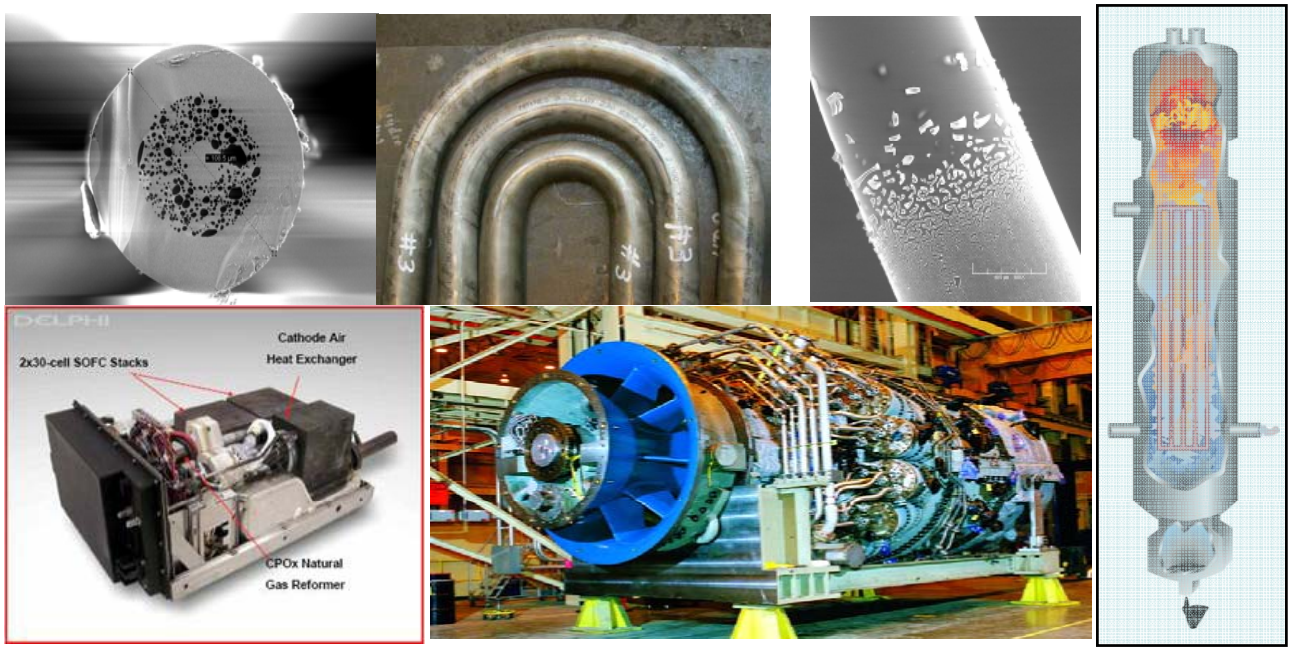
NATIONAL ENERGY TECHNOLOGY LABORATORY



US-UK Collaboration

March 18, 2010

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Advanced Research Technology Manager

U.S. DEPARTMENT OF ENERGY

Potential Areas for Collaboration

Sequestration

- **CO2 storage assessment – capacity assessments. A potential quid pro quo would be to learn about how each is going about any assessments, particularly how they quantify storage capacity.**

- **NETL is looking at tracers for storage applications and this was an area where the UK also has some interest. Use of tracers to detect leakage including lessons learned from site operations may be useful for exchange.**

- **Public Outreach – NETL has developed and published a Best Practice Manual for Public Outreach. A one-size fits all approach is not possible and lessons learned in dealing with public outreach from each country may be useful for exchange.**

- **Best Practices – DOE/NETL is publishing a series of Best Practice Manuals for geologic storage from site selection through well closure and will also be publishing one on terrestrial sequestration. Collaboration would include review from the UK.**

Existing Area for Collaboration
Computational Flow Sculpting
Iowa State University/Cambridge

- **Develop a common visual representation for CFD and flow sculpting tools**
- **Select a set of components and analyses to use in plant design**
- **Validate flow sculpting in power plant design**
- **Quarterly reviews of work in progress**

Potential Areas for Collaboration

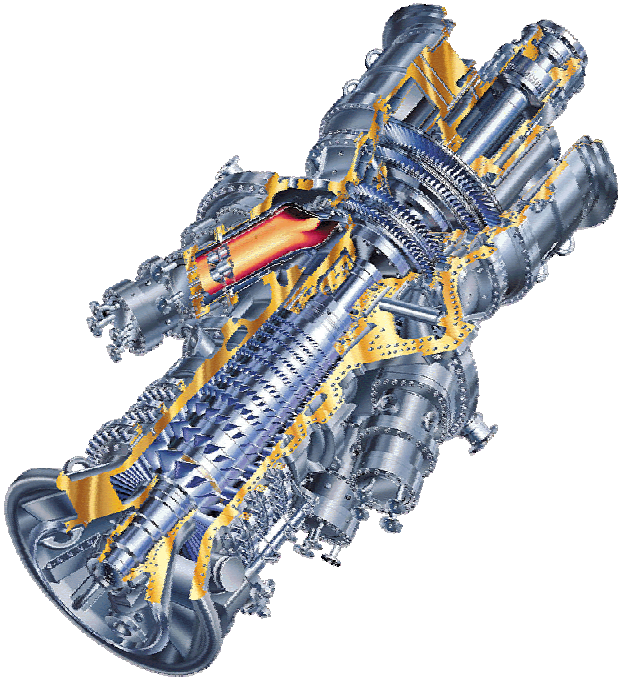
Computation Modeling NETL/UK

- **Dynamics and Control of IGCC Systems with CO2 Capture**
- **Immersive, Real-Time Dynamic Virtual Simulation of Advanced Energy Plants**
- **Process/Equipment Co-Simulation of Advanced Energy Plants**

Potential Areas for Collaboration

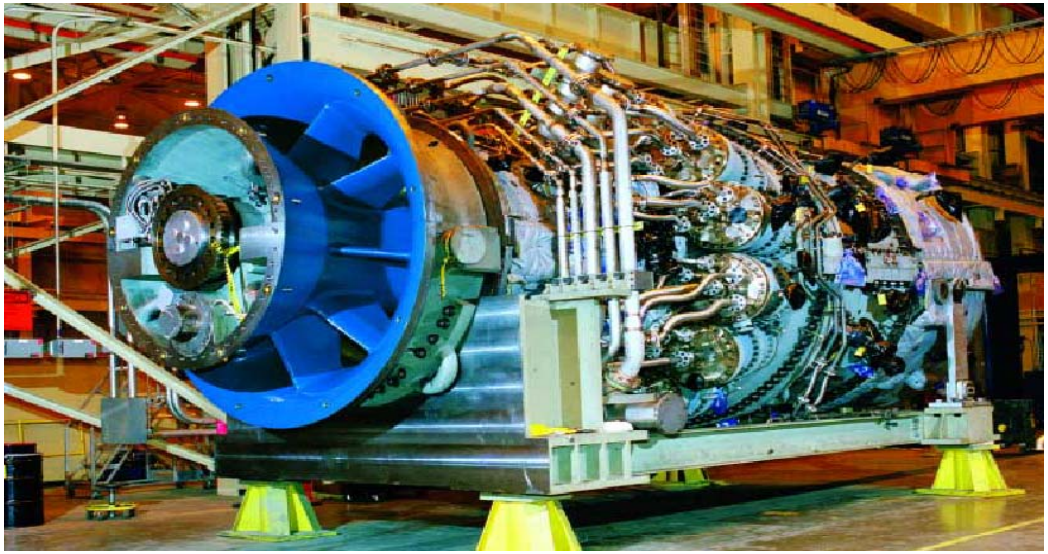
Advanced IGCC/H2 Gas Turbine

Design and develop gas turbines for IGCC (syngas) and FutureGen (hydrogen) type applications



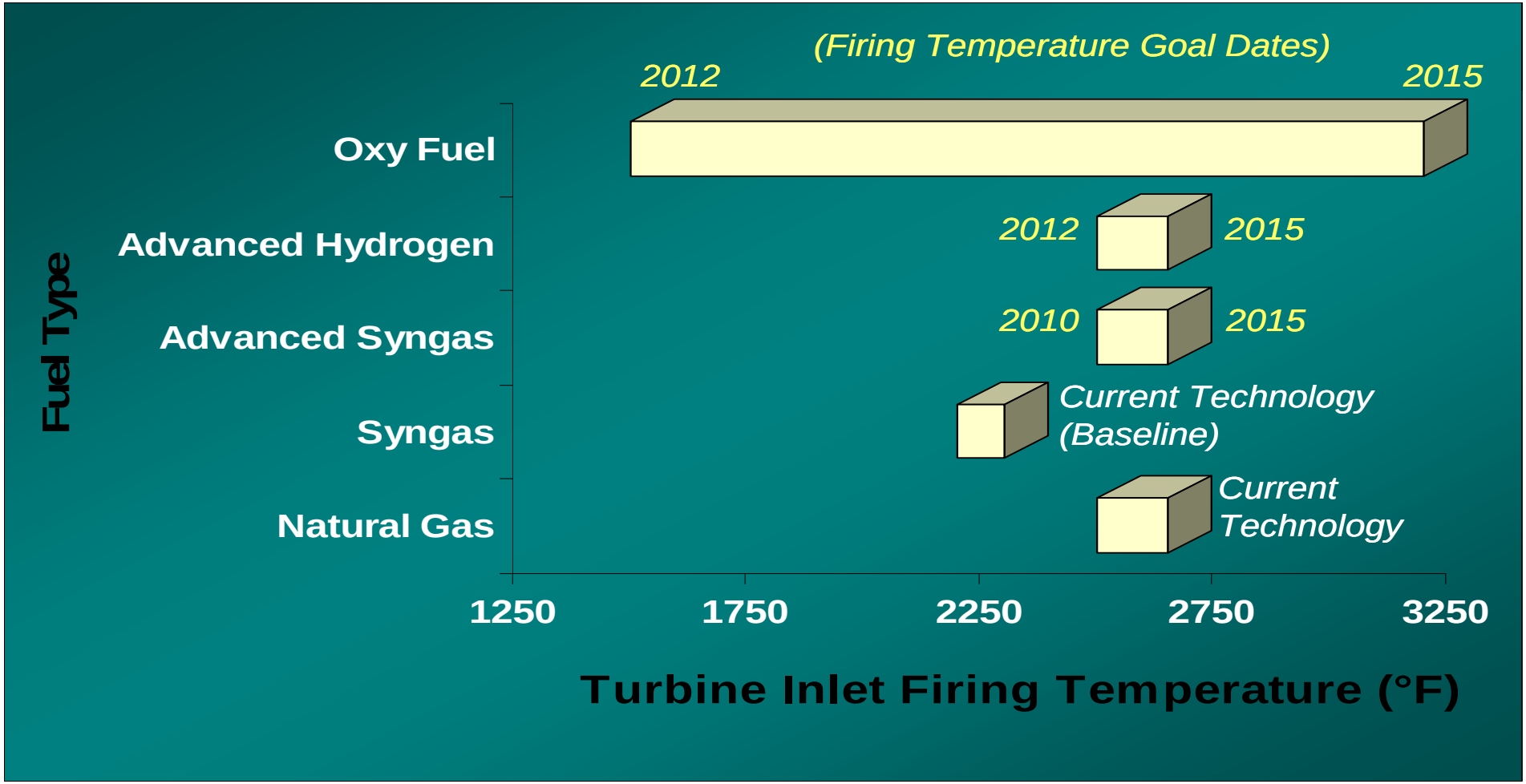
<u>2010 Goal for IGCC System</u>

- ***High efficiency (45-50% HHV)***
- ***Near zero emissions (2 ppm NOx)***
- ***Competitive cost (<$1000/kW)***



GE 7FB Turbine

Turbines


(Firing Temperature Goal Dates)
2012
2015
Oxy Fuel
Advanced Hydrogen
2012
2015
Advanced Syngas
2010
2015
Syngas
Current Technology (Baseline)
Natural Gas
Current Technology
Fuel Type
1250
1750
2250
2750
3250
Turbine Inlet Firing Temperature (°F)

Gas Phase Conditions for Advanced Turbines
IGCC Based syngas and H_2 Fueled Turbines

- **Syngas Turbine (2010 goal)**
  - Combustor exhaust temp. ~ +2700 °F
  - Turbine inlet temp. ~2500 °F
  - Turbine exhaust temp. ~ 1100 °F
  - Turbine inlet pressure ~ 265 psig
  - Combustor exhaust (turbine working fluid) composition (%): ~ CO_2 (9.27), H_20 (8.5), N_2 (72.8), Ar (0.8), O_2 (8.6)

- **Hydrogen Turbine (2015 goal)**
  - Combustor exhaust temp. ~ +2700 °F
  - Turbine inlet temp. ~2600 °F
  - Turbine exhaust ~ 1100 °F
  - Turbine inlet pressure ~ 300 psig
  - Combustor exhaust (turbuine working fluid) composition (%): ~ CO_2(1.4), H_20(17.3), N_2 (72.2), Ar (0.9), O_2 (8.2)

Potential Areas for Collaboration

Advanced Turbine

- **High temperature materials for thermal barrier coatings**

- **Advanced materials for use in hydrogen turbines**

Fuel Cells

- **High T air/air heat exchangers (800 °C+) for cathode air preheat**
- **Critical BOP component**
- **H2 Turbines Intergration**

Previous Areas for Collaboration

Plant Asset Management (PAM)

- **Target collaboration in areas of monitoring and characterization of systems, components, and materials**
  - Impact on reliability, availability, and maintainability (RAM)
  - Enable predictive capability for optimization of a plant's assets.

- **Suggested subtask**
  - Subtask 1: Creep Fatigue, Environmental Effects & Monitoring
  - Subtask 2: Corrosion Effects and Monitoring
  - Subtask 3: On-line Monitoring for PAM

Previous Areas for Collaboration

Plant Asset Management (PAM)

Subtask 1: Creep Fatigue, Environmental Effects & Monitoring

Subtask 2: Corrosion Effects and Monitoring

- **No current interest**

Subtask 3: On-line Monitoring for PAM

- **A workshop was targeted to initiate task activities and define specific areas for collaborative research**
- **No workshop has been held and no activity is current on these tasks**

Potential Areas for Collaboration

Proposed Activity in PAM Tasks

- **Collaborative work on wireless communication, networking, and powering of sensors for diagnostics and health monitoring.**
  - Requirements of wireless communication in industrial environment
  - Network architecture and prognostic capability
  - Sensor development for on line materials and component monitoring
  - Energy harvesting for powering sensors and signal transmission

Potential Areas for Collaboration

Options for Research

- **Embedded passive wireless sensors**
  - Ceramics and metamaterials (UCF, Prime Photonics)
- **Component Sensing**
  - TBC – TG sensors (ORNL)
  - Wear and Crack sensing (Siemens & Jentek)
- **Topologies for industrial wireless communication**
  - Architectures for embedding intelligence at sensor nodes and self organizing sensor networks (Signal Processing, Crossfield Technology, LLC, AmesNL, OregonSU)
- **Energy Harvesting –** SBIRs

Options for research using fiber optic sensor materials and devices

- **Distributed silica fibers for temperature and strain**
  - Variety of device designs for up to 700°C
- **Distributed silica fibers for gas sensing**
  - Suitable materials sets for sensing H2, H2S, CO at 500°C temperatures
- **Novel silica based 3-dimension fiber constructs for gas sensing and other applications**
- **Sensor packaging for fiber optics**
- **Fundamental sensor material and device design**
  - Miniaturization of light injections and collections optics
  - Novel high temperature optical materials for fiber sensors

Advanced IGCC Systems Roadmap

Challenges

Optimization of Coal Use with
- Zero emissions
- High efficiency
- Low cost plants

for production of
- Electric power
- Fuels
- Chemicals
- Hydrogen

Reduction of Power Plant Pollutants (NOx, SOx, Hg, As, Cd, Se, PM)

Reduction of CO_2 Emissions

Maintain Low Cost of Electricity to the Public through diversified mix of indigenous fuels

R&D Pathways

By 2010
- Transport gasifiers
- Advanced materials & instrumentation
- Dry feed pump
- Warm gas cleaning
- 7FB gas turbines
- ITM oxygen
- 85% capacity factor
- 98% carbon conversion

By 2015
- Hydrogen gas turbines
- 90% capacity factor
- CO_2 capture & sequestration

By 2020
- Chemical looping gasifiers
- SOFC topping cycle
- Advanced gasifiers
- Multi-product capability

Targets

By 2010
- Net plant efficiency, 45-47% (HHV)
- Capital cost, $1600/kW*

By 2015
- IGCC technology with 90% CO_2 capture resulting in less than 10% increase in COE

By 2020
- Technology ready for demonstration/deployment
- Multi-product capability (e.g. power + H_2)
- Net plant efficiency, 60% (HHV)**

*Cost in 2007$
**Targets for Plants w/o Carbon Capture

Advanced IGCC Systems Goal

- **2010: R&D Focused on Achieving**
  - **45- 47% Efficiency (HHV)**
  - **$1,600/kWe capital cost**
  - **99% SO_2 removal**
  - **NOx< 0.01 lb/MM Btu**
  - **90% Hg removal**
- **2015: Technology Ready for Demonstration w/ CCS**
  - ***90% CO_2 capture***
  - ***<10% increase in cost of electricity (COE) with carbon sequestration***
- **2020: Technology Ready for Deployment**
- **Beyond 2020: Technology Ready for Demonstration**
  - **Multi-product capability (e.g, power + H_2)**
  - **60% efficiency (measured without carbon capture)**

Proposed activity under PAM Task

- **Collaborate on the deployment of fiber optic sensor technology for on line measurement of temperature, strain and pressure**
  - Adequate activity and projects on the US side to support collaboration (e.g. Virginia Tech, Alstom, GE, University of Cincinnati, University of Missouri Science and Technology, University of Maryland)
  - Identify participants in the UK including universities and companies (e.g. Oxsensis)
- **Collaborative work can include sensor design and deployment and industrial testing of the devices.**

Evolution and Revolution of Technology

- **Evolution**
  - Material development
  - Air foil design
  - Optimization of conventional CO_2 compression technology
  - Approach to system studies

Courtesy of Siemens Energy

- **Revolution**
  - Hydrogen combustion
  - Oxy-fuel turbines
  - Ramgen shock wave compressor
  - Spare and shell air foil design

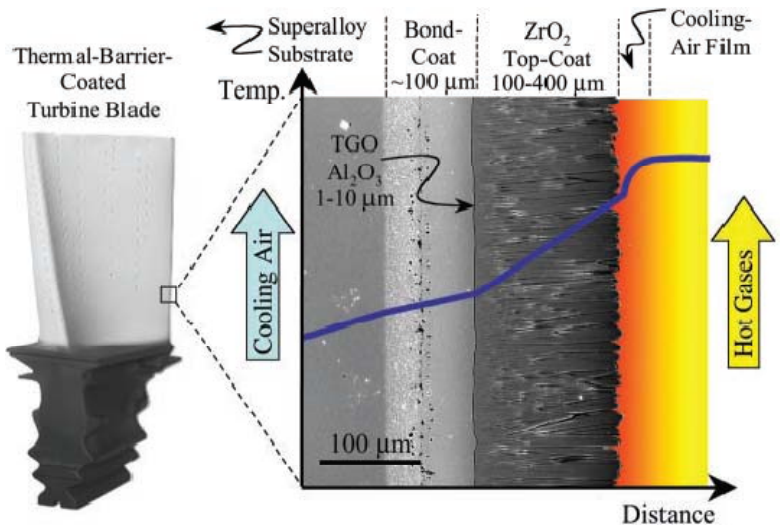
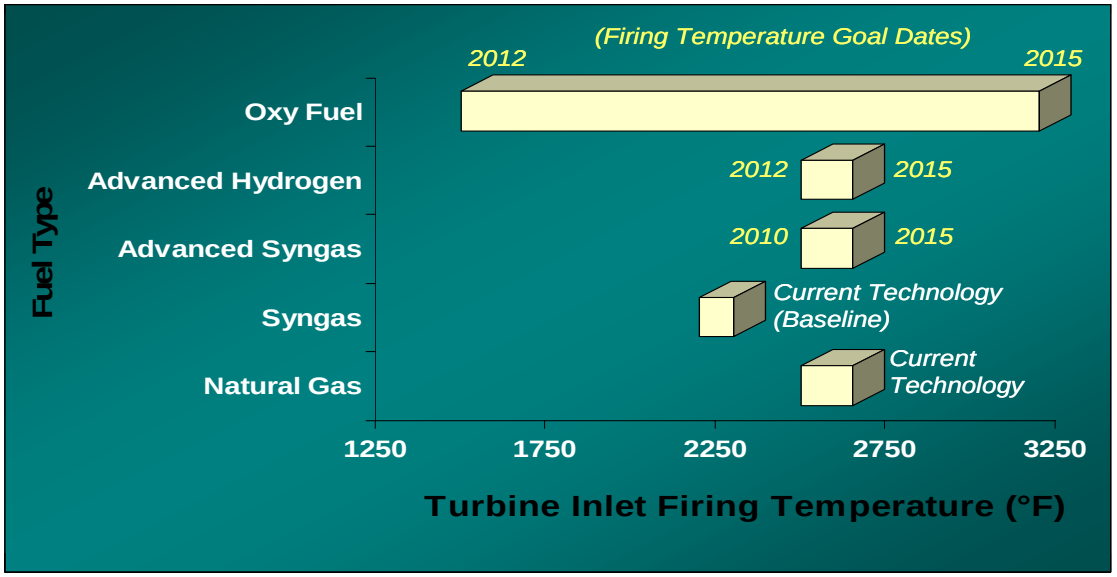
Gas Phase Conditions for Advanced Turbines

IGCC Based Syngas and H2 Fueled Turbines

Parameter	ST 2010	HT 2015
Combustor exhaust temp	2700 °F	2700 °F
Turbine inlet temp	2500 °F	2600 °F
Turbine exhaust temp	1100 °F	1100 °F
Turbine inlet pressure	250 psig	300 psig
Combustor exhaust composition	CO_2 (9.27), H_2O (8.5), N_2 (72.8), Ar (0.8), O_2(8.6)	CO_2 (1.4), H_2O (17.3), N_2 (72.2), Ar (0.9), O_2(8.2)

IGCC Oxy-Fuel Turbine Cycle

Turbine Parameters	OFT 2010	OFT 2015
Intermediate Pressure		
Turbine inlet	1150 °F	3200 °F
Pressure	450 psig	625 psig
High Pressure		
Turbine inlet	-	1400 °F
Pressure	-	1500 psig
Working Fluid Composition (%)	H2O (82), CO_2 (17), O2 (0.1), N_2 (1.1), Ar (1)	H2O (75-90), CO_2 (25-10), balance (17) O2, N_2, Ar

Turbines

- Technical Barriers
- Environmental Conditions
- Research Underway