Investments in low and zero-emission technologies

Bart Stoffer
GE Energy

UNFCCC Workshop on Mitigation SBSTA26
Power Generation, including Clean Fossil Fuels and Renewable Energy

Bonn, 15 May, 2007
GE ... Six businesses at a glance

GE Infrastructure
- Aviation
- Water & Process Tech
- Oil & Gas
- Transportation

GE Infrastructure Services
- Aviation Fin Services
- Energy Fin Services
- Energy

GE Industrial
- Consumer & Industrial
- Plastics
- Security
- Equipment Services

GE Industrial Services
- Sensing
- Silicones / Quartz
- Strategy / Integration
- Fanuc

GE Consumer Finance
- Europe
- Asia
- Americas
- Australia / New Zealand

GE Commercial Finance
- Healthcare Fin Services
- Global Media & Communications
- Real Estate
- Corporate Financial Services

NBC Universal
- Network
- Sports / Olympics
- Entertainment
- Universal

GE Healthcare
- Diagnostic Imaging
- Biob Sciences
- Inf Technology
- Clinical Systems

imagination at work
Global Trends ...

Population   Consumption   Energy Security   Environment

... Create Big Challenges
And Big Challenges ... Drive Technology

- High Fuel Prices ...
  Higher Energy Efficiency

- Energy Security ...
  Technology Diversity

- Environmental Requirements ...
  Emission Reduction, Renewable Energy, Nuclear, Clean Coal
GE Energy ... Technology Diversity

**Thermal**
- Gas turbines
  - Heavy duty (10-500MW)
  - Aeroderivatives (1.5-100MW)
- Coal
  - ECC
  - Steam turbines
- CCGT
- CHP

**Nuclear**
- Nuclear
  - ABWR & ESBWR
  - Advanced fuel
  - Candu fuel & services
  - Reactor & field services
  - Performance services
  - Nuclear isotopes

**Renewables**
- Wind
  - Land-based
  - Offshore
  - Solar
    - Grid connected
    - Stand-alone
- Biomass
  - Gas engines
  - Container Sets
  - Biogas Power Houses
  - Wood gas and Pyrolysis gas engines
ecomagination ... committed to deliver

1. Increase R&D investment from $700M to $1.5B by 2010

2. Grow revenues to $20B by 2010 by delivering customer value

3. Improve our energy efficiency and lower our GHG emissions

4. Keep the public informed on progress
ecomagination ... grow the portfolio

Launch  Current  Goal
17       32       40+

Driving ecomagination into R+D
A Way to Classify Environmentally Friendly Technology

**Cleaner**
- Reduced Fossil Emissions
  - Efficient CCGT (H, LMS)
  - Efficient ST (HEAT)
  - Environmental Services

**“Greener”**
- Zero Emissions + Renewable Energy
  - Nuclear
  - Large Hydro
  - Offshore Wind
  - Small Hydro / Refurbishment
  - Biomass
  - Geothermal
  - Offshore Wind
  - Photovoltaics
  - Hydro Std Plant
  - Fuel Cells
  - Hydrogen
  - Ocean Energy

- Carbon Storage
- Next Gen Reactor
- Energy Storage
- Grid Integration
- & Mini-Grids
PowerGen Forecast... Next 10 Years

Total Capacity Additions - GW (2006 - 2015)

<table>
<thead>
<tr>
<th>Region</th>
<th>10 Year Avg Annual Cap Adds (GW)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nuclear</td>
<td>8</td>
</tr>
<tr>
<td>Renewables</td>
<td>21</td>
</tr>
<tr>
<td>Hydro</td>
<td>24</td>
</tr>
<tr>
<td>Coal</td>
<td>35</td>
</tr>
<tr>
<td>Gas/Oil</td>
<td>59</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td><strong>146</strong></td>
</tr>
</tbody>
</table>

Source: GE Energy PG Marketing
IGCC Carbon Capture ... Proven Process

Gasification

- Oxygen, Feedstock
- CO\(_2\) and H\(_2\)
- Slag

Optional Shift

- Water Gas Shift
  \[ \text{CO} + \text{H}_2\text{O} \rightarrow \text{CO}_2 + \text{H}_2 \]

Process Gas Only
- High P, Low Vol
- High Driving Force

Diffusion
- Combustor
- Diluent NO\(_x\)
- Control

Proven Gasification
- 60+ GE Licensed Gasification Units operating worldwide
- 12 with solid feedstock

Proven Shift & CO\(_2\) Capture Process
- >25 GE Licensed Gasification Units using shift reaction
- 8 with solid feedstock
- Used in refineries to produce H\(_2\)

Proven Gas Turbines
- 28 GE Gas Turbines operating at 50% + H\(_2\)
- F-class combustion validation up to 90% H\(_2\)

AGR / SRU
- H\(_2\)
- Hg
- S
- CO\(_2\)
IGCC ... Emissions approaching CCGT

IGCC Environmental Benefits Versus Best in Class Supercritical Pulverized Coal

- 33% less NO\textsubscript{x}
- 75% less SO\textsubscript{x}
- 40% less PM\textsubscript{10}
- 90% + Hg removal
- 30% less water
- CO\textsubscript{2} capture ready

Source: GE internal data, average of 30 permits granted, applications and publicly reported emissions
The answer to climate change is technology

Mitigation technology already exist or is fast emerging

- **Technology diversity** is key... there is no silver bullet addressing all customer and policy needs

- Solutions require **big bets** on technology development... anything else does not work

- **Renewable energy** continues to require dedicated policies to achieve ambitious global targets

- Technology for **carbon capture** already exists... or is emerging fast

- GE is part of **USCAP**, the US Climate Action Partnership of companies and NGOs, to urge the US government to introduce a mandatory cap and trade system for GHG

- GE is part of **3C**, Combat Climate Change, an initiative of business leaders in Europe
Utilize all policy instruments in a coordinated manner

Principles for energy policy

- Implement a portfolio of policy instruments ... to drive energy efficiency, renewable energy and low carbon energy technologies
- Utilize all policy levers in coordinated manner
- Develop a global market for CO$_2$, enable trading between regional trading systems, and create a long term price for carbon to drive technology deployment, thus development
- Combine cross-atlantic efforts between EU and US to support R&D, technology development and deployment

Specific on CCS policy

- Implement a legislative framework for storage
- Implement market based instruments (ETS) and financial incentives to drive commercialization
- Create awareness, drive demonstration and public acceptance
"We are living in a carbon constrained world. The ability to lead innovation will be the primary management focus for this decade."

— Jeff Immelt
Chairman and CEO GE

"I find out what the world needs, then I proceed to invent."

— Thomas Edison
founded GE in the year 1892
Investments in low and zero-emission technologies
Back-Up

Bart Stoffer
GE Energy

UNFCCC Workshop on Mitigation SBSTA26
Power Generation, including Clean Fossil Fuels
and Renewable Energy

Bonn, 15 May, 2007
Power Generation Technology – Higher Energy Efficiency

Advanced GT technology
**Combined Cycle Gas Turbine H-Turbine**

- GE’s highest combined cycle efficiency ... 60%
- Advanced steam cooling and integrated control system

109H 50 Hz – 520 MW

- <15ppm NO\textsubscript{x} emissions to 50% load
- CO\textsubscript{2} – 3–5% improvement vs. F Class
- Baglan Bay W ales -11,600+ fired hours

107H 60 Hz – 400 MW

- CO\textsubscript{2} vs. F Class = 73,000 tons/yr. improvement
- NO\textsubscript{x} vs. F Class ~ 20 tons/yr. improvement
Simple Cycle Gas Turbine LMS 100™

Flexible Power

- 44% simple-cycle efficiency
- 10-minute fast starts
- Hot day performance
- Load following and cycling capabilities without maintenance penalties

Better efficiency means less fuel burned per megawatt and less CO₂ emissions.

- Yields up to $0.6 MM/year CO₂ tax savings
- Reduces CO₂ emissions by more than 30,000 tons—the equivalent of the amount of CO₂ absorbed by approximately 7,400 acres of forest!
Power Generation Technology - Renewables
Renewable Energy... Growing Demand

- Significant growth... ~25% CAGR (95-13)
- ~40% global power capital spending
- Ambitious global targets
- Only 3% of electricity production

World continues to require dedicated policies for renewable energy

Global Renewable Installed Capacity (GW)

- Wind >50% of growth
- Solar
- Biopower
- Geothermal
- Small Hydro

Source: REN21 2006 update
Wind... Advancing Technology

Next Gen Turbines...

- Higher Capacity Factors
- Improved Reliability
- Lighter, longer Blades
- Advanced Controls
- Seamless Grid Integration

~30% More Energy Capture
Power Generation Technology - Nuclear
Nuclear Technology Development

**ABWR**
- Licensed in three countries
- Improved safety & reliability
- Enhanced operability & maintainability
- Reduced capital and O&M costs

**ESBW R**
- Passive safety & simplified design
- Standardized/ modular
- Reduced CAPEX/ improved OPEX
- Faster construction schedule

**GEN IV - PRISM**
- Sodium cooled fast reactor
- Passive safety
- Modular/scalable
- Factory build
<table>
<thead>
<tr>
<th>Location</th>
<th>Status</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kashiwazaki 6 &amp; 7, Japan</td>
<td>Approved</td>
</tr>
<tr>
<td>Ham aoka 5, Japan</td>
<td>Online</td>
</tr>
<tr>
<td>Shika 2, Japan</td>
<td>Online</td>
</tr>
<tr>
<td>Shimane 3, Japan</td>
<td>Building</td>
</tr>
<tr>
<td>Lungmen 1&amp;2, Taiwan</td>
<td>Building</td>
</tr>
<tr>
<td>Online</td>
<td></td>
</tr>
<tr>
<td>Online</td>
<td></td>
</tr>
<tr>
<td>Online</td>
<td></td>
</tr>
<tr>
<td>Building</td>
<td></td>
</tr>
<tr>
<td>Building</td>
<td></td>
</tr>
<tr>
<td>Ohma, Japan</td>
<td>Approved</td>
</tr>
<tr>
<td>Hijashihori 1&amp;2, Japan</td>
<td>Planning</td>
</tr>
<tr>
<td>STP /NRG 3&amp;4</td>
<td>Planning</td>
</tr>
<tr>
<td>USA 3&amp;4</td>
<td>Study</td>
</tr>
</tbody>
</table>
Power Generation Technology - GCC
Capture Routes for Fossil Power Plants

<table>
<thead>
<tr>
<th>Natural Gas</th>
<th>Coal</th>
</tr>
</thead>
<tbody>
<tr>
<td>Advanced CCGT</td>
<td>Pulverized Coal</td>
</tr>
<tr>
<td>Integrated Reforming CC</td>
<td>Integrated Gasification CC</td>
</tr>
<tr>
<td>Oxyfuel CC</td>
<td>Oxyfuel Coal</td>
</tr>
</tbody>
</table>

Post-combustion CO₂ Capture

- Fossil Fuels (Coal, Natural Gas, Oil, Biomass)
- Air

Pre-combustion CO₂ Capture

- Fossil Fuels
- Air / O₂

Oxyfuel-based CO₂ Capture

- Fossil Fuels
- Air

Combustion process

- CO₂ Separation
- CO₂ Storage
- CO₂-lean Flue gas

Power & Heat

- Syngas
- H₂

Gasification/Reforming

- Air Separation
- N₂

- H₂O
IGCC ... Solution for Cleaner Coal
Pre-combustion CO₂ capture

Main Drivers
• Fuel flexibility ... i.e. coal, pet coke
• Syngas allows for polygeneration
• Simplified CO₂ capture
• Low emissions and usage of water

Gas Turbine & Cycle Status
• Components commercially available ... focus on optimization
• Commercial pet coke plant with EOR planned (Carson CA.)
• 3 Reference plants planned in US

BP/Edison Mission
Carson CA.—
Pet coke IGCC with EOR and carbon storage

Development trends
• Fuel flexibility, efficiency, low NOₓ
GCC Reference Plant status

Meigs County, Ohio

Mason County, West Virginia

Edwardsport, Indiana

AEP IGCC Project
- 9/05 announced FEED study
- 2012 expected commercial start up*

AEP IGCC Project
- 08/06 announced project
- 2014 expected commercial start up*

Duke IGCC Project
- 03/06 announced FEED study
- 2011 expected commercial start up*

... and multiple projects in Europe at a feasibility stage

* Pending project approval