ANALYSIS GROUP
ECONOMIC, FINANCIAL and STRATEGY CONSULTANTS

Variable Resources in Capacity Markets

Market Rule Adjustments and Balancing Resource Options

Paul J. Hibbard

Clean Energy Regulatory Forum, Golden, CO

April 2012

Overview

- **Variable energy resources (VERs) and power system reliability**
  - What is the reliability context for integration of VERs, and how is that changing?
- **Challenges in existing market structures**
- **Two lenses on infrastructure development response**
  - "Aggregate Response:" Wholesale market rules changes to properly value generating assets
  - "Portfolio Response:" Potential combinations of resources to mitigate the variability impacts of variable resources and take advantage of complimentary characteristics

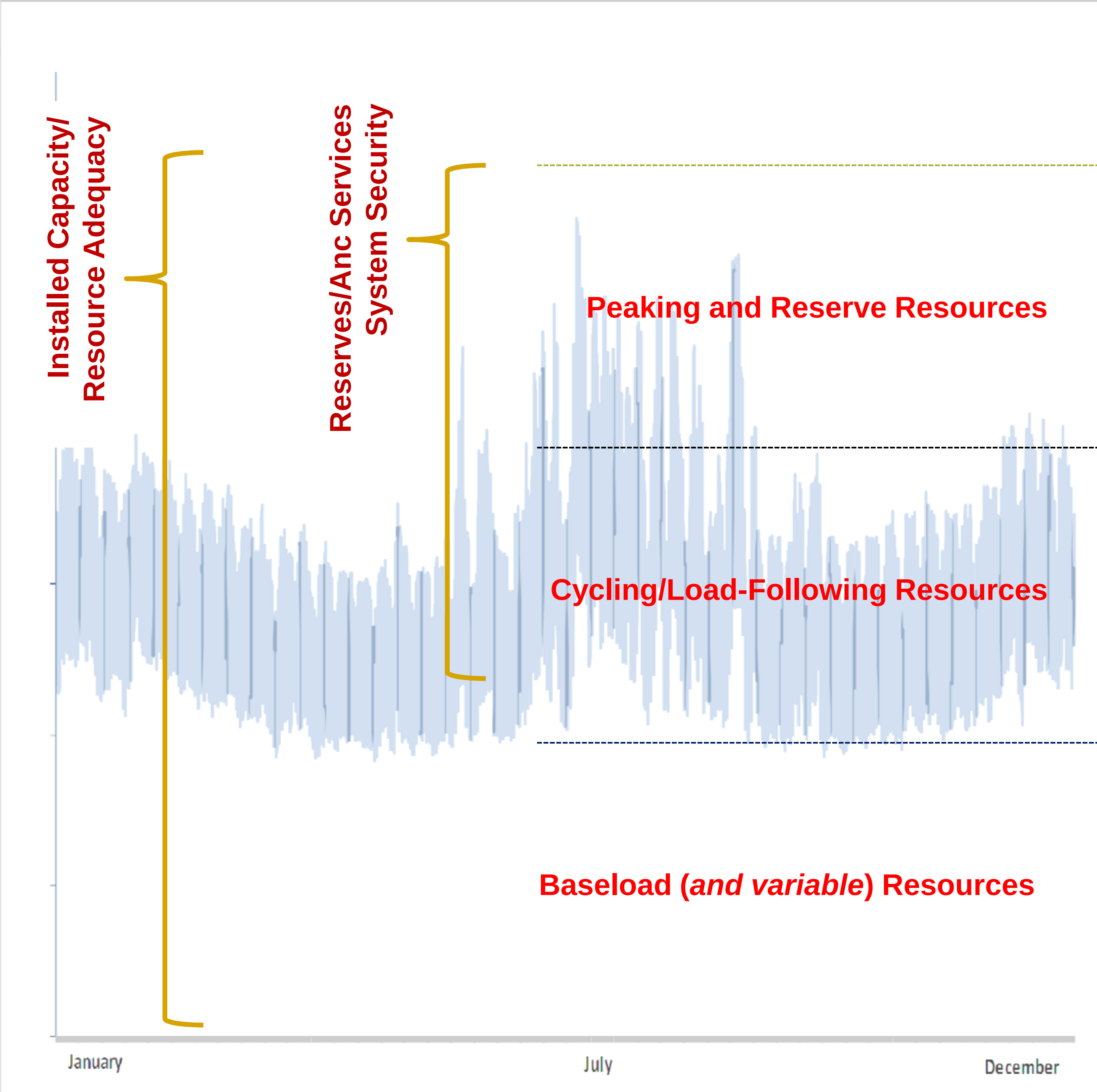
The Reliability Context

ANALYSIS GROUP
ECONOMIC, FINANCIAL and STRATEGY CONSULTANTS

- **Two somewhat distinct mandates (and for VERs, it matters!)**
  - ***Resource Adequacy*:** Planning and long-term procurement (or obligations) to meet probabilistic standard – e.g., load disconnected not more than once in ten years due to inadequate supply resources, considering peak demand plus reserve margin
    - Capacity markets, or Capacity/Reserve Margin obligations
    - Longer-term resource planning
  - ***System Security:*** The day-to-day configuration of the bulk power system (generation and transmission) is sufficiently robust to maintain reliable operations under a variety of adverse conditions (peak load, stressed system, contingencies)
    - Maintenance/outage scheduling
    - Forward or current reserve markets and/or obligations (thirty-minute, ten-minute, spin/non-spin)
    - Unit commitment/posturing
    - Real-time dispatch, curtailment
    - Regulation/Automatic Generation Control (AGC)
    - Operating Procedures during deficiencies (voltage reduction, demand response, reserve depletion, public appeals…)
    - Emergency actions, load shedding

→ Trend is towards integrating the two

ANALYSIS GROUP
ECONOMIC, FINANCIAL and STRATEGY CONSULTANTS



Performance Needs

Must be available almost always, but rarely operate

- **Very Fast Start (10 minutes)**
- **Very Fast ramp**
- **Minimum run time, to cover peaks (12 hours?)**
- **Maximum dispatch range**

Must be available almost always, and operating heavily at widely varying output levels

- **Some Fast Start (30 mins/few hours)**
- **Medium – Fast ramp**
- **Some dispatch range**

Must be available almost always, run at high capacity factor; also includes near-zero marginal cost variable resources

- **No Fast Start**
- **Some ramping ability**
- **No maximum run time,**
- **Dispatch range less important**

The Reliability Challenge of VERs

ANALYSIS GROUP
ECONOMIC, FINANCIAL and STRATEGY CONSULTANTS

- **System operators have always managed *load* variability, and have developed the tools necessary to do so**
  - Forecasting: load variability is relatively predictable
  - Ramping, reserves, regulation, AGC
  - Operating procedures
- **System operators have also had to deal with *generation* uncertainty**
  - Contingencies; loss of units; and units failing to start
  - (To a much lesser extent) units failing to respond precisely to dispatch signals
- **VERs create a new challenge on the generation side; becomes an issue at significant penetration levels**
  - Increase generation uncertainty (forecast wind/solar generation vs. actual)
  - Introduce significant generation *variability* (unavoidable swings in output); much less predictable than load variability
- **→ Increased net load variability, increased need for fast-start and load-following resources (swings on the order of tens of minutes to hours)**

A Little Bit of History

- **Will changing reliability standards make it easier for VERs? NO.**
  - Since middle-20th century: Voluntary agreements and coordination around reliability standards; cooperation and best-practice development, through (eventually) North American Electric Reliability *Council*
  - Significant regional flexibility around standards and operational procedures
  - No federal statutory construct/obligation, or repercussions for failure
- **Federal Policy Act of 2005**
  - Made reliability a mandatory legal obligation
  - Created an Electric Reliability Organization within FERC jurisdiction (ultimately, the North American Electric Reliability *Corporation)*
  - Compliance by regional entities (RTOs/ISOs/Balancing Authorities) mandatory, subject to enforcement and significant financial penalties

→ *Will lead to tightening of reliability standards, and closer attention/lower tolerance for reliability risks by system operators*

Market Challenges and Options

Pricing Reliability: Simplistic Market Overview

- **All RTO/ISO regions have energy markets that pay resources based on bids tied to variable costs**
  - …allows for some fixed cost recovery for inframarginal resources
- **Regions typically also have short-run compensation for reliability-based ancillary services**
  - Monthly or daily markets for reserves, cooptimized with energy
  - Monthly or daily compensation by system operator for reserves, regulation/AGC
  - Compensation for units committed out of market for reliability (“uplift”)
- **Some RTOs have longer-term “investment markets”: Capacity and Forward Reserves**
  - Various forms: some open auction, several years in advance, with potential for multi-year commitment
  - Others shorter-term, or based on obligation to obtain/assign capacity/reserve resources (with penalty charges for failure to meet)
  - (Only New England, for now) forward reserve market, one year

Challenges in Market Response to VERs

A MW is a MW is a MW

- Wholesale markets, and capacity obligation regions, value all MW the same
  - To-date, capacity markets/obligations are resource adequacy-based
  - All that matters is quantity – a MW from a poor-performing, slow-ramping resource with a long start time and excessive minimum-run and minimum-down times ***has the same value as*** an efficient, fast-start, fast-ramp, flexible resource
  - This makes little sense now, and even less with substantial VER integration

Challenges in Market Response to VERs

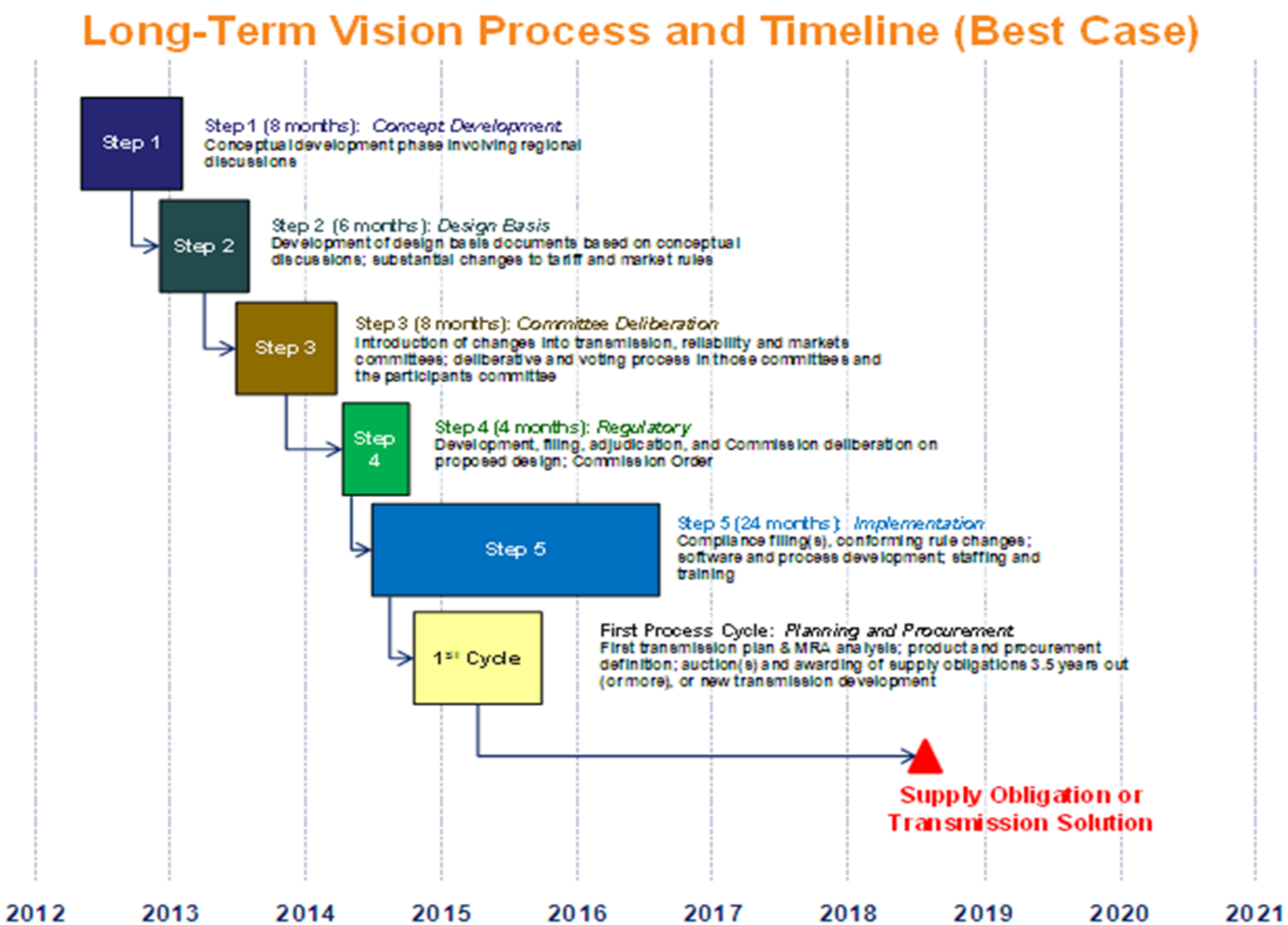
Location, location, location…

- VERs are tied to where the fuel is, typically distant from load
- Markets do not factor in the increased flexibility needed to integrate VER, so prices in these zones remain low
- And there is little to induce the siting of flexible resources *in the right locations*

Timing is everything…

- Electricity infrastructure development is very lumpy
- The next build cycle is upon us, with the potential for (1) significant attrition, along with (2) significant VER addition…
- The pace of change requires capacity/reserve market signals to be nimble
- But they are anything but…

Changes to New England's Capacity Market – Too late?



Changes to Address VER integration

ANALYSIS GROUP
ECONOMIC, FINANCIAL and STRATEGY CONSULTANTS

Reliability Need	Market Context		Market Change Options	Resource Options
	Short-Term/Day-Ahead	Long-Term/Forward		
REGULATION **Increase in load forecasting error requires greater level of regulation to balance greater level of net load variability on a second-by-second basis**	Regulation market prices regulation service based on prices bid or costs submitted by generators with AGC	No long-term market signal for specific quantities of regulation; Regulation market/payments may be sufficient incentive to install AGC	-Review regulation market pricing to ensure it is sufficient to obtain necessary increases; consider price cap increases. -Product definition in forward capacity markets *to the extent* daily market is not inducing the inclusion of AGC on new capacity, in sufficient quantities	-Most generating facilities can equip with AGC and offer into regulation market
SPINNING RESERVES **Increase in potential net load variability minute-to-minute requires a greater level of flexible ramping resources synchronized to grid to manage significant swings**	Spinning reserves are cooptimized with energy market commitment and dispatch, and compensated (e.g., considering opportunity costs); units may be held back for spinning reserves, with costs collected out of market	No capacity or other forward market signals for spinning reserves, or resource flexibility	-Increase quantities of spinning reserves purchased in day-ahead market -Include unit flexibility characteristics as product specifications/tranches in capacity market purchases	-Natural Gas CC and CT -Pumped storage, other hydro -Oil, coal, nuclear, biomass -Storage -Demand response?
OFFLINE RESERVES **Increase in potential net load variability hour-to-hour requires a greater level of flexible ramping resources available to be brought on line to manage significant swings**	-Resources assigned as reserves are paid reserve market price -Units may be held out of market for reserves, with costs collected out of market	-No capacity market signals for spinning reserves, or resource flexibility -Forward reserve market (New England) provides portfolio-based forward procurement	-Create a forward market signal (capacity, or separate reserve market) to purchase capacity with specific flexibility performance requirements -Increase quantities of offline reserves purchased on forward basis (where there is a forward market)	- Natural gas CT (10/30 minute) and CC (intraday) -Hydro/pumped storage -Oil steam turbines -Storage -Demand response
TRANSMISSION **Potential net load variability is heightened where significant variable resources operate within transmission-constrained region; greater geographic dispersion of variable resources mitigates system net load variability**	Transmission constraints can decrease the prices of energy sold behind the constraint, and increase the frequency when variable resources are dispatched down or off to stay within transmission limits	Transmission investment to relieve constraints or deliver renewable resources may be rate-based, merchant, or generator leads; not considered or priced in forward capacity markets	Change cost allocation or otherwise encourage transmission development to support wider geographic integration of variable resources and responsive balancing resources	

Resource Characteristics and Combinations

Resource Characteristics

ANALYSIS GROUP
ECONOMIC, FINANCIAL and STRATEGY CONSULTANTS

Resource Category	On-Peak Capacity Value	Day-Ahead Schedule &Commit	30-Minute; Intraday	Offline Fast Start (10 Min)	Online (Spin)	Regulation / AGC	Key Issues
Nuclear	✓	~	X	X	~	✓	Generally self-scheduled, baseload resource; challenging to finance, site, permit
Coal	✓	✓	X	X	~	✓	Relatively slow response; difficult to site/permit; facing regulatory challenges
NG Combined Cycle	✓	✓	~	X	✓	✓	Efficient dispatch range may limit flexibility as spinning resource
Pumped Storage, Pondage Hydro	~	~	✓	✓	✓	✓	Most flexible/fast reacting resource; energy limited nature affects scheduling, operation
NG Combustion Turbine	✓	✓	✓	✓	✓	✓	Greatest potential for explicit balancing of VAR resources; can be sited in key load pockets
Run of River Hydro	X	~	X	X	X	X	Seasonal/daily limits affect flexibility
Wind	X	~	X	X	~	X	Dispersal across BA area affects net load variability; beginning to consider ramping ability
Solar	X	~	X	X	X	X	Dispersal across balancing authority important; OFF state is predictable
Storage	~	~	~	✓	✓	✓	Size, duration of response varies by technology; additional steps needed for grid-scale deployment
Demand Response	~	~	✓	✓	X	X	Useful if infrequent; not clear how useful for balancing frequent swings from VAR resources

Discussion: Portfolio Options

ANALYSIS GROUP
ECONOMIC, FINANCIAL and STRATEGY CONSULTANTS

- **Combinations of resources to either (a) maximize market value or (b) meet capacity/reserve obligations on self-scheduling basis**
- **Reviewed: set of potential resource combinations:**
  - VER and demand response
  - VER and storage
  - VER and pondage hydro
  - VER and natural gas-fired generation

VER and Demand Response

Benefits

- Demand response (DR) can be a relatively fast-start resource, and can be timed for peak load activation
- DR can be scheduled day-ahead, or in some cases have a shorter notice time depending on actual VER output
- Some DR programs are seasonally focused (e.g., air-conditioning based programs), and thus match well with wind's lower summer output – thus can maximize combined capacity value
- DR use with VERs can be paid on a performance basis; may not require up-front investment
- To some extent, DR can be localized
- Integrated utilities particularly well-suited to combining VER with DR

Challenges

- DR is not always a particularly flexible resource
- DR has limited potential; aggregate DR opportunities may not match well with location of wind resources
- DR is relatively new as a capacity resource; system operators are not particularly comfortable with it
- Potential of DR is diminished (or cost is increased) as frequency of calling on it increases; not a lot of experience with DR called on multiple times per year; this may not match well with the frequency of need to support VERs
- DR in significant quantities can require aggregation of many different sources, increasing resource uncertainty

VER and Storage

ANALYSIS GROUP
ECONOMIC, FINANCIAL and STRATEGY CONSULTANTS

Benefits

- Some storage technologies have the potential to be significant in size, fast in response, and highly flexible for following net load
- Storage can be charged by the VERs it is backing, allowing for coordinated scheduling and dispatch, and electricity price arbitrage; some storage may be able to switch from charge to discharge quickly
- Storage could be collocated with VERs
- Thus, notice time, scheduling and ramping make storage a potentially highly-flexible and complementary match to VERs
- Storage can likely be localized, allowing for solutions on either side of congestion interfaces (i.e., shoring up generation in load pockets, and reducing VER curtailment in constrained-out zones)

Challenges

- Few grid-scale storage technologies have reached commercial demonstration; cost and performance are highly uncertain
- Storage may “miss the boat:” it may not be developed enough to effectively join with VER during the near-term VER build-out phase; other solutions will be developed before storage can reach commercialization

VER and Pumped Storage/Ponding

ANALYSIS GROUP
ECONOMIC, FINANCIAL and STRATEGY CONSULTANTS

Benefits

- Pumped storage (PS) and ponding hydro are and can be significant in size
- PS/ponding is fast in response, and highly flexible for following net load
- PS can be charged by the VERs it is backing, allowing for coordinated scheduling and dispatch, and electricity price arbitrage
- Notice time, scheduling and ramping capability of PS is a highly-flexible and complementary match to increased load-following needs of VERs
- In some regions there is major, new, and complementary hydro potential that could be brought to US markets (e.g., Newfoundland/Labrador, Quebec) to balance VER

Challenges

- The best PS and ponding hydro sites in the US may have been used already; siting/permitting new large dams and PS facilities is not easy; thus there may be limited incremental capability
- New potential (e.g., Eastern Canada) may require significant transmission investment
- PS/ponding hydro is energy-limited; coordination for use to balance VERs could compromise ability to maximize value in energy markets

VER and Natural Gas-Fired Generation

Benefits

- Natural gas-fired generation can be fast in response and highly flexible for following net load
- NG combustion turbines (NGCT) in particular can be used as fast-start, fast-ramp resources, and provide net-load-following capability in off-line and on-line mode
- NG combined cycle (NGCC) facilities can help follow net load on an intraday basis, but in particular can provide significant ramping and spinning reserve capability

Challenges

- NGCC plants are often operated as close to the most efficient operational point, with a dispatch range that is narrow relative to its size, limiting ramp/flexibility potential
- Natural gas emits CO_2; less than coal or oil-fired facilities, but enough that NG-fired plants will be affected by CO_2 requirements
- In some regions the reliance on natural gas for power generation introduces fuel diversity and reliability concerns

Paul J. Hibbard
Analysis Group
111 Huntington Avenue, 10th Floor
Boston, MA 20199
phibbard@analysisgroup.com
617-425-8171