
# Energy & Technology: Global Interconnections

NCSL Task Force on Energy Supply
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Denver, CO

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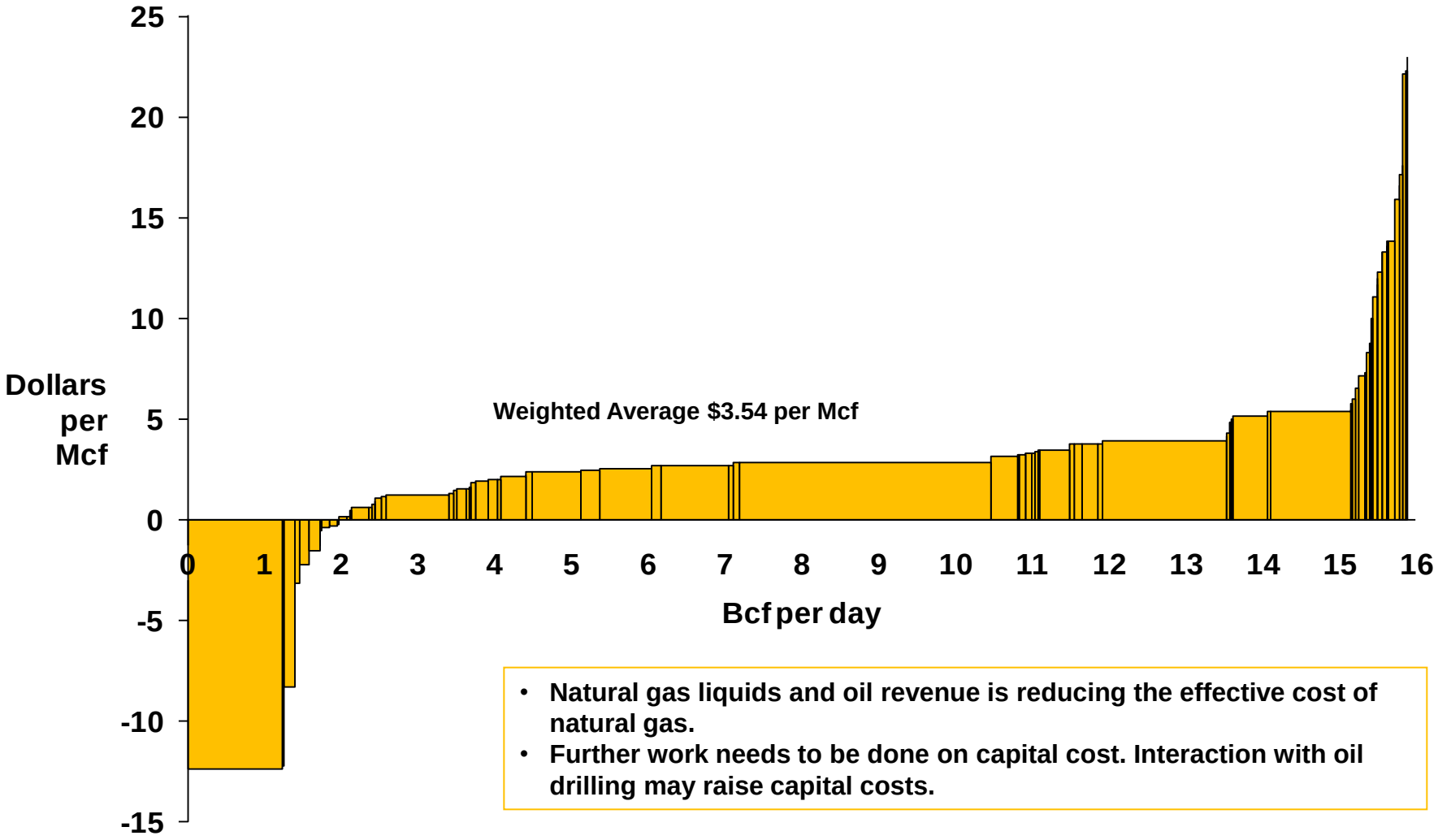
# North American Full-Cycle Unit Cost of New Supply 2012, Includes NGLs Credit

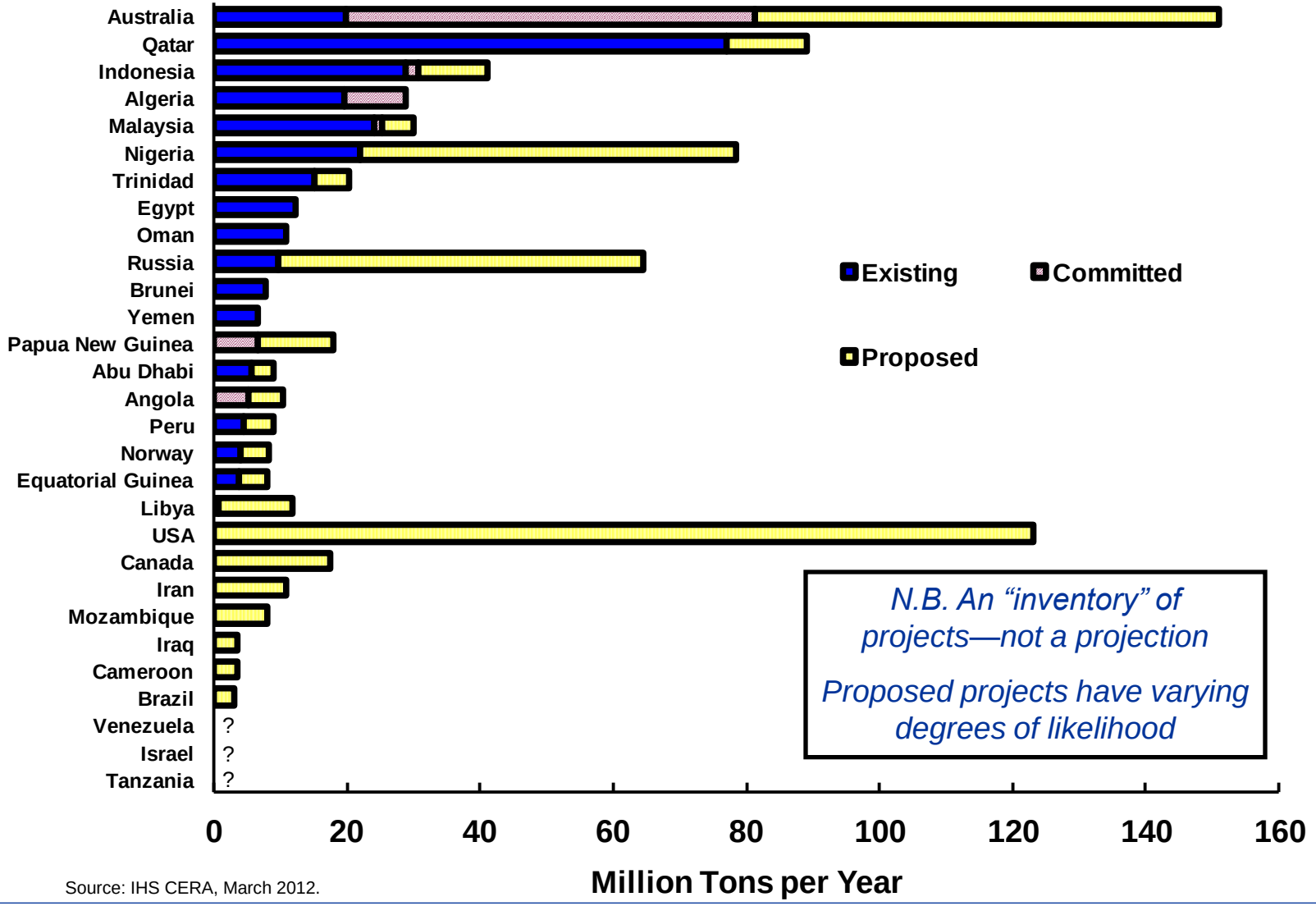



- **Natural gas liquids and oil revenue is reducing the effective cost of natural gas.**
- **Further work needs to be done on capital cost. Interaction with oil drilling may raise capital costs.**

Source: IHS CERA.

# Large Inventory of Proposed Projects, All Planned for a Pre-2025 Start-Up, but High Uncertainty

## LNG Capacity by Status and Country

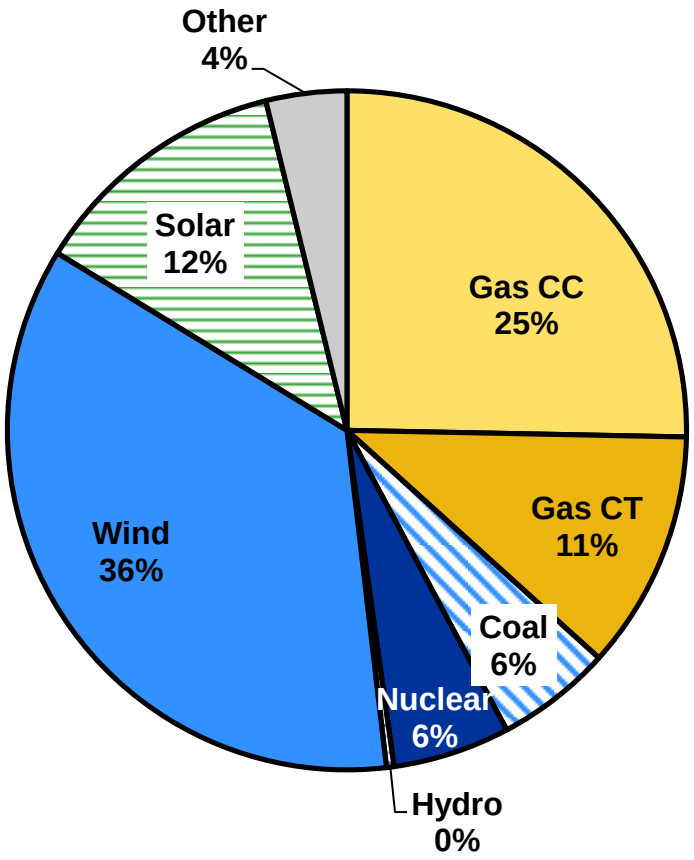



Source: IHS CERA, March 2012.

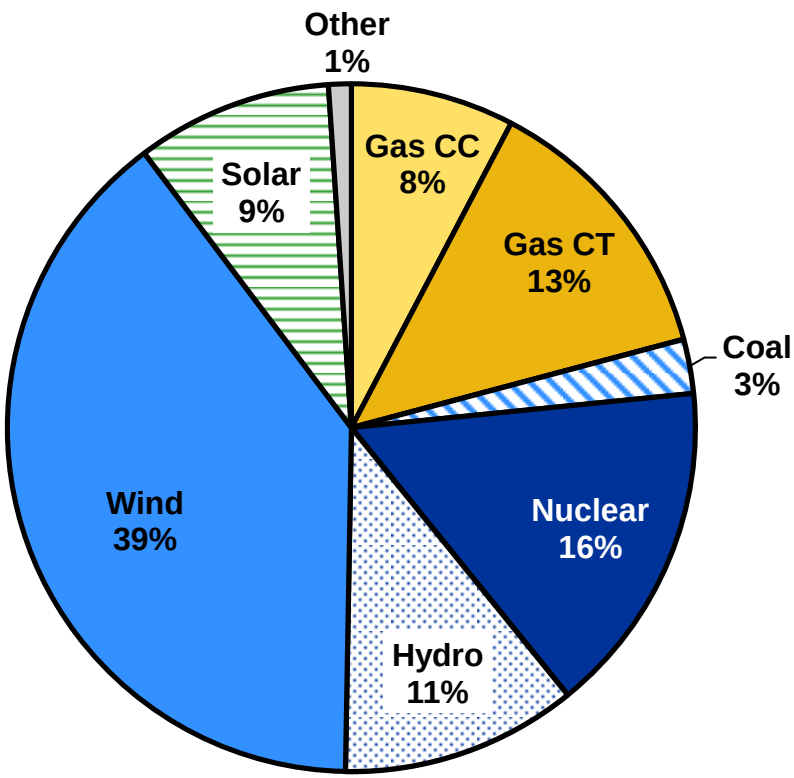

# Power Sector Outlook

# North American Power Capacity Additions, 2011–20

## United States (191 GW)

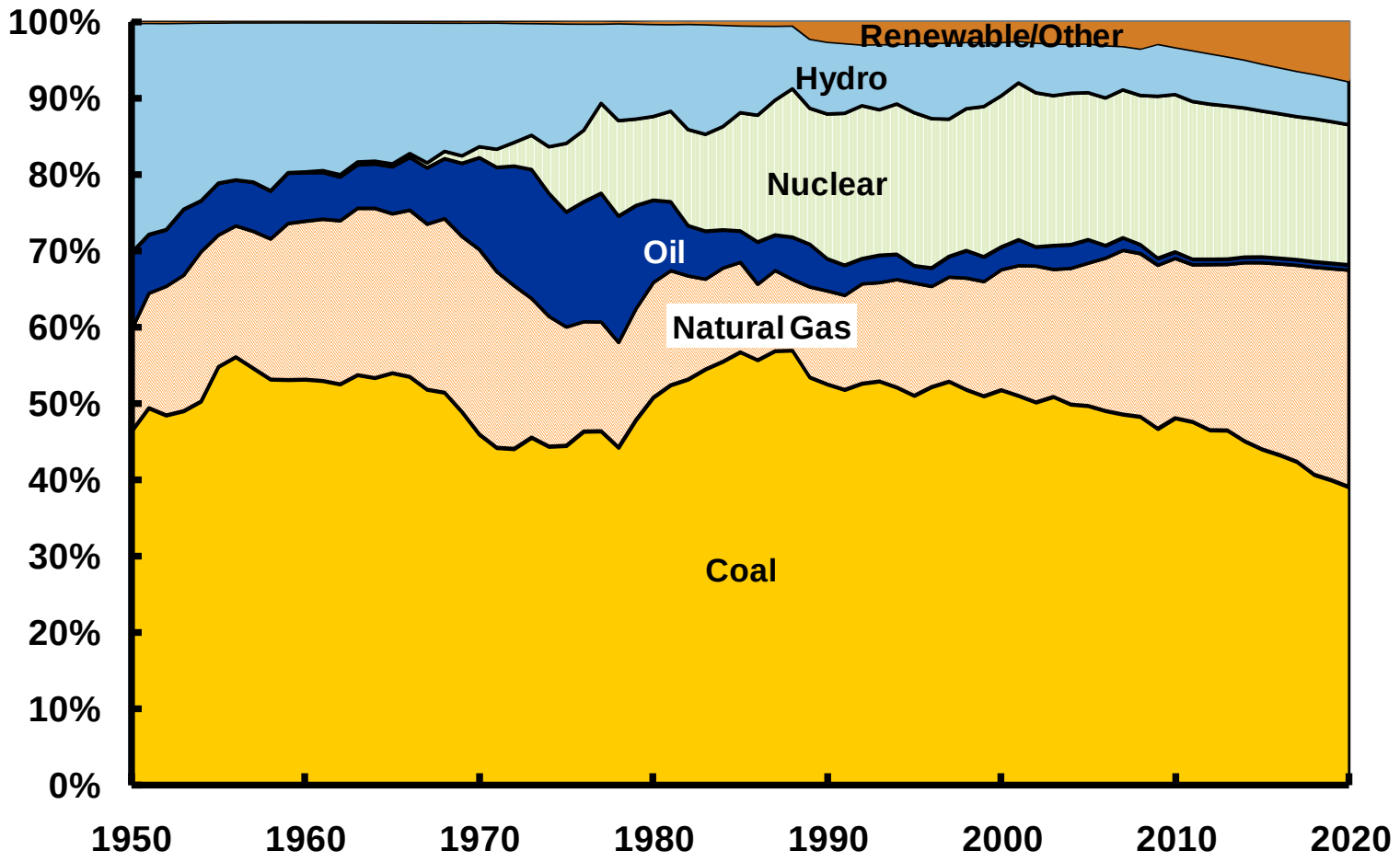



## Canada (35 GW)




Sources: IHS CERA and Ventyx Velocity Suite.
Note: CC = combined cycle; CT = combustion turbine.

# Share of US Power Generation Is Changing



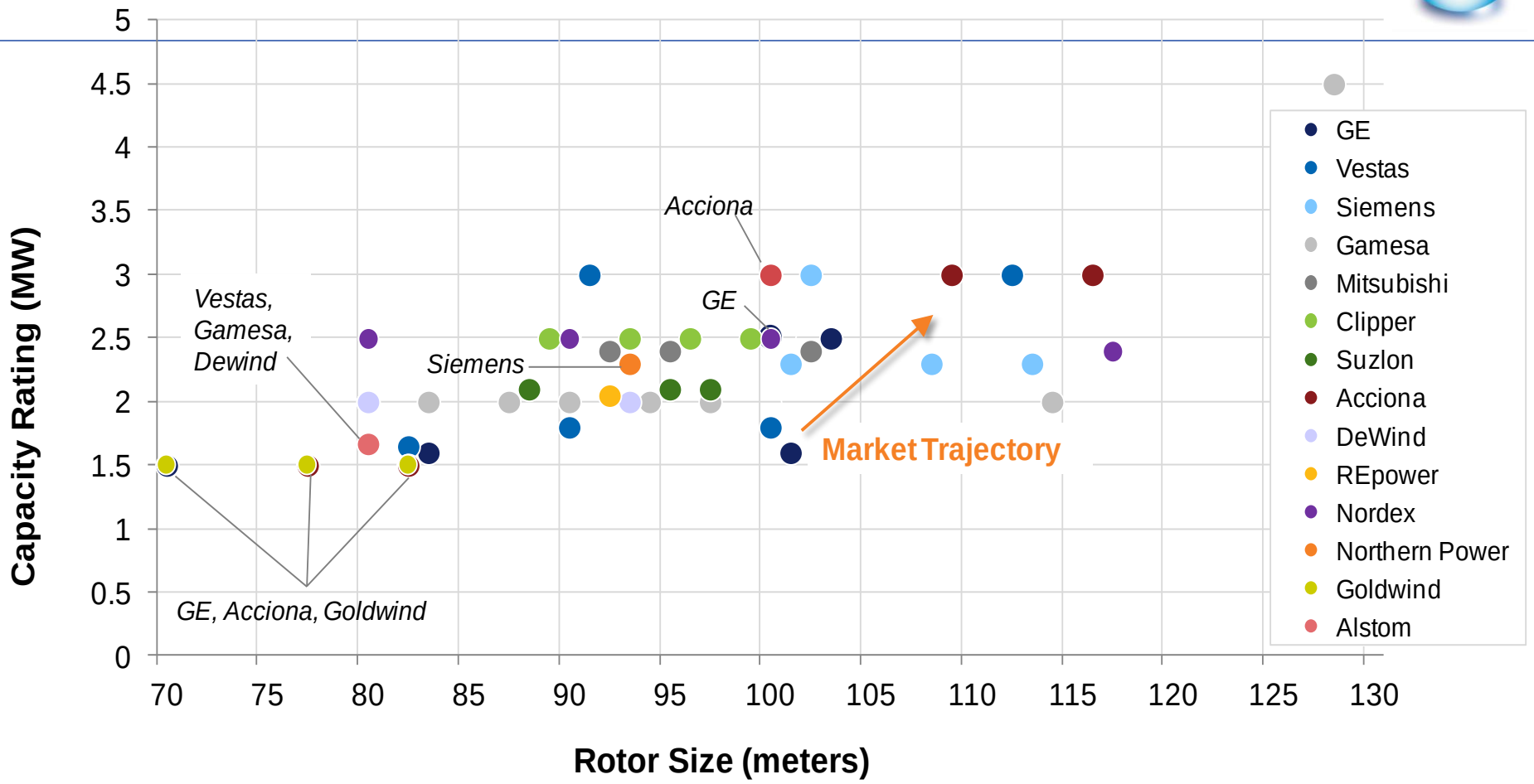

Source: IHS CERA and US Energy Information Administration.

# Global Power Equipment Markets

- China is emerging as a more dominant player in the power equipment markets from solar to nuclear. This position is evolving on both the demand side as well as the supply chain side and covering most fuels with gas being the only current exception.

- The demand for new gas plants, which is the default choice for new investment in advanced countries, has been pushed out due to low economic growth and plant retirement delays. Current activity for gas plants is primarily for smaller peaker plants or overseas installations.

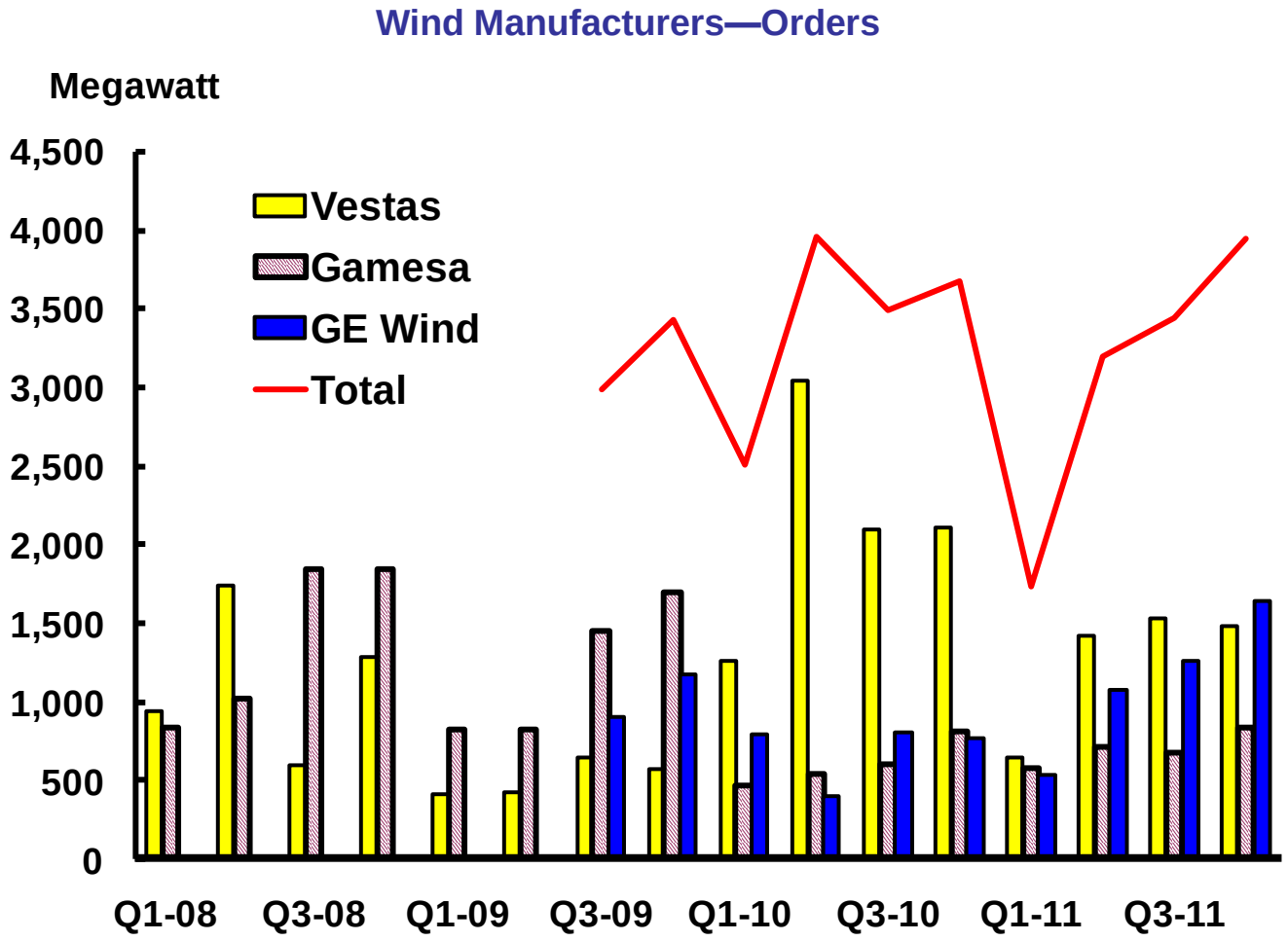
# Wind Turbine Technology Trends




Note: OEMs added to exhibits where similar rotor sizes overlap and may not be visible within exhibit

***OEMs are rapidly introducing new products aimed at increased efficiency and overall cost reduction***

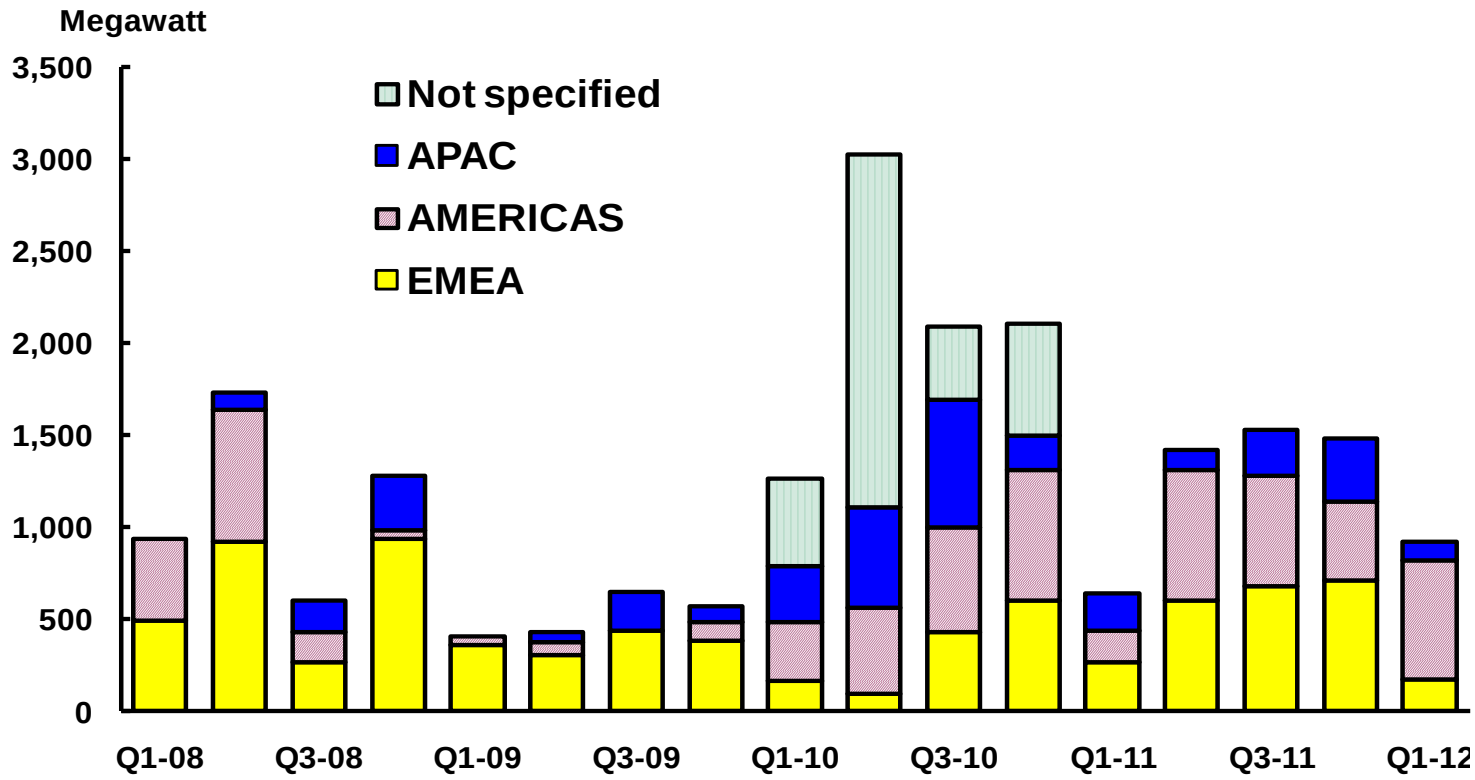
# Wind Manufacturers Orders




Source: IHS CERA, Vestas (based on orders in megawatts [MW]), Gamesa, (based on megawatts sold), GE Wind (based on number of wind turbines ordered time 1.6MW).

# Vestas Global Orders

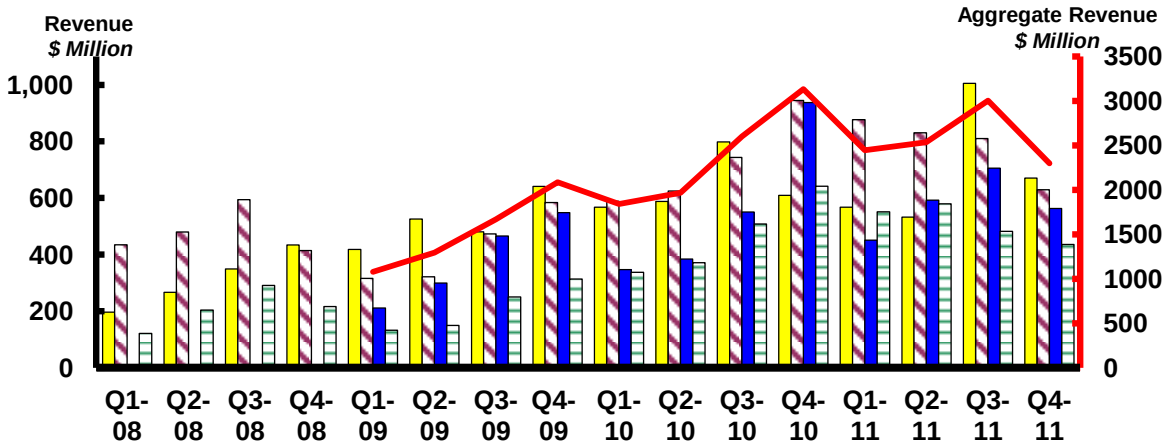
## Flat to falling orders



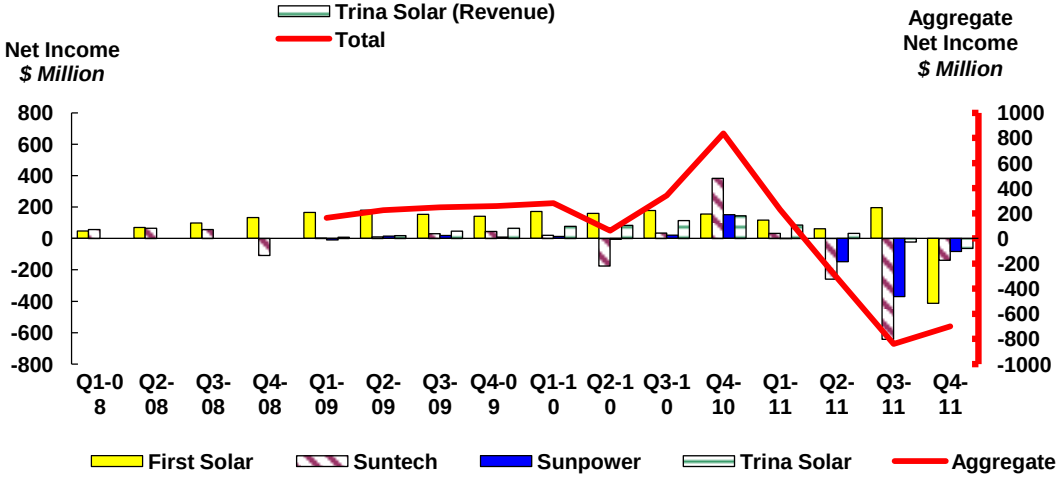

Source: IHS CERA, Vestas.
Note: APAC = Asia, Pacific; EMEA = Europe, Middle East, Africa.

# Solar Manufacturers Results
## Large losses

### Solar Manufacturers—Revenue


### Solar Manufacturers —Net Income




Source: IHS CERA, First Solar (net sales), Suntech, Sunpower, Trina Solar (Operating Income).


# Technology Snapshot: Advanced CT and CCGT

# Advanced CT and CCGT: Key Messages

- **State of the technology**
  - Combustion turbine (CT) based power generation (SC and CC) is a mature technology. Dramatic efficiency gains are no longer possible without the use of more expensive turbine materials, though further improvement in turbine flexibility appears possible
  - Four major Original Equipment Manufacturers (OEMs) dominate the global CT market for power generation applications: General Electric (GE), Siemens, Mitsubishi Heavy Industries, LTD. (MHI), and Alstom
  - Current innovations include single-crystal alloys, thermal barrier coatings (TBC), higher inlet temperatures (up to 1,600°C), and new firing techniques to minimize $NO_x$ emissions. Recently announced combined-cycle configurations promise greater flexibility and thermal efficiencies exceeding 60%
- **Policy/R&D support**
  - US R&D funding has slowed. Past R&D focus from the US Department of Energy (DOE) programs and OEMs improved thermal efficiency from 58% to 60%
  - Japan's Ministry of Economy, Trade and Industry is promoting development of the technology for high-efficiency 1,700°C inlet temperature gas turbines
- **Cost and performance**
  - A combination of high thermal efficiency and low natural gas prices (shale gale) has made CCGT the benchmark technology for new North American capacity additions from both a cost and emission profile standpoint

Source: IHS CERA

# Advanced CT and CCGT: Major OEMs Technology Advances

| Major OEMs | Turbine | Key Technology Advancement | Output | Thermal Efficiency* |
|---|---|---|---|---|
| **GE** | FlexEfficiency 50 Combined-Cycle Power Plant | Introduced in 2011, based on 9FB 50 Hz unit, high thermal efficiency, 50 MW per minute ramp rate. Marketed for quick response to facilitate renewable power integration | 510 MW | 61% CC efficiency (6,400 Btu per kWh HHV net ) |
| | H System | GE's H-class CC system, larger and more efficient than F-class technology. Installations include<br>• 2003—Baglan Bay, South Wales, UK (50 Hz)<br>• 2007—TEPCO's Futtsu-4 plant, Japan (50 Hz)<br>• 2008—Inland Empire Energy Center, US/CA (60 Hz) | 520 MW (50 Hz)<br>400 MW (60 Hz) | 60% CC efficiency (6,500 Btu per kWh HHV net) |
| | OpFlex Auto Tune Control System | Control system enhancement for 7FA turbines. Enables real-time "tuning" of the combustion turbine to maintain emission levels and improve reliability. | N/A | N/A |
| | LMS100 Gas Turbine | LMS100 design combines elements of GE's aeroderivative LM6000 and frame units. First unit entered commercial operation in 2006. Startup—10 minutes for SC | 100 MW | 44% SC efficiency (8,750 Btu per kWh HHV net) |
| | FlexAero LM6000-PH | Introduced in 2011, latest generation of GE's LM6000 aeroderivative unit. Startup—10 minute for SC, with 5 minute fast start capability. 50 MW per minute ramp rate. Marketed for quick response to facilitate renewable power integration | 50 MW | 42% SC efficiency (9,150 Btu per kWh HHV net) |

Note: *Claimed.

# Advanced CT and CCGT: Major OEMs Technology Advances (continued)

| Major OEMs | Turbine | Key Technology Advancement | Output | Thermal Efficiency* |
|---|---|---|---|---|
| **Siemens** | SGT5-8000H | Siemens' H-class turbine. Capacity of 400 MW in SC and over 500 MW in CC. Fast starting—500 MW of CC capacity within 30 minutes, ramp capability of 35 MW per minute. First US orders slated for 2012 delivery | 561 MW | 60.75% CC efficiency (6,450 Btu per kWh HHV net) |
| **MHI** | J-Series Gas Turbines (60-Hz M501J) | Introduced in 2011, MHI's J-series has a turbine inlet temperature of 1,600°C (100°C higher than the G-series turbine). 320 MW SC and 460 MW CC. First shipments targeted for 2014 | 460 MW | 60% CC efficiency (6,500 Btu per kWh HHV net) |
| **Alstom** | KA26 CCGT | Introduced in 2011, Alstom's new 50 Hz unit is currently being tested in Birr, Switzerland. Fast starting—less than 30 minutes in CC. Low load operation to 20% of CC capacity | over 500 MW | 61% CC efficiency (6,400 Btu per kWh HHV net) |

Note: *Claimed.


# Technology Snapshot: Small Modular Reactors

# Small Modular Reactors: Government Support

## State of the technology

- The desire for low-carbon generation has renewed interest in small modular reactors (SMRs).
- SMRs are nuclear reactors with less than 300 megawatts (MW) of capacity.
- The technology offers the advantage of factory production and less complicated equipment delivery as reactors are railed or trucked preassembled.
- IHS CERA expects SMRs to come online after 2020.

## United States

- US Department of Energy (DOE) announced in January that it is seeking applications for two grants, estimated to total $452 million over five years. The funds will pay up to half the cost of developing and deploying up to two small modular reactor designs.

## China

- China has developed a high-temperature gas-cooled reactor with pebble-bed technology (HTR-PM), and a 210 MWe unit is to be installed by 2020. The Institute of Nuclear and New Energy Technology (INET) began research on the HTR-PM in the early 1990s, and in 2003 a 10 MW thermal demonstration reactor reached full power.

Source: IHS CERA

# SMR Design Certification Applications Expected to Be Submitted to NRC for Licensing

| Technology Type | Reactor | Size of Reactor (MWe) | Developer | Expected NRC Design Certification Application | Fueling Cycle (years) |
|---|---|---|---|---|---|
| **Light Water Reactors** | mPower | 160 | Babcock & Wilcox | 2013 | 4.5 |
| | NuScale | 45 | NuScale Power* | 2012 | 2 |
| | Westinghouse SMR | 200 | Westinghouse | TBD | 2 |
| **Liquid Metal-Cooled and Fast Reactors** | 4S | 10 | Toshiba | 2012 | 30 |
| | Hyperion | 25 | Hyperion Power Generation | TBD | 7–10 |
| | PRISM | 311 | GE-Hitachi | TBD | 1–2 |
| **High-Temperature Gas-Cooled Reactors** | TBD | TBD | US Department of Energy (NGNP) | 2013 | TBD |

Source: IHS CERA and the Nuclear Regulatory Commission (NRC).
Notes: 4S = Super-Safe, Small, and Simple; NGNP = Next Generation Nuclear Plant; PRISM = Power Reactor Innovative Small Module; TBD = to be determined.
*On October 13, 2011, Fluor Corporation become majority investor in NuScale Power.

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