

# Emerging Opportunities in Sustainable Energy

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imagination at work

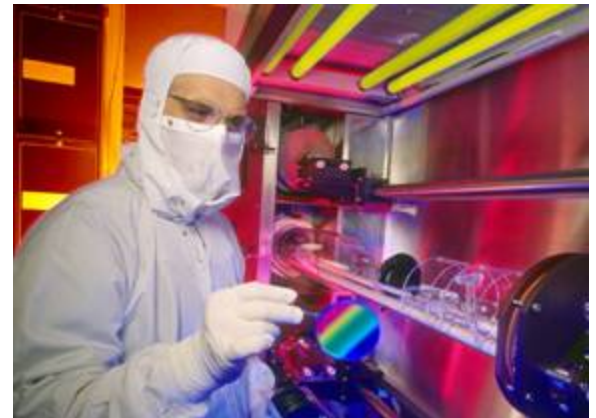
# GE ... a heritage of innovation

Founded in 1892

\$180 billion in annual revenues

Only company in Dow Jones index  
originally listed in 1896

300,000 employees worldwide



# 3,000 technologists strong



**Global Research Center**  
Niskayuna, NY



**John F. Welch Technology Center**

Bangalore, India



**China Technology Center**  
Shanghai, China



**Global Research – Europe**  
Munich, Germany

# Role of Global Research

Delivering core technologies for NPIs + productivity

Discovering new technology opportunities

Establishing foothold in advanced technologies

Spreading technology across businesses

Developing world-class talent

Connecting with the world's technology



# Top level energy innovation enablers

- **Cap & trade** ... to reflect the “true cost” of green house emissions
- **RPS with “teeth”** ... to accelerate adoption in the near term
- **R&D** ... to drive more efficient & lower cost generation technologies
- **Large demos** ... clean coal with CCS + next generation nuclear
- **Grid upgrades** ... ties to remote wind and solar resources & “smarter grids” at the local level
- **Energy education** ... general public & next generation of engineers



# GE sustainable energy programs

- **Wind** ... proven & cost effective renewable power
- **NG fired gas turbines** ... low carbon backup to wind and solar
- **Nuclear** ... proven & cost effective base load renewable power
- **Biomass** ... emerging renewable option in select regions
- **Solar** ... the next big renewable play
- **Energy storage** ... cost effective large batteries & compressed air
- **IGCC with CCS** ... sustainable and secure base load power source
- **Smart Grid** ... ties it all together



# Sustainable Energy ... within reach but government support is required

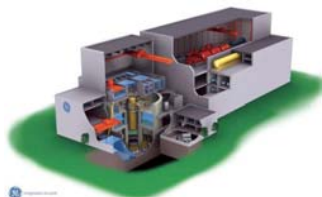
Today



Wind & Biomass



NG backup

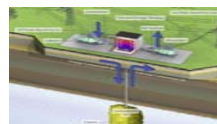


Nuclear

2015-2020

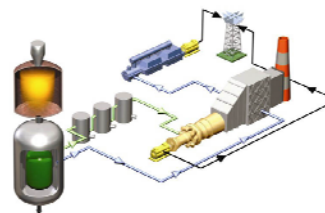


Solar



© RWE

Energy Storage



Carbon Free Coal

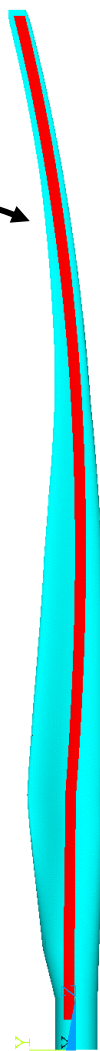


Smart Grid

# Wind Turbines



**1.5-MW Turbine  
40-Meter Blade**



## 2.5-megawatt turbine with 55 meter advanced blades

- Advanced composite hybrid of carbon and fiberglass
- Aeroelastic tailored
- Creates higher efficiency and produces lower noise

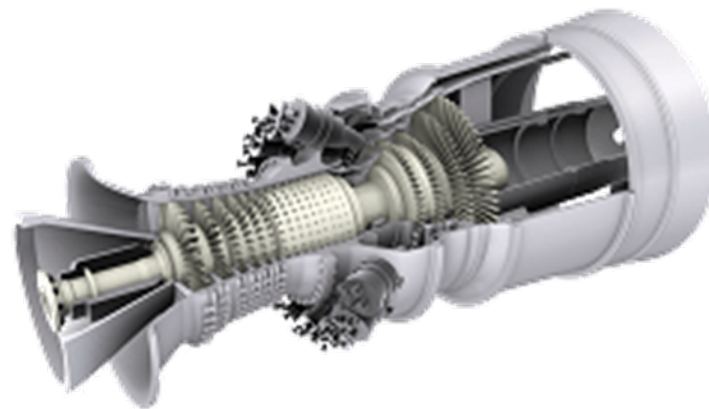
**Key Needs:** Long distance grid ties to population centers & renewable portfolio standards with “teeth”

# Gas Turbines

## Next Gen GT Technologies

- H<sub>2</sub> or NG fueled
- Improved cooling, sealing and materials for higher firing T
- Improved aero performance
- Reduced emissions
- Fast starting & shutdown ... key to backing up wind & solar supplies

**Key Need:** R&D for fast starting and efficient GT based power plants

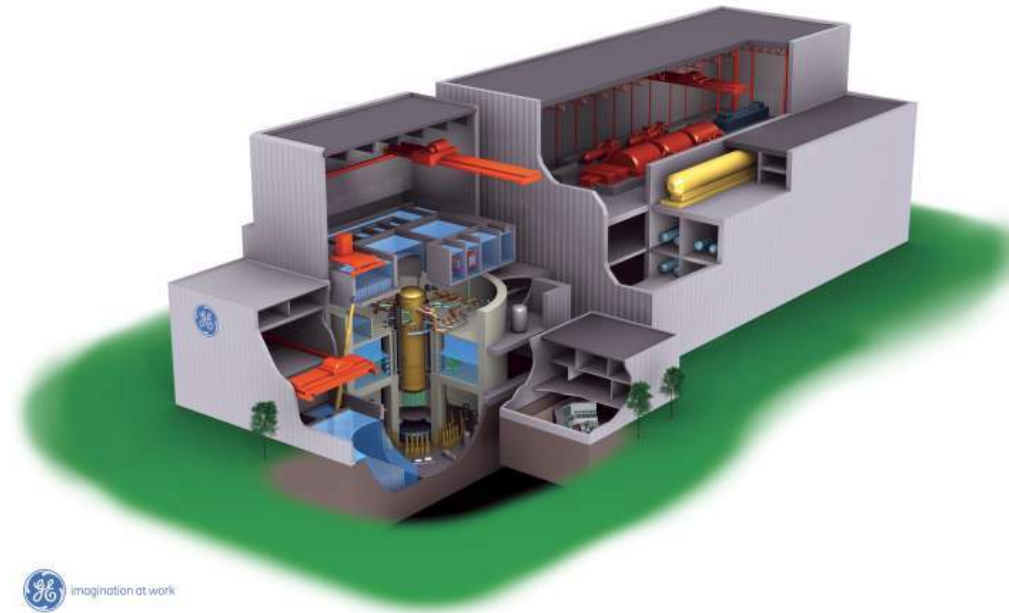


# Nuclear Power

## Next gen reactor ... ESBWR

- Passive safety enhancements
- Projected to significantly reduce operating costs
- Long term solution for CO2 free base load generation

**Key Need:** Risk sharing ... Gov backed financing for demo plants



# Biomass Fired Engines

**Jenbacher engines currently a \$1B business with growth areas in coal-bed methane, biogas, landfills**

Exploring other biomass technology

- Wood pyrolysis/gasification
- Combined with sequestration... negative CO<sub>2</sub>

**Key Needs:** Renewable portfolio standards with “teeth”



# Solar

## World's fastest growing energy technology

- Shift from rooftop PV to utility-scale ground-mount
- CdTe thin film PV module cost leader
- CSP 1 GW/year... but no clear technology winner yet (needs lower cost collection systems)



**Key Needs:** Renewable portfolio standards with “teeth”

# Energy Storage

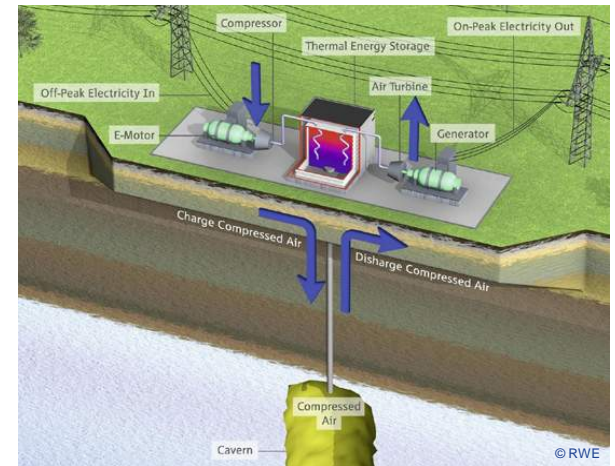
## Batteries

- A123 partnership ... lithium ion for automobiles & other applications
- Sodium batteries ... high energy storage for UPS and grid stabilization
- Key need ... R&D to reduce cost and improve reliability



## Adiabatic Compressed Air

- Large-scale, efficient, zero-emission
- New tech ... turbomachinery & thermal storage
- Key need ... large technology demos

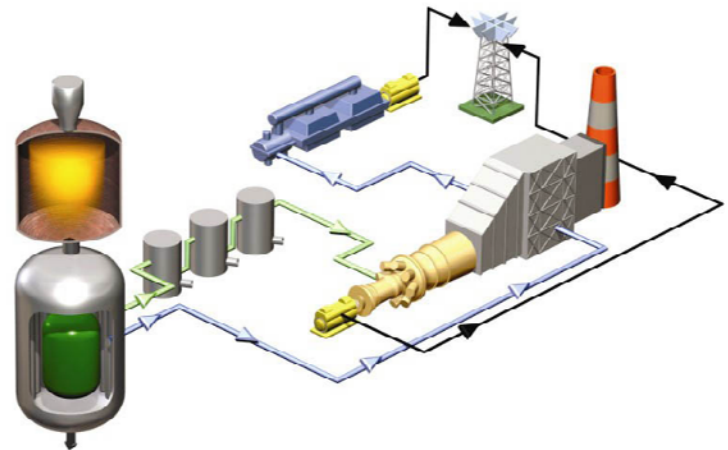


# Clean Coal with CCS

## Industry leader in gasifier technology

- Coal ... key to US energy self sufficiency
- Converts coal to  $H_2 + CO_2$  ...  $CO_2$  removed prior to burning
- Much less expensive  $CO_2$  separation... 1/100 of gas flow treated

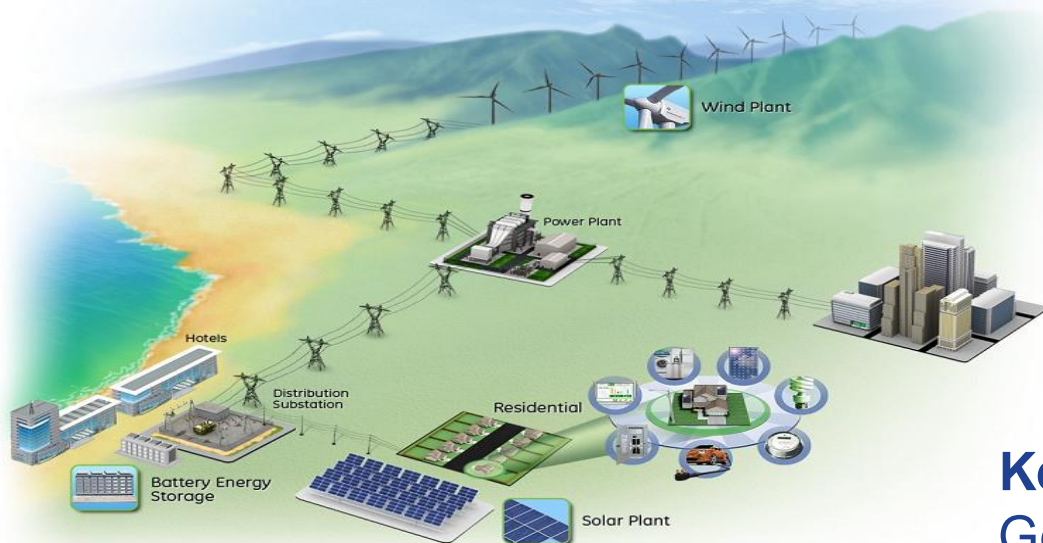
**Key Need:** Risk sharing ... Gov backed financing for demo plants with CCS



# Smart Grid

## Differentiating through system solutions

- Transmission... . Advanced EMS with Grid Visualization, Renewables/ES Controls
- Distribution... Advanced Control systems for Improved Efficiency and Enhanced Power Quality
- Demand... Response using Load, DG and PHEV as a Resource
- Assets... Predictive Health Monitoring Solutions



**Key Need:** Risk sharing ...  
Gov backed financing for  
wide scale deployment



imagination at work