Aggregator Model with Short-Term Markets (MO/TSO & DSO's Local Flexibility Market Platform)

# Stage 1 – DER Aggregator Model with Existing Short-Term Markets (MO/TSO Only)



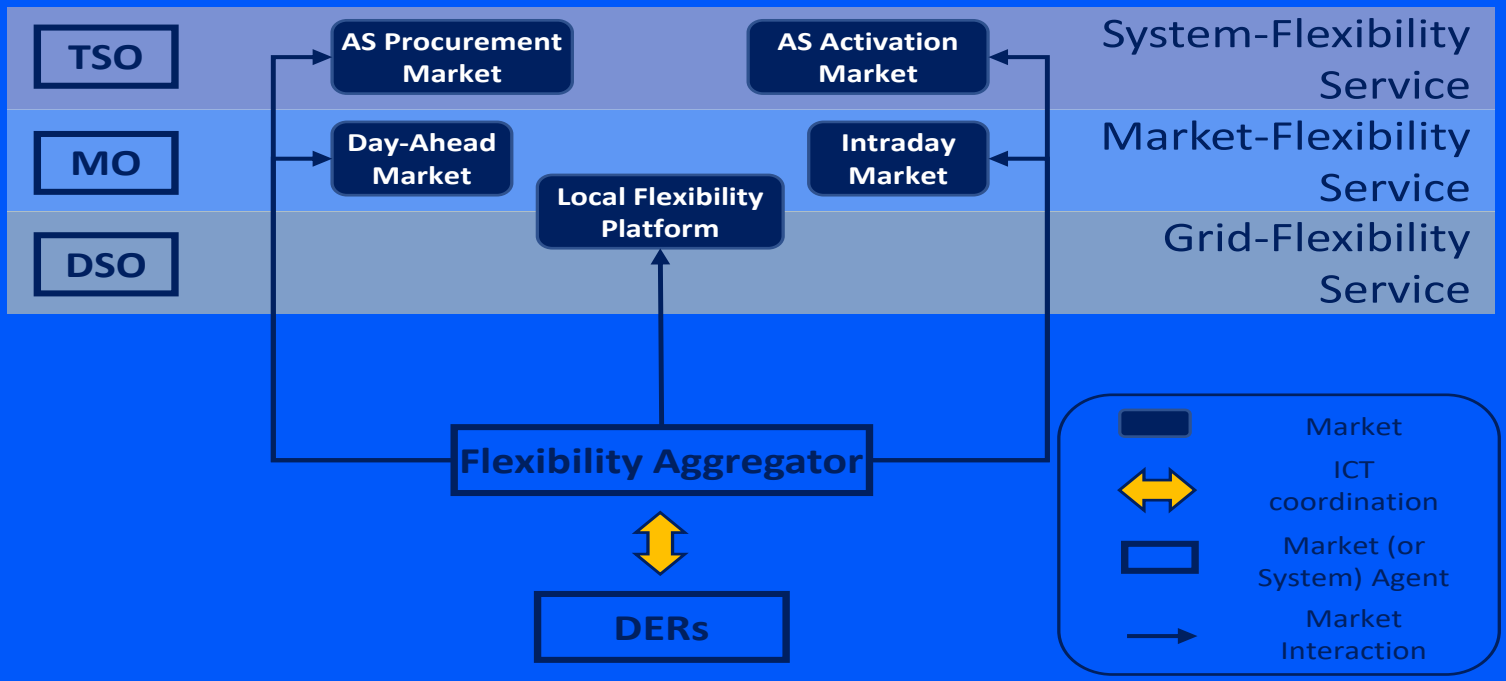
# Stage 2 – DER Aggregator Model with Short-Term Markets (MO/TSO, DSO) (Monopoly Test Phase)

- Local DSO Platform: 1) manage local problems by exploiting DER flexibility at the distribution level and 2) avoid grid investments on additional transfer capacity
- Two market products: 1) reservation contracts, and 2) activation market

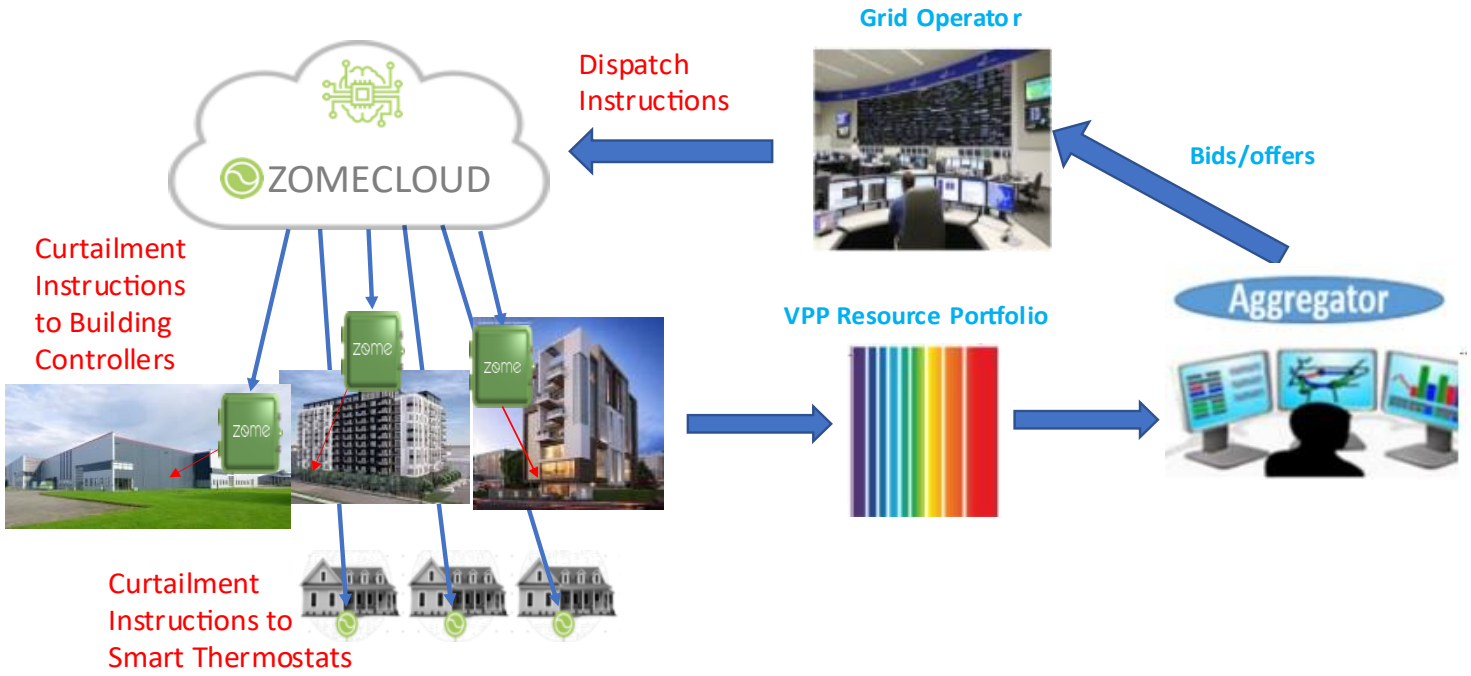


# Stage 3 – DER Aggregator Model with Short-Term Markets (MO/TSO, DSO) (Local Flexibility Market Platform)

- DER market has enough liquidity and the final step will be the shift to a fully-competitive local DSO flexibility market where competition is allowed on both sides
- DERAs can trade different services: grid services and market services



# The VPP Resource Portfolio Creation for Market Participation



# The EU Horizon 20/20 Project: A Practical Path to the Transactive Energy Model

## CONVENTIONAL BUILDING

Basically, energy "dumb"
95% of Today's
Multiple Dwelling Units

## SMART ENERGY BUILDING

Installation of IOT Devices and
A control system linked to the
Energy cloud

## MICRO-GRID BUILDING

Add Modules for
Solar, Batteries, EV Chargers

## COMMUNITY MICRO-GRID

Local Energy Footprint
Distribution-mapped Energy Control
Fast-Acting Demand Response
Building to Building Energy Sharing
Peer-to-Peer Energy Trading
Transactive Energy / Blockchain

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# Transactive Energy and Blockchain

## TRANSACTIVE ENERGY

MARKET OPERATOR

BUY SELL

SMART HOME

BUY SELL

SMART BUIDLING

BUY SELL

SMART CAMPUS

PRICE
DEMAND
TIME

AUTOMATED MARKET TRADING
BASED ON VALUE SIGNALS

## BLOCKCHAIN

SMART CONTRACT

SELLER

Contract Value
Energy Amount
Tariffs

BUYER

PUBLIC LEDGER

Smart Contract | Smart Contract | Smart Contract | Smart Contract | Smart Contract | Smart Contract | Smart Contract

VALUE EVENT

TOKENS

Execution
Validation
Settlement

ENERGY

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# Key Messages

- The action has shifted from the wholesale ISO/TSO transmission markets to distribution DSO/LEM markets
- The EU DSO markets have emerged and the regulatory framework is evolving
- Unfettered participation in hierarchical multi-tier energy market is needed for maximize the value of DERs to the grid
- DER subsidies need to be phased out gradually to reduce the DER perverse incentives and allow markets to work
- Location is important and DSO/LEM markets should include distribution constraints and produce prices that reflect locational effects
- The DSO and TE markets are at an inflection point moving from pilot programs to mass implementation