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Capacity expansion planning of alternative resources – Formulation of a new mechanism to procure flexible capacity

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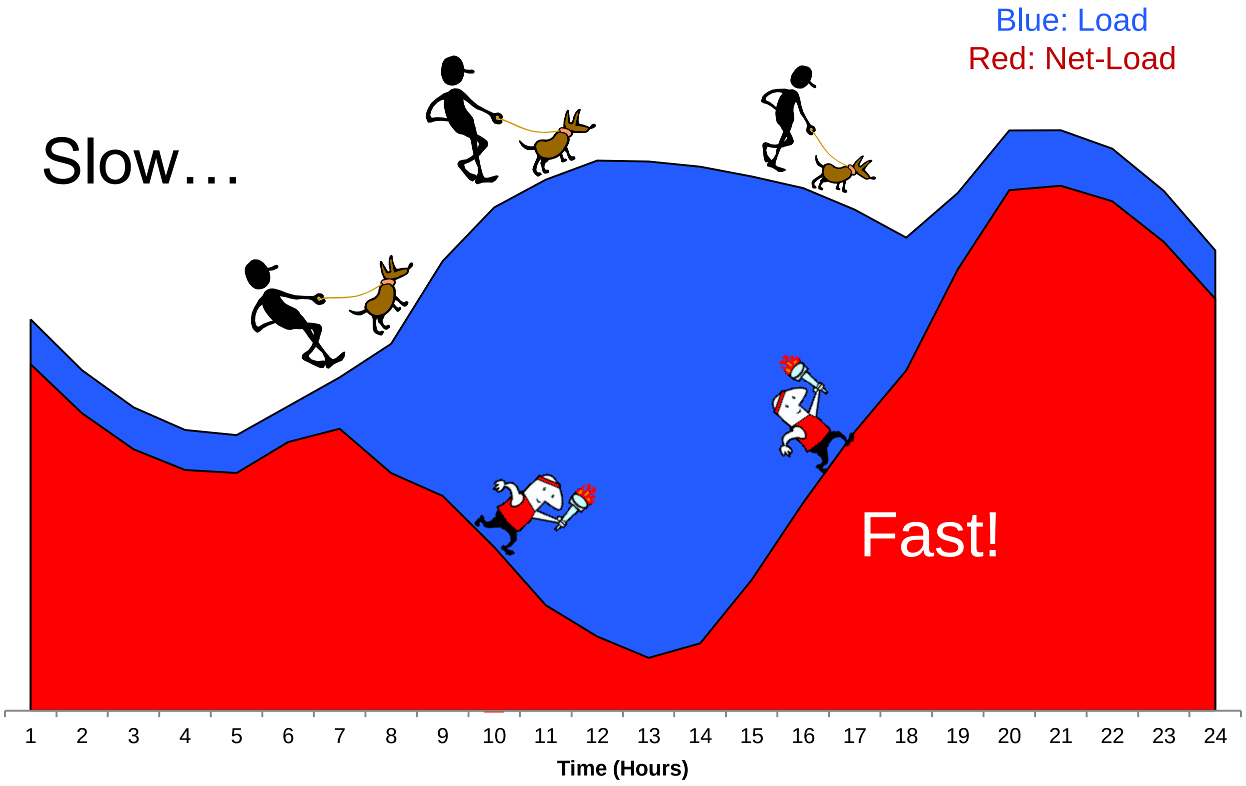
Adequacy in terms of peak + variability

Ensure the area's installed generating capacity will almost always exceed the area's peak requirement for each year in a given planning horizon[1]

…and Load Following, Regulation, Contingency

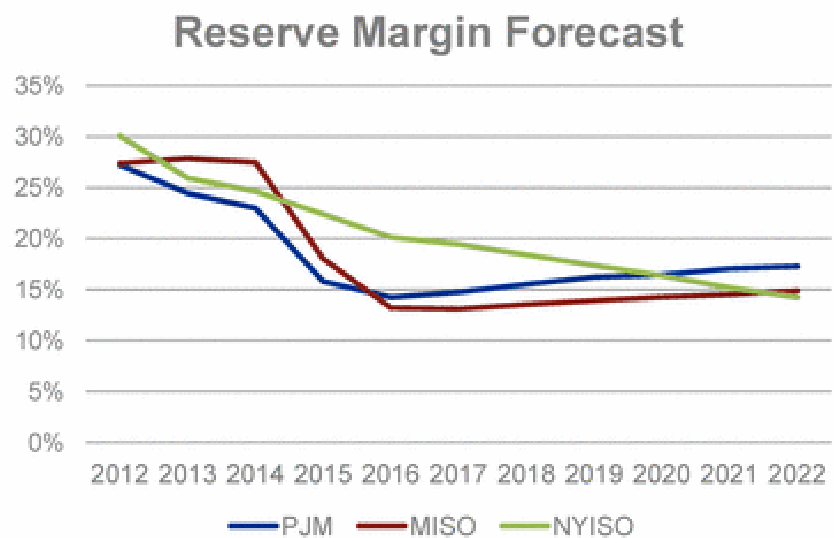
- Other means of ensuring adequacy: Alternative resources



[1] McCalley, J.D., "Reliability Evaluation", EE-552X Power System Planning, Class Notes, Fall 2013

Declining Reserve Margins

Impact of expected retirements on forecasted reserve margins



- Based on expected retirements, PJM and MISO reserve margins projected to be between ~16%-18% by 2015
- Additional retirements expected in 2016 would reduce reserve margins to ~13% -14% in PJM and MISO
- NYISO reserve margin anticipated to be decline steadily over several years

...At the same time: Retirements of Conventional Units, Increase in Demand & VG penetration → The latter creates a new dimension in the ***adequacy*** problem…

Robert Flexon, “Power and Gas Deep Dive Conference”, Dyenergy, Inc, April 2013.

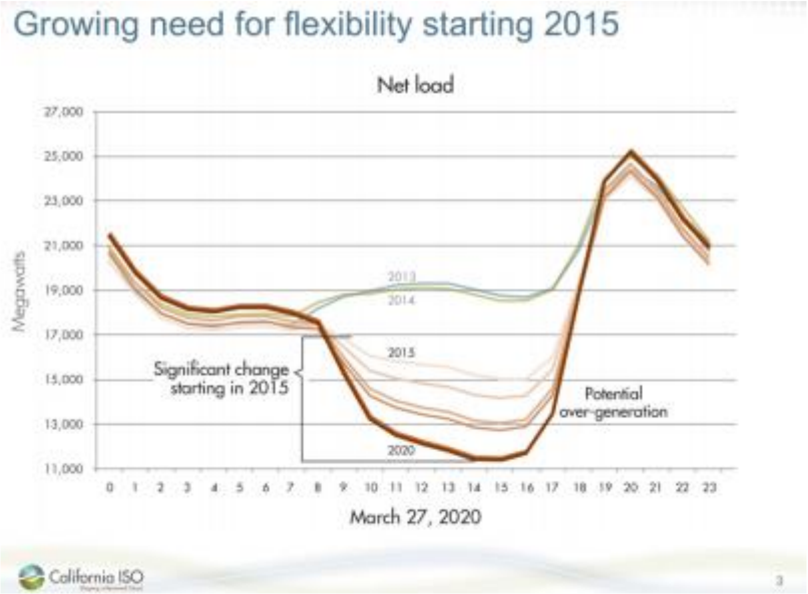
Will There Be Enough Flexible Capacity to Accommodate High % of VG penetration?

- 1-year forward mechanism: calculate a single flexible capacity need as a function of: ramping, contingency reserves, regulation and load following

$$\text{Flexibility Need}_{MTHy} = \text{Max}[(3RR_{HRx})_{MTHy}] + \text{Max}(MSSC, 3.5\% * E(PL_{MTHy})) + \varepsilon$$

Where,

- $\text{Max}[(3RR_{HRx})_{MTHy}]$ = Largest three hour contiguous ramp starting in hour x for month y
- E(PL) = Expected peak load
- MTHy = Month y



- Existing mechanisms:
  - 1-2 yrs. procurement
  - 10 yrs. procurement

CAISO, "Comprehensive Forward Capacity Procurement Framework", February 2013.

What is the need? A new mechanism

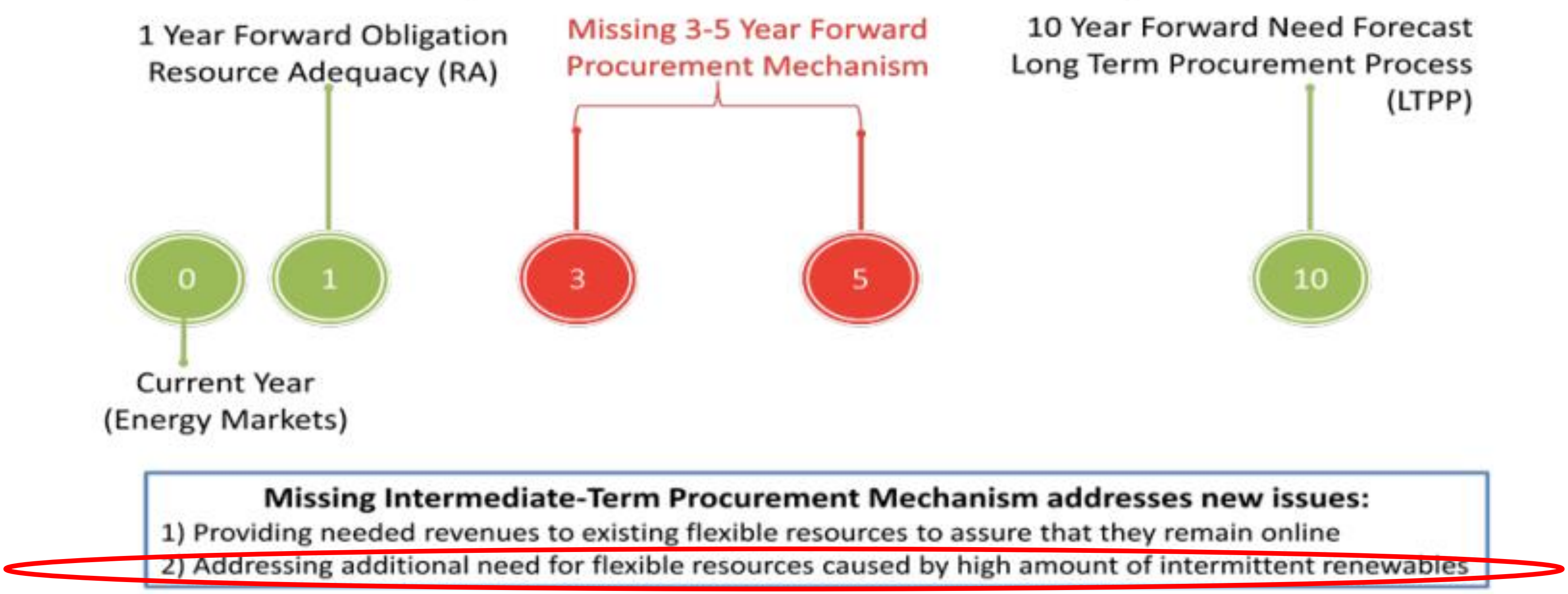


Figure 2: Intermediate-term Procurement Gap

CAISO, “Comprehensive Forward Capacity Procurement Framework”, February 2013.

Procurement of Flexible Generation…

Ancillary services markets (SCUC/SCED)

Capacity markets (Short-term GEP)

Interactions

Research Objective

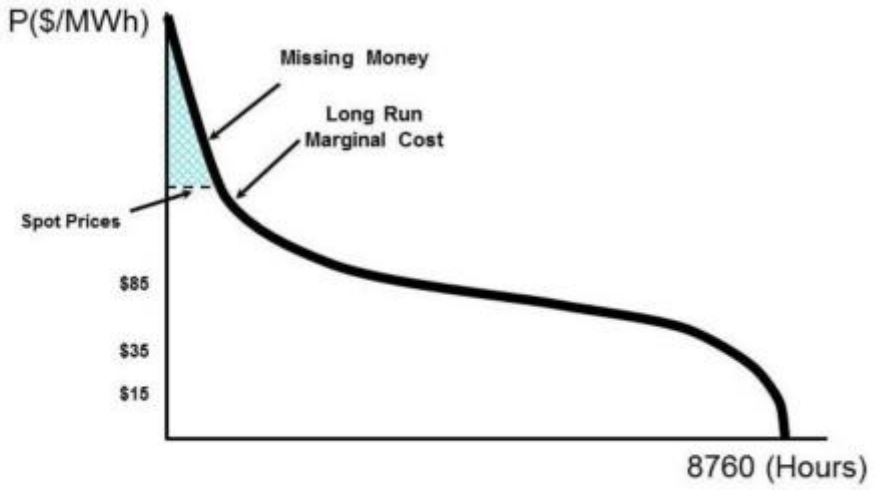
- Generation Flexibility
  - *Optimal combination of resources subjected to* <u>*security*</u> *constraints*
  - min (Production $)

- Generation Adequacy
  - *Optimal combination of resources subjected to* <u>*reliability*</u> *constraints*
  - min (Investment $)

The “missing money” problem

- Gap between net revenues produced by energy markets and the capital costs of investing in new capacity measured over several years
  - Energy + A.S. revenues need to be very high to supply the load…
    - Why? To cover incremental cost of conventional units… <u>results in higher electricity costs</u>

Figure 1
A Market Price Duration Curve



FTI Consulting, “Evaluation of the New York Capacity Market”, March 2013

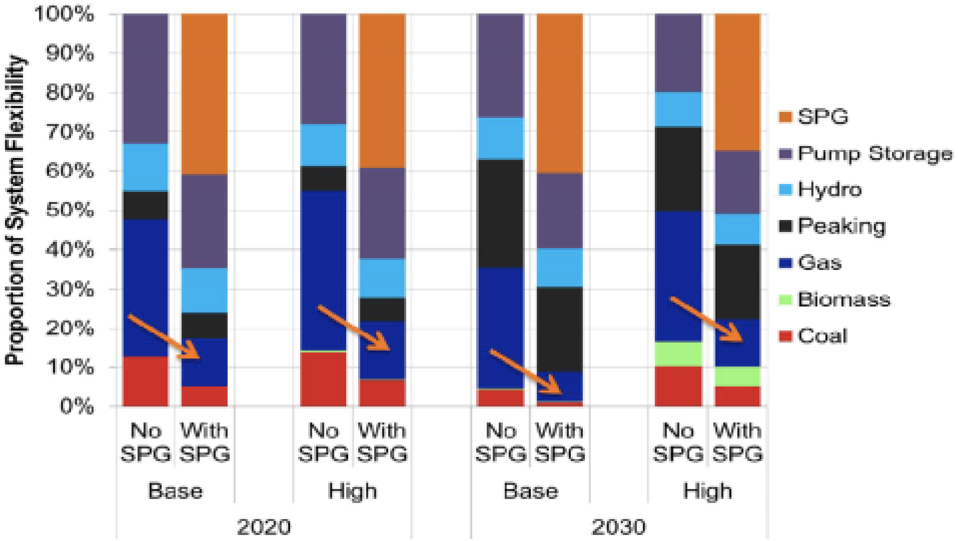
Paul L. Joskow, COMPETITIVE ELECTRICITY MARKETS AND INVESTMENT IN NEW GENERATING CAPACITY, MIT 2006

Short-term flexible capacity procurement mechanisms

- Ramp capability products (e.g., FlexiRamp) $\min\ (E) + (A.S.) + (Ramp\ Products)$
- Imbalance market (New; Spatial-temporal benefits)
- Increase reserves requirements (High prices → Market signal?)
- **Forward Capacity Market**
  - ✓ Alternative resources provide different services (e.g., fast response, regulation, load following)
    - ❖ Co-optimize the cost of investment + O&M of alternative resources to provide these services for flexible capacity procurement → Operational flexibility

“Smart Power Generation” – The UK case

- Storage, Demand-Side, Transmission Expansion
- Quick response (almost instantaneously)
- “Standby as reserve” costs are minimum
  - [2] Author claim savings in generation costs
  - Adequacy is always met
  - Suggested new mechanisms to procure flexible generation



[2] Rautkivi, M., Kruisdijk, M., “Future market design for reliable electricity system in Europe”, POWERGEN Europe 2013

The capacity expansion planning problem

- Minimize investment + operational costs
- Subjected to
  - Power balance
  - Transmission limits
  - Energy requirements
  - **Adequacy requirements**
  - **Reserves requirements**

$$\min \quad f(x) = c_1(x_1) + c_2(x_2) + \cdots + c_n(x_n)$$

$$a_1 x \leq b_1$$

$$a_2 x \leq b_2$$

$$\vdots$$

$$a_m x \leq b_m$$

The Co-Optimization Problem

$$f(x) = c_1(x_1) + c_2(x_2) + \cdots + c_n(x_n)$$

- Simultaneous optimization of two or more variables
- For example, to minimize cost of…
  - Investment (f_1)
  - Operation (f_2)
  - Cycling (f_3)

$$\min \; f_1(x) + f_1(y) + f_1(z) + f_2(x) + f_2(y) + f_2(z) + f_3(x) + f_3(y) + f_3(z)$$

Regulation (x)

Load Following (y)

Contingency (z)

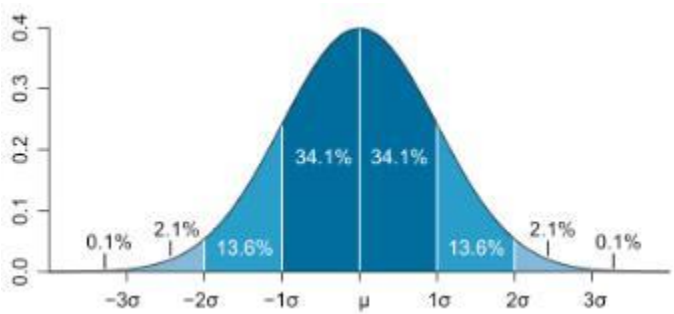
Subjected to…

…FLEXIBILITY, PERFORMANCE, AND ADEQUACY CONSTRAINTS…

Flexibility Constraints

- Characterization at low penetration levels (e.g., 10%)
- Stdev. of two random variables

$$\sigma_z{}^2 = \sigma_x{}^2 + \sigma_y{}^2$$



- Industry accepted ramp requirement ~ $3*\sigma_{\text{Net-Load}}$ (10-min)
- Does this approach still apply at higher penetration levels?

Research Objective: Interface with forecasting models

Adequacy metrics

- Loss of load expectation $LOLE = t_{C_T} = g(C_T)$
- Loss of load probability $LOLP = P(D \geq C_T) = F_D(C_T)$
- ELCC-The additional conventional generation capacity required to achieve the same level of the reliability → $\frac{C_{additional}}{C_{wind}}$ →

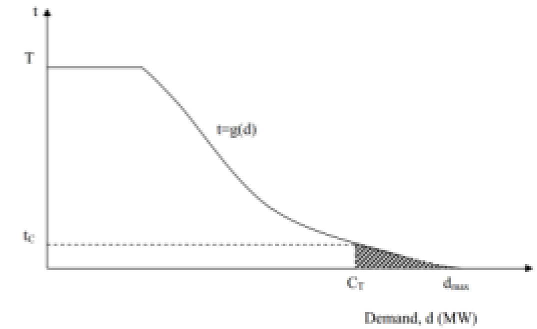


Figure 7: Illustration of Unserved Demand

Table 1. Raw ELCCs for all Load Profiles, Wind Regions and Study Years

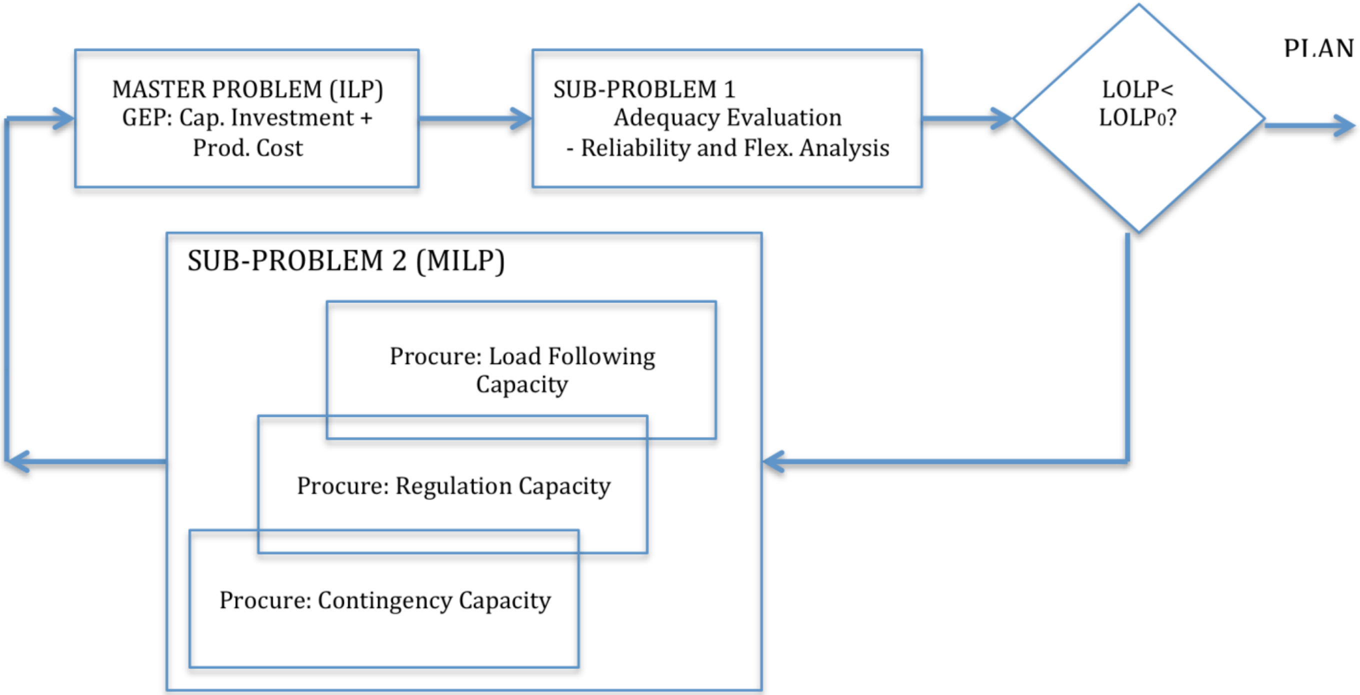
Load Profile	Coastal ELCC		West ELCC	
	2014	2016	2014	2016
1997	26.1%	48.2%	9.0%	12.2%
1998	50.8%	66.5%	22.5%	18.7%
1999	12.0%	29.5%	15.0%	10.6%
2000	17.2%	21.3%	8.2%	8.9%
2001	66.7%	63.3%	13.7%	9.0%
2002	18.0%	19.0%	35.0%	16.6%
2003	39.7%	34.0%	12.3%	14.1%
2004	40.3%	73.7%	15.9%	24.7%
2005	43.9%	35.7%	3.5%	5.8%
2006	50.2%	32.2%	32.9%	22.9%
2007	7.1%	1.8%	14.9%	4.8%
2008	24.1%	43.3%	25.3%	33.6%
2009	46.7%	18.0%	18.4%	14.7%
2010	19.0%	11.8%	4.1%	4.8%
2011	23.5%	31.4%	8.6%	12.2%

ECCO International, "2012 ERCOT Loss of Load Study", March 2013

[1] McCalley, J.D., "Reliability Evaluation", EE-552X Power System Planning, Class Notes, Fall 2013

Sequential, Iterative or Simultaneous?

- Tradeoff between computational time and number of scenarios



Concluding remarks

- Summary
  - The technologies are there, but the mechanisms are not
  - Short-run mechanism to procure flexible capacity is needed for higher levels of VG
  - Co-optimization can be used to assess the different A.S. needs simultaneously
- Objectives
  - *Design* a mechanism to procure load following, regulation, and contingency via alternative resources
  - *Illustrate* processes and procedures to identify "flexible portfolios"

Existing technologies can provide operational flexibility…

Questions?