Eastern Interconnection Planning Collaborative

Gas-Electric System Interface Study

Target 4
Fuel Assurance:
Dual-Fuel Capability v. Firm Transportation

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LEVITAN & ASSOCIATES, INC.
MARKET DESIGN, ECONOMICS AND POWER SYSTEMS

Acknowledgement and Disclaimer

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Agenda

- Overview of Target 4 research goals

- Specific analyses
  - Simple Cycle and Combined Cycle Storage Capability
  - Dual-Fuel Operating Characteristics and Costs
  - Oil Market Availability and Resupply Options
  - Fuel Switching Design and Practice
  - Economic Tradeoffs between Dual-Fuel v. Firm Transportation

- Q&A

Target 4 Study Limitations

- Fuel assurance from PPAs' perspective
- No quantification of wholesale energy price effects with Firm Transportation v. Dual-fuel capability
- Other factors affecting generators' willingness to invest in Firm Transportation
  - Different performance on gas v. ULSD
  - Profit margin from incremental energy sales
  - Increased permitting difficulty to store and burn ULSD
  - Penalty avoidance as a capacity resource

Target 4 Highlights

Primary Findings

- Going forward, new gas-fired plants are expected to use ultra low sulfur diesel (ULSD) as the primary back up fuel
- Anticipated heavy reliance on ULSD represents a major change in the distillate oil market
  - ULSD supply chain is robust
- Air permits typically cap oil use to 720 hours, but some permits have established lower annual hourly limits
- At most locations, the cost of dual-fuel capability is much less expensive than the incremental cost of firm transportation to satisfy the fuel assurance objective

Target 4 Approach

- Identify constrained locations across the Study Region from Target 2 Frequency – Duration results
- Define gas turbine technology types in Simple Cycle (SC) and Combined Cycle (CC) mode
- Design cost model to account for regional differences in dual-fuel capability, firm transportation (FT)
  - Account for non-firm transportation costs
  - Account for local facility improvements where applicable
- Develop a flexible financial modeling tool that can be updated by the PPAs in response to changing market and operational dynamics

Current Dual-Fuel Capability

- Liquid Fuel Storage and Resupply Methods
  - Focus on backup fuel storage capacity and backup fuel consumption at full load
  - Data on resupply/delivery logistics
- Data pieced together from public and confidential data sources, i.e., PPAs, generators, air permit applications, U.S. EPA
- Database contains consistent storage and fuel use data for 52 units (CTs and CCs)
  - Unit-specific details will not be published

CT Characteristics & Costs

- Focus on differential performance and cost for
  - Single Fuel (natural gas)
  - Dual-Fuel (natural gas and ULSD)
- Selected CT models representative of recent and near future new SC and CC plants
  - Heavy frame units using “F” technology:
    - GE 7FA (7F.05)
    - Siemens SGT6-5000F
  - Aeroderivative units:
    - GE LM6000
    - GE LMS100

Information Sources

- Review and reliance on 2014 PJM CONE Study
  - Capital and operating cost account structure
    - SC and CC 7FA-based plants
    - Single fuel and dual-fuel cost estimates
  - Cost adjustments for multiple locations
    - Labor cost
    - Property, sales, and income taxes
    - Environmental regulation
- Review and reliance on 2013 NYISO CONE study
  - Capital costs for LMS100 SC
    - Single fuel and dual-fuel configurations
    - Different site conditions, including NYC/LI
- Fuel storage tank construction cost information from NYSERDA study prepared by ICF
- Discussions with CT manufacturers

Cost Models

- Cost models developed for incremental dual-fuel capability
  - Three plant types
    - Standard CC plant (2x1 7FA)
    - Heavy-frame SC plant (2 x 7FA, no SCR)
    - Aeroderivative SC plant (2 x LMS100, with SCR)
  - Location-specific parameters
    - Labor cost factors
    - Taxes (sales, property, income)
    - NO_x limitations (attainment v. non-attainment zone)
    - Liquid fuel inventory and tankage requirements
  - Capital cost and fixed operating cost differentials

Dual-Fuel Capital Cost for 2x7FA CC

Location	Base	RTO	EMAAC	SWMAAC	WMAAC	Dominion
Locational Assumptions	OH	OH	NJ	MD	PA	VA
Nominal Capital $MM for 2018 CO						
Gas Turbine Scope	$4.700	$4.700	$4.700	$4.700	$4.700	$4.700
Other major equipment	$0.000	$0.000	$0.000	$0.000	$0.000	$0.000
Other construction labor	$0.000	$0.000	$0.000	$0.000	$0.000	$0.000
Liquid Fuel, Demin water handling (Mat'l)	$0.900	$0.900	$0.900	$0.900	$0.900	$0.900
LIquid Fuel, Demin water handling (Labor)	$0.900	$0.900	$1.170	$0.887	$0.920	$0.804
Liquid fuel storage tank (Mat'l)	$0.827	$0.827	$0.846	$0.843	$0.825	$0.838
Liquid fuel storage tank (Labor)	$0.556	$0.556	$0.740	$0.559	$0.568	$0.504
Demin water storage tank (Mat'l)	$0.498	$0.498	$0.498	$0.498	$0.498	$0.498
Demin water storage tank (Labor)	$0.335	$0.335	$0.436	$0.331	$0.343	$0.300
Incremental Land for Tanks	$0.038	$0.038	$0.066	$0.074	$0.042	$0.054
Startup Testing ULSD	$5.087	$5.087	$5.244	$5.217	$5.070	$5.179
Startup Testing Energy Sales on ULSD	($1.611)	($1.611)	($1.812)	($1.647)	($1.605)	($1.636)
Inventory carrying cost as O&M	$0.000	$0.000	$0.000	$0.000	$0.000	$0.000
Total Incremental Direct Cost	$12.232	$12.232	$12.788	$12.362	$12.261	$12.142
Sales tax on equipment and materials	$0.416	$0.416	$0.488	$0.418	$0.413	$0.434
EPC Fee	$1.096	$1.096	$1.173	$1.096	$1.100	$1.077
EPC Contingency	$1.023	$1.023	$1.095	$1.023	$1.027	$1.005
Development Cost	$0.563	$0.563	$0.602	$0.563	$0.565	$0.553
Mobilization & Startup	$0.113	$0.113	$0.120	$0.113	$0.113	$0.111
Non-fuel Inventories	$0.056	$0.056	$0.060	$0.056	$0.056	$0.055
Owner's Contingency	$0.332	$0.332	$0.331	$0.343	$0.331	$0.339
Financing Fees	$0.380	$0.380	$0.400	$0.383	$0.381	$0.377
Indirect (factored) Costs	$3.977	$3.977	$4.271	$3.996	$3.986	$3.951
Total Overnight Cost	$16.209	$16.209	$17.059	$16.357	$16.247	$16.093
Total Installed Cost	$17.765	$17.765	$18.697	$17.928	$17.806	$17.638
Installed Cost per kW of ICAP	$27.29	$27.29	$27.99	$27.00	$27.44	$26.72

Dual-Fuel O&M Costs

CT Model and Configuration	2x1 7FA CC	2x7FA SC	2xLMS100 SC
Location	Base	Base	Base
Locational Assumptions	OH	OH	Newburgh
Annual Fixed O&M Cost (2018 $MM /yr)			
Materials & Contract Services	$0.118	$0.044	$0.011
Administrative & General Expense	$0.023	$0.047	$0.011
ULSD for Regular Testing	$1.060	$1.070	$0.491
Energy Offset for Testing	($0.336)	($0.223)	($0.116)
Property Taxes	$0.259	$0.303	$0.068
Insurance	$0.107	$0.126	$0.054
ULSD Inventory Carrying Cost as Fixed O&M	$0.203	$0.206	$0.094
Total Fixed O&M (2018 $MM/yr)	$1.435	$1.572	$0.612
Total Fixed O&M (2018 $kW-yr)	$2.20	$4.08	$3.32

Fuel Oil Market Assessment

- Continued discussions with generators re backup fuel issues
  - Going forward most backup fuel use will be ULSD
  - Reduction in seasonal supply constraints
  - Some constraints on supply reported for last winter
    - Weather conditions affecting deliveries by truck
    - Confusion between low sulfur diesel and ULSD
- Data from refiners, suppliers and distributors re availability, costs, and storage issues
  - Some storage and use considerations, i.e., lubricity and microbiological contamination
  - Treatment with additives and biocide applications to storage tanks

Fuel Switching (Manufacturer View)

- Fuel switching capability is common design option
- Switching can be "on the fly"
  - Frame units drop load (e.g. 80%) to switch
  - Easier for aeroderivatives (e.g. LMS100) to switch at 100% load
- Entire process takes a few minutes *if* systems ready
  - Liquid fuel systems are on stand-by (recirculating between tank and CT)
  - Water injection systems (not required for gas firing)
- Switching can be automatic (based on delivery pressure signal) or operator-initiated

Testing of Switchover Capability

- Regular testing of liquid fuel systems
  - Testing does not require a 100% switchover
  - Liquid fuel only needs to be fired for a few minutes
  - Long-term service agreements which guarantee emissions may require weekly testing

- Water injection for heavy frame CTs on liquid fuel
  - Needed to meet NO_x limits
  - Additional equipment to maintain in ready status
  - Additional extreme cold-weather concerns

Fuel Switching – Operator View

Operator (Genco) Perspective: Costs & Benefits

- Reasons for periodic oil operation
  - Reliable switching requires training and practice
  - Service Agreements may require testing to maintain oil firing and emission guarantees
  - Fuel and water systems tested and ready
  - Operator training critical due to frame CT complexities
- Benefits of periodic oil operation
  - Systems and operators ready if called upon
  - Less chance of trip or emission excursion
- Costs of periodic oil operation
  - High ULSD price relative to LMPs
  - Higher maintenance accrual rate is *not* an issue

Fuel Switching – Operator View (2)

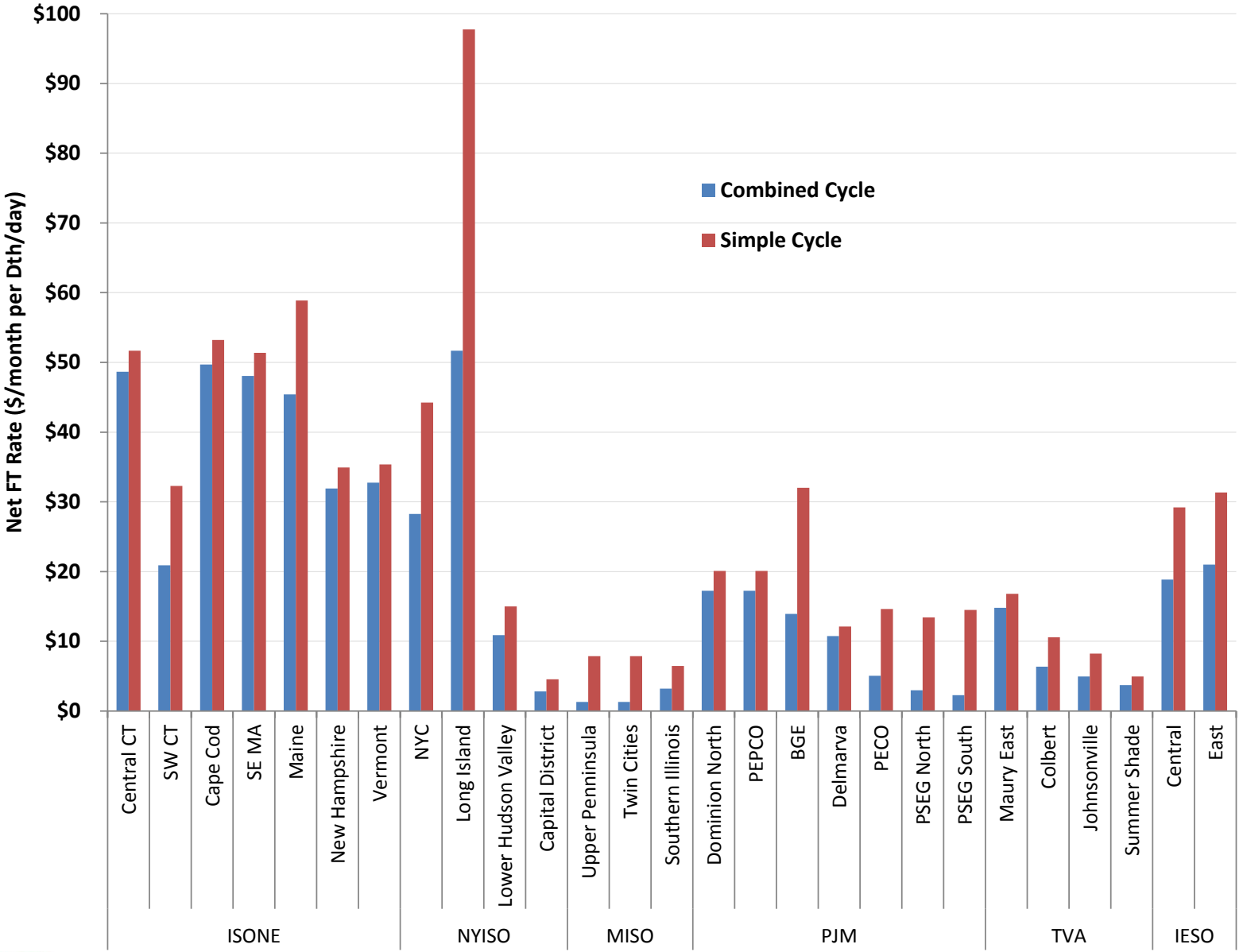
Operator (Genco) Perspective: Would Periodically Test on Oil *if Costs Were Recoverable* through Tariff

- Fuel switching practices
  - GTs can run at reduced load if gas pressure drops
  - If need to switch, GT load reduced to minimize chance of trip and avoid emission exceedence
  - Problems with oil *and water systems* in cold weather
  - GTs injecting water for gas are less vulnerable
  - Switching virtually always by operators; seldom automatic
- Gencos do not test / practice on oil
  - Costs > benefits (higher chance of successful switch)
  - Inadequate financial incentive to test on oil

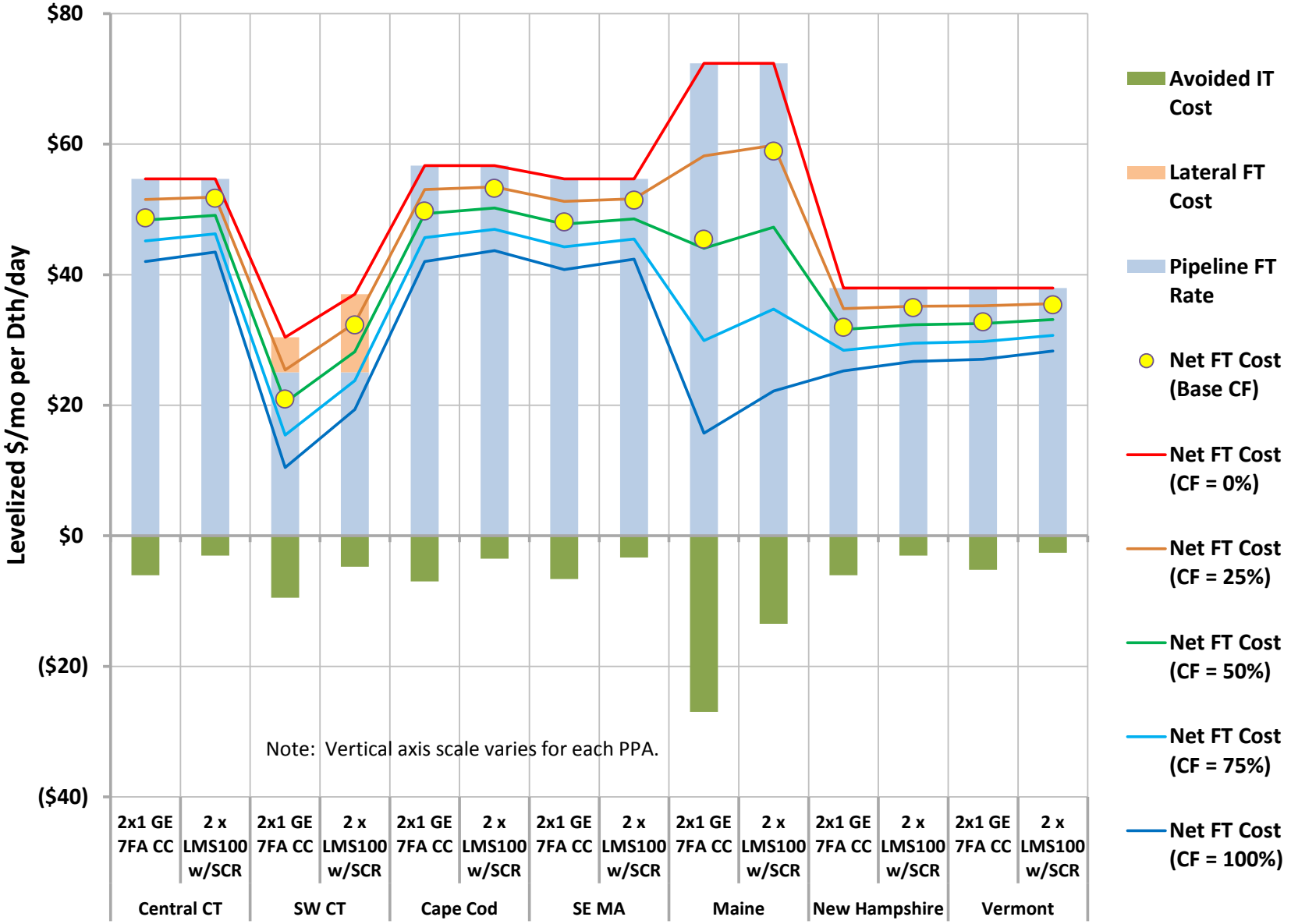
Dual-Fuel v. Firm Transportation

- 27 constrained locations selected by PPAs
  - Target 2 Frequency – Duration results
  - Focus on areas where new development likely
- Natural gas supply and delivery by location
  - Identification of pipeline path from a production basin to plant location
  - FT reservation rates (incremental), avoided IT costs
  - Lateral as proxy for LDC upgrade costs, if applicable
  - Net Cost of FT
    - FT rate less the avoided cost associated with non-firm transportation costs

Net Cost of FT



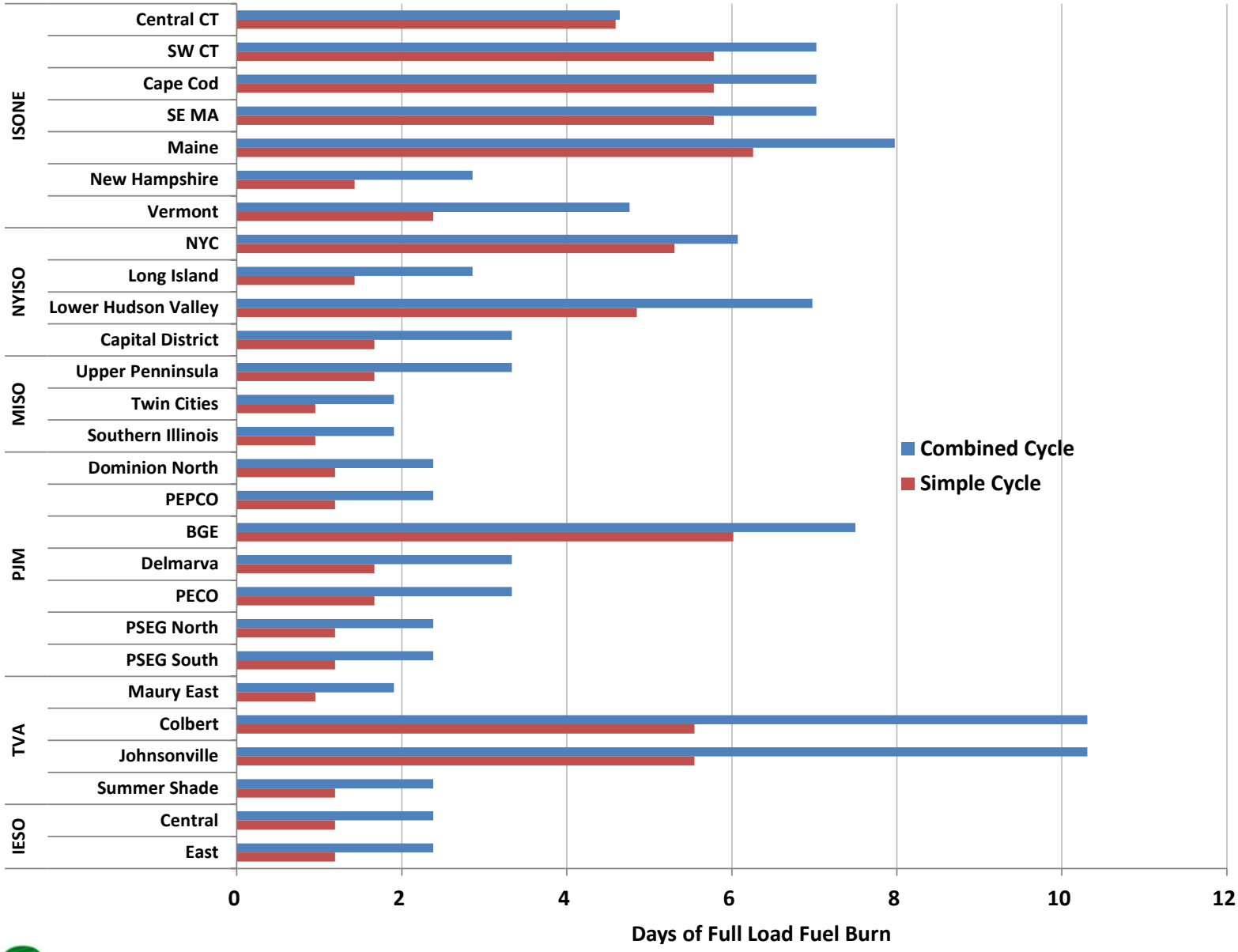
Components of Net Cost of FT



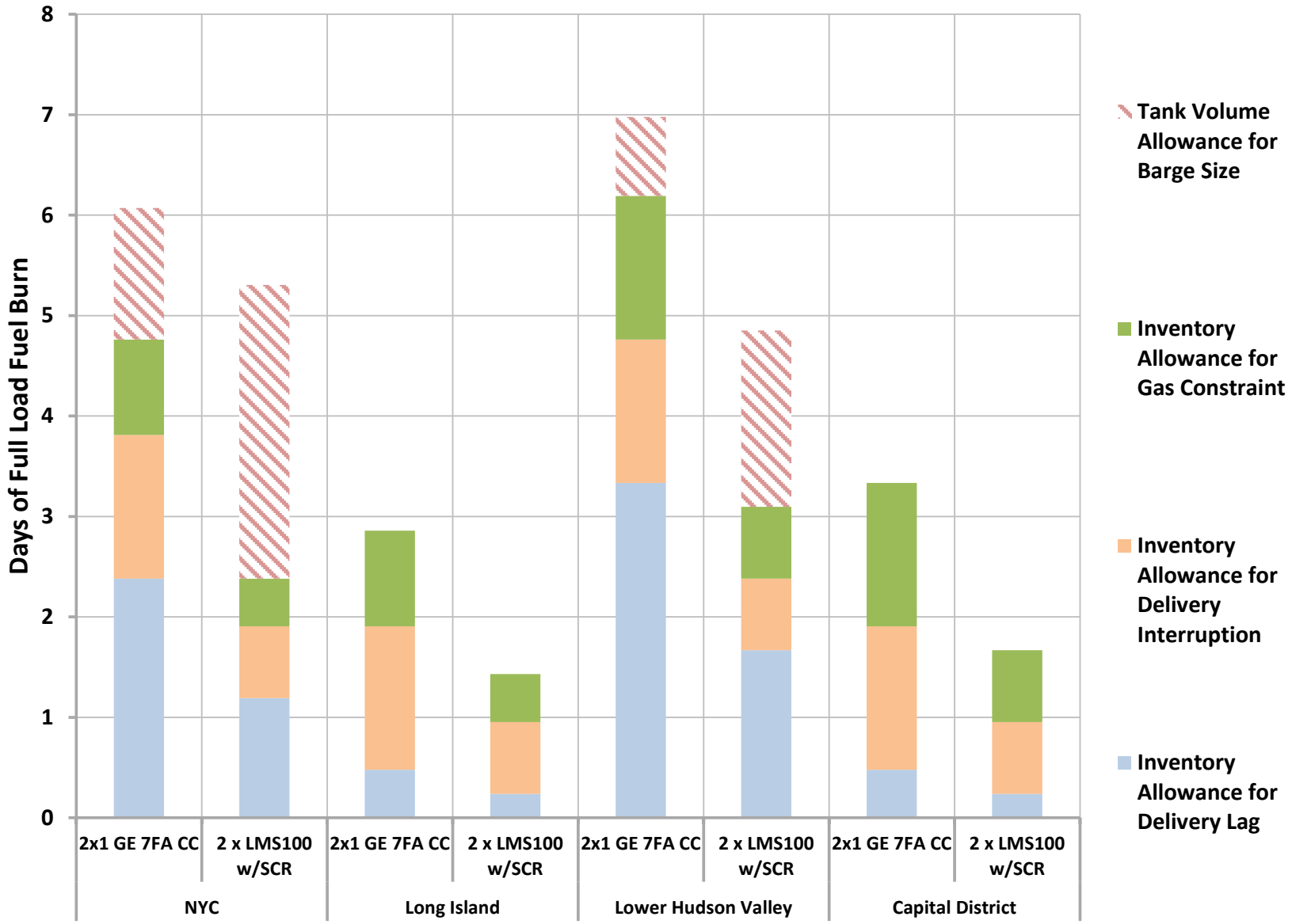
Dual-Fuel v. Firm Transportation

- ULSD Logistics by Location
  - Identification of depot
  - Identification of transport mode (truck or barge)
  - Estimation of normal delivery lag (order to receipt)
  - Estimation of potential weather delays (snow, ice)
  - Net price based on rack price, shipping, demurrage
- Target Inventory and Fuel Storage Tank Volume
  - Expressed in days of full load burn
  - Location-specific variables
    - Severity of natural gas delivery constraint
    - Delivery lag and potential weather delay
    - Expected capacity factor when operating on ULSD
    - Tank volume allowance for “lumpy” barge delivery size

ULSD Tank Capacities by Location



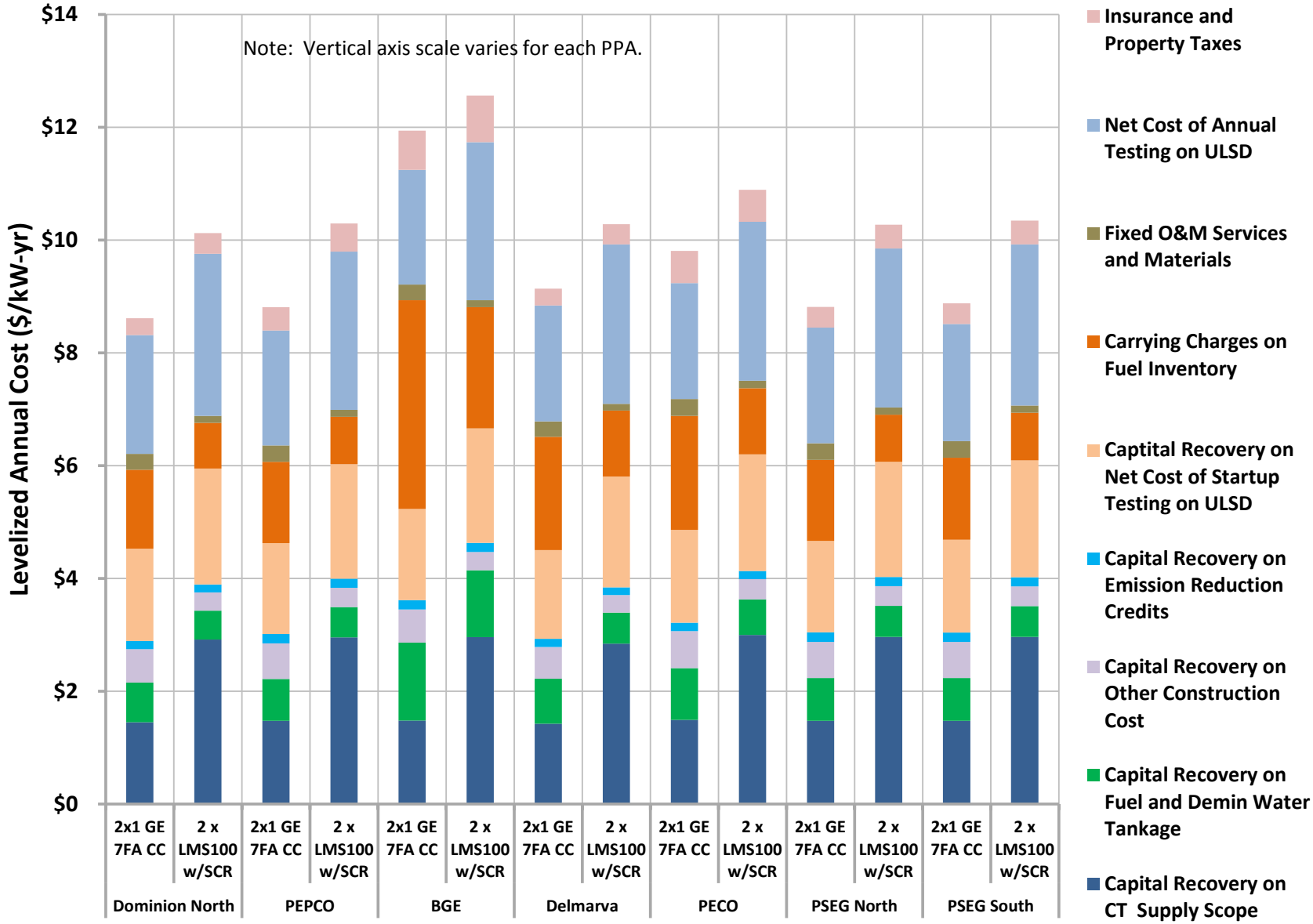
ULSD Tank Capacity Drivers



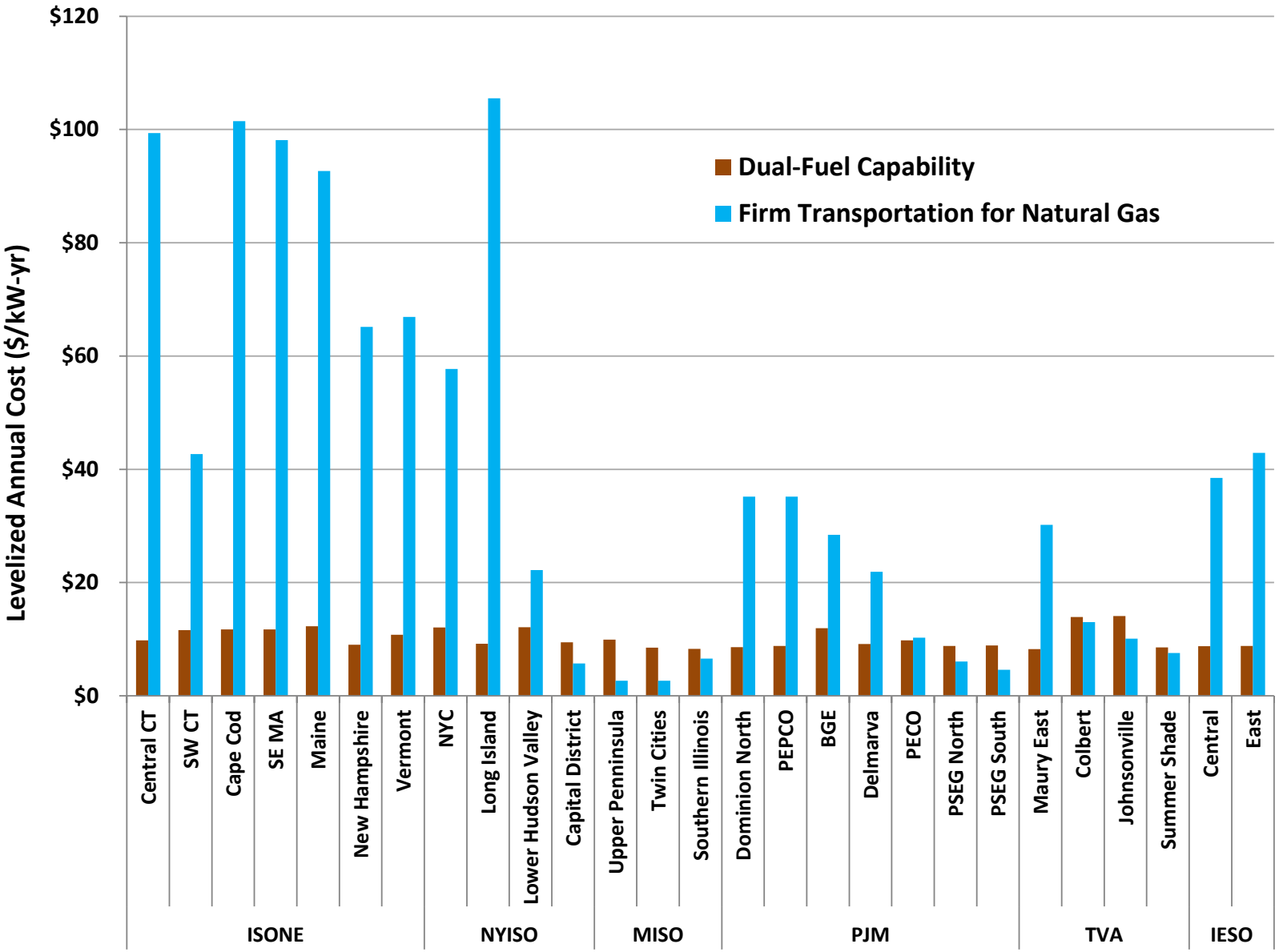
Dual-Fuel v. Firm Transportation

- Levelized Annual Cost of Fuel Assurance (2018 $/kW-yr)
  - Dual-fuel capability
    - Capital Recovery
      - CT supply scope (burners, I&C, etc.)
      - Fuel and demin water storage / handling / receipt
      - Other construction costs
      - Emission reduction credits
      - Net cost of startup testing on ULSD
    - Carrying charges on ULSD Inventory
    - Fixed O&M Costs
      - Incremental labor, services and materials
      - Net cost of annual testing on ULSD
      - Incremental insurance and property taxes
  - Net cost of FT – Monthly rate x 12 * MDQ / ICAP

Cost of Dual-Fuel Capability

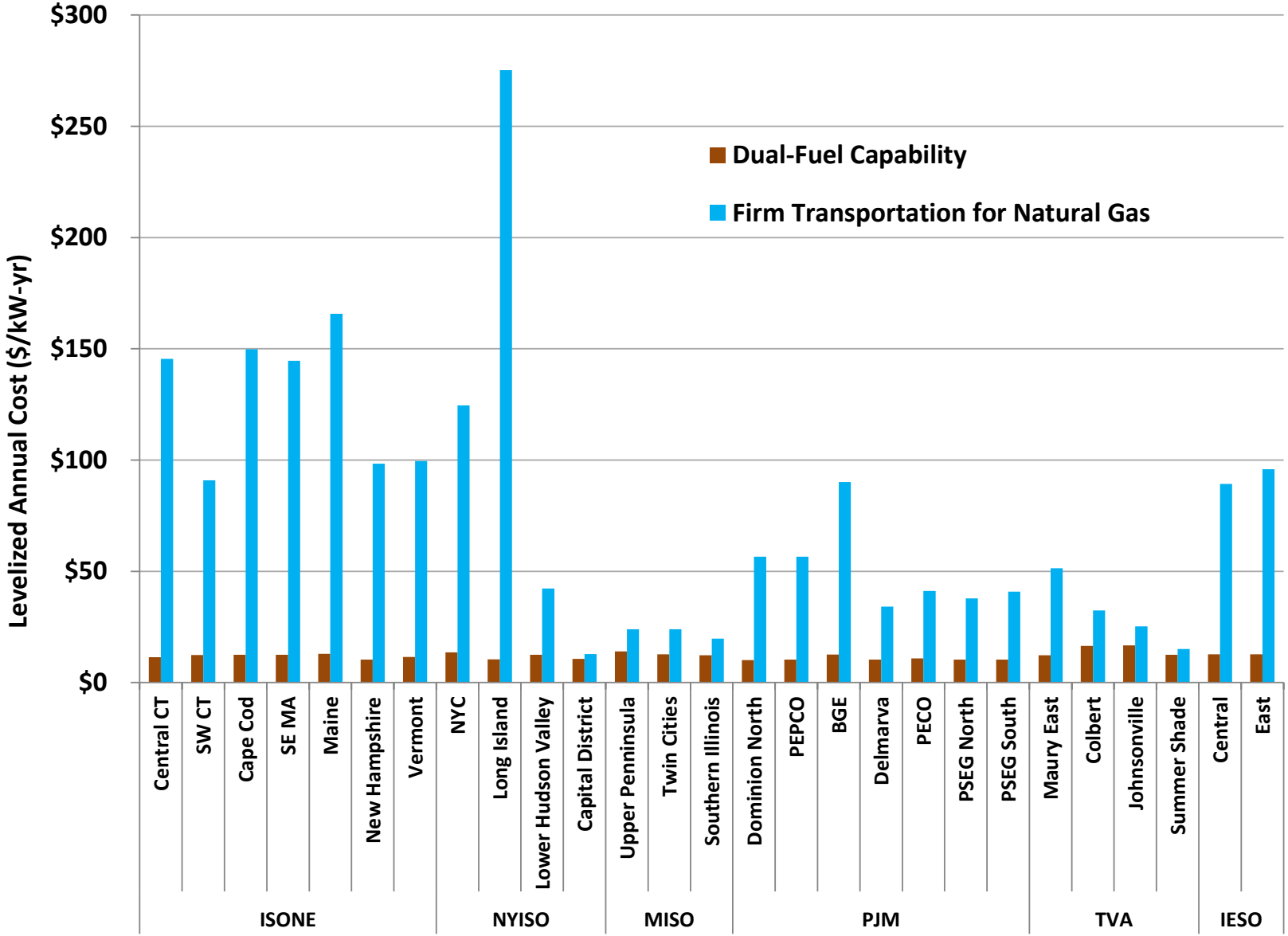


Comparison Results for Combined Cycle



Target 4 Results

Comparison Results for Simple Cycle



Target 4 Results

Conclusions (1)

- The cost of dual-fuel capability is relatively consistent over the range of locations
  - Primary driver is inventory and storage requirements for barge delivery
  - Unit cost is higher for simple cycle due to higher heat rates (partially offset by lower capacity factor)
- Cost of fuel assurance through FT varies widely by location
  - Primary drivers are the cost of incremental FT and the cost of local improvements
  - Unit cost is higher for SC due the higher heat rate and the lower installed capacity
- Dual-fuel capability has a lower cost than net FT cost (with few exceptions)

Conclusions (2)

- In some locations where incremental FT = embedded costs, FT has a comparable cost to dual-fuel for CCs
- Dual-fuel capability is the lower cost fuel assurance alternative for SCs at all sites
- Study limitations
  - Fuel assurance from PPAs' perspective
  - Other factors affecting generators' willingness to invest in FT
    - Different performance on gas v ULSD
    - Profit margin from incremental energy sales
    - Increased permitting difficulty to store & burn ULSD
    - Penalty avoidance as a capacity resource

Target 4 Production Schedule

- Proposed key milestones
  - Report to stakeholders: 11/07/2014
  - SSC webinar re results: 11/14/2014
  - Stakeholder comments due: 11/21/2014
  - Final draft report to DOE: 12/05/2014