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Gas Turbines – What Does the Future Hold?

Thursday 7 October | Technical Topic Webinar

Presented By

Dr. Lucas Skoufa | EIT Lecturer & Turbine Engineer

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Introduction - Presenter

Dr. Lucas Skoufa

Lucas Skoufa has a varied background across military (naval), power generation and university roles. Lucas's current role as a Turbine Engineer is with Rio Tinto, he is also a Lecturer with EIT (MME508). Prior to this position he was a Lecturer and Researcher in Power Generation and Carbon Management at The University of Queensland's Business School. Lucas has also worked at power stations as turbine engineer. He is serving as an Active Reservist (Marine Engineering Officer) in the Royal Australian Navy.

He has completed a PhD on the strategic behaviours of electricity generation firms, and also has a Master of Business Administration, a Bachelor of Business (Economics) and a Bachelor of Engineering (Mechanical).

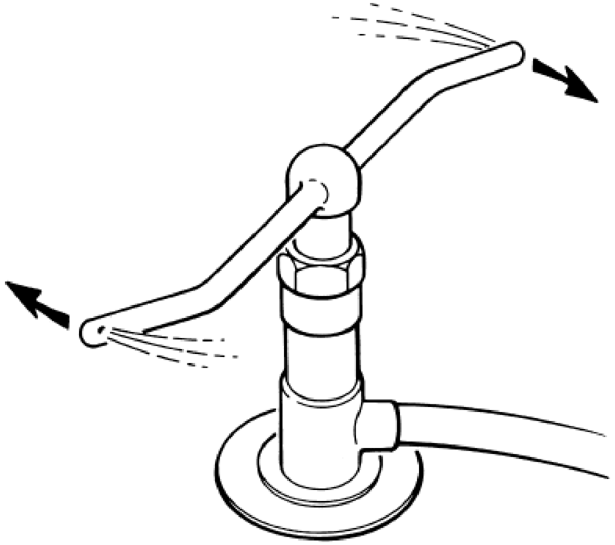
Agenda

1. Welcome & Introduction
2. Gas Turbines – Brief History and their Uses
3. Is Hydrogen the Answer?
4. The Outlook for Gas Turbines
5. Conclusion and Q&A

Background

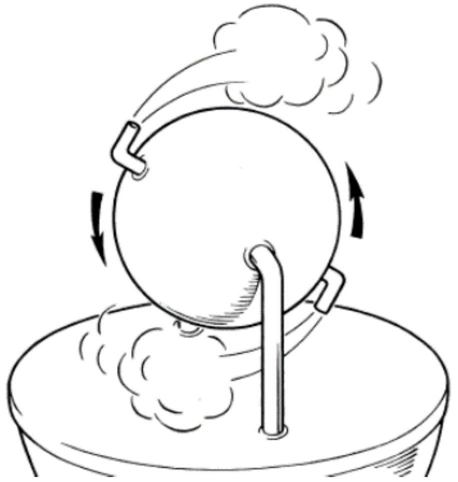
- Turbojet / Turbofan engines for civilian and military aircraft (~ 80% of the market)
- Installed for propulsion plants in:
  - Naval Warships
  - M-1 tanks
- Power generation and industrial applications

Aircraft Gas Turbines – Principles of Flight



A Brief History

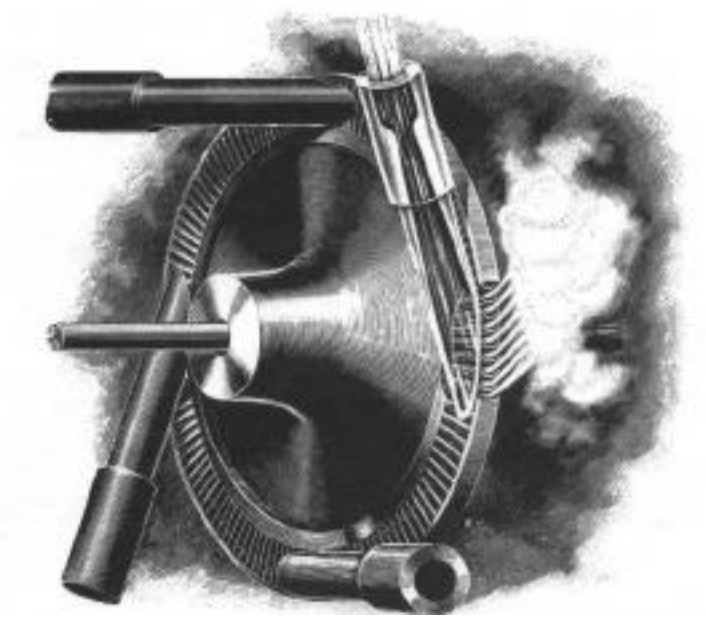
Date	Name	Invention
130BC	Hero of Alexandria	Reaction Steam Turbine
1550	Leonardo da Vinci, Italy	Smoke Mill
1629	Giovanni Branca, Italy	Impulse Steam Turbine
1791	John Barber, England	Steam Turbine and Gas Turbine
1831	William Avery, USA	Steam Turbine
1837	M. Bresson	Steam Turbine
1850	Fernimough, England	Gas Turbine
1872	Dr. Stolze, Germany	Gas Turbine
1884	Charles A. Parsons	Reaction Steam Turbine & Gas Turbine
1888	Charles G.P. de Laval	Impulse Steam Turbine Branca type
1894	Armengaud+Lemale, France	Gas Turbine
1895	George Westinghouse	Steam Turbine Rights
1896	A.C. Rateau, France	Multi Impulse Steam Turbine



Source: *Gas Turbine Handbook: Principles and Practices*, Giampaolo, A., 2012

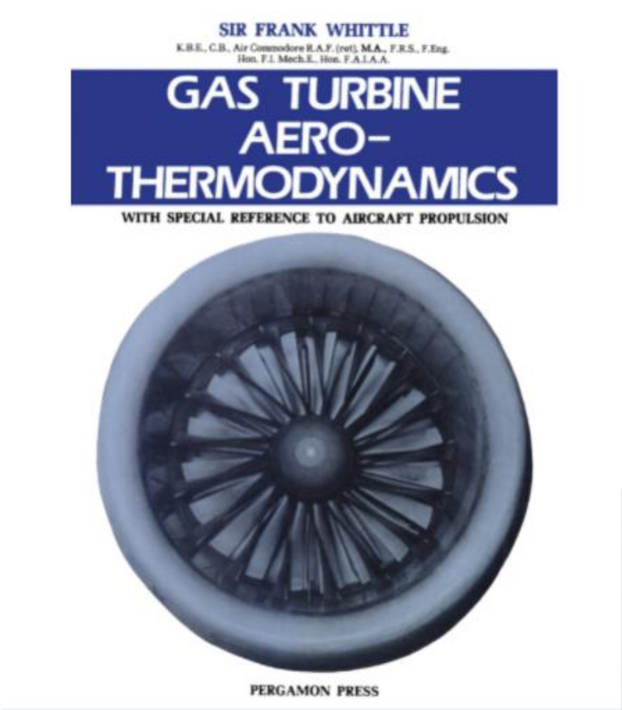
A Brief History

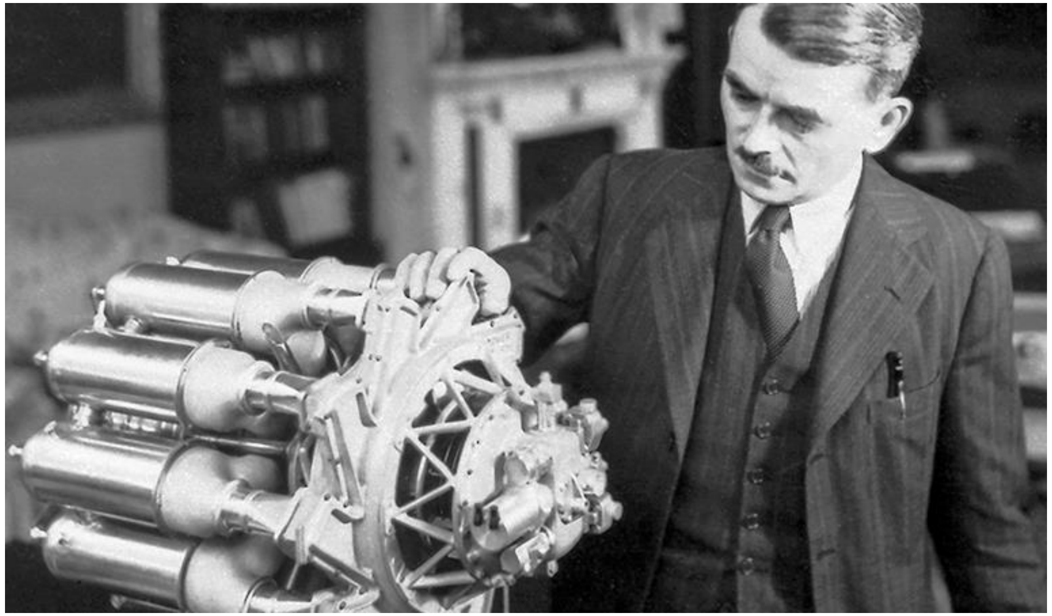
1896	Charles Curtis	Velocity Compound Steam Turbine/Gas Turbine
1895	Dr. Zoelly, Switzerland	Multi Impulse Steam Turbine
1900	F. Stolze, Germany	Axial Compressor & Turbine Gas Turbine
1901	Charles Lemale	Gas Turbine
1902	Stanford A. Moss, USA	Turbo-Charger/Gas Turbine
1903	A. Elling	Gas Turbine
1903	Armengaud+Lemale	Gas Turbine
1905	Brown Boveri	Gas Turbine
1908	Karavodine	Gas Turbine with deLaval Steam Turbine
1908	Holzwarth	Gas Turbine with Curtis + Rateau Compressor
1930	Frank Whittle, England	Aero Gas Turbine (Jet Engine)
1938	Brown Boveri—Neuchatel, Switzerland	1st Commercial Axial Compressor & Turbine



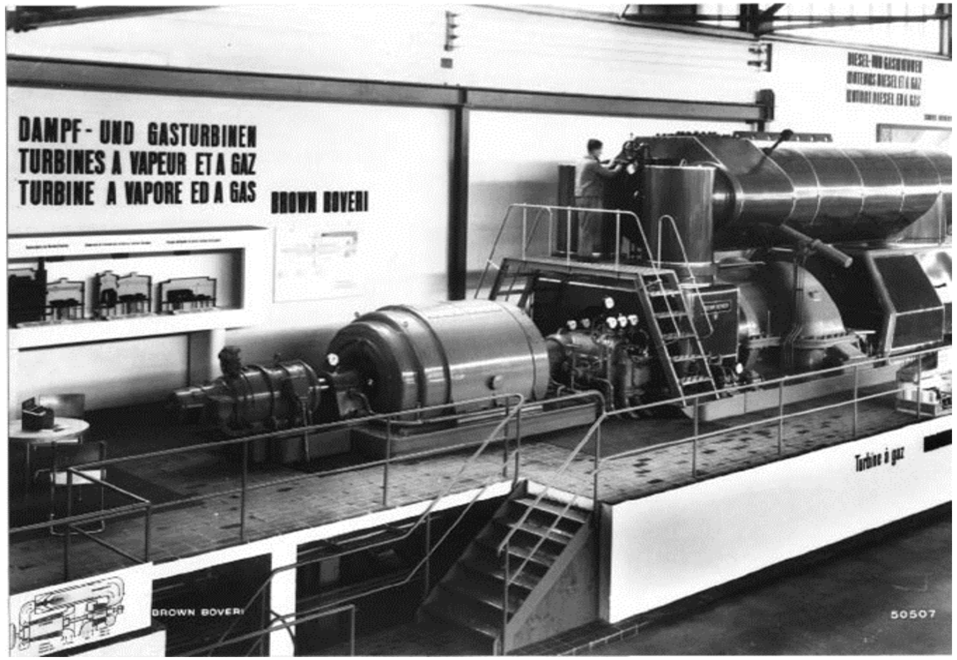
Source: *Gas Turbine Handbook: Principles and Practices*, Giampaolo, A., 2012

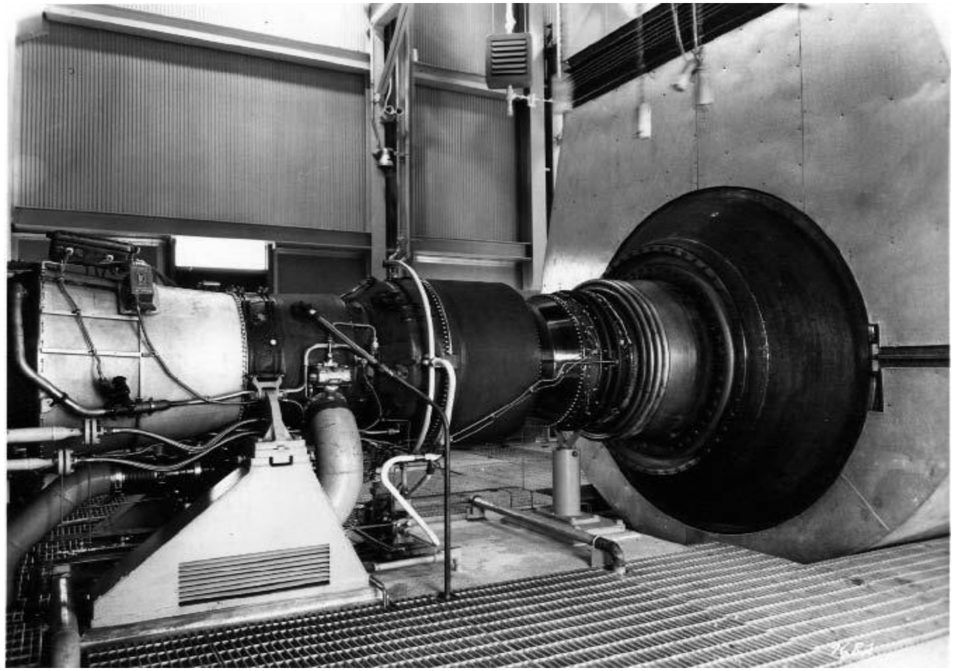
Sir Frank Whittle





Early Industrial Uses



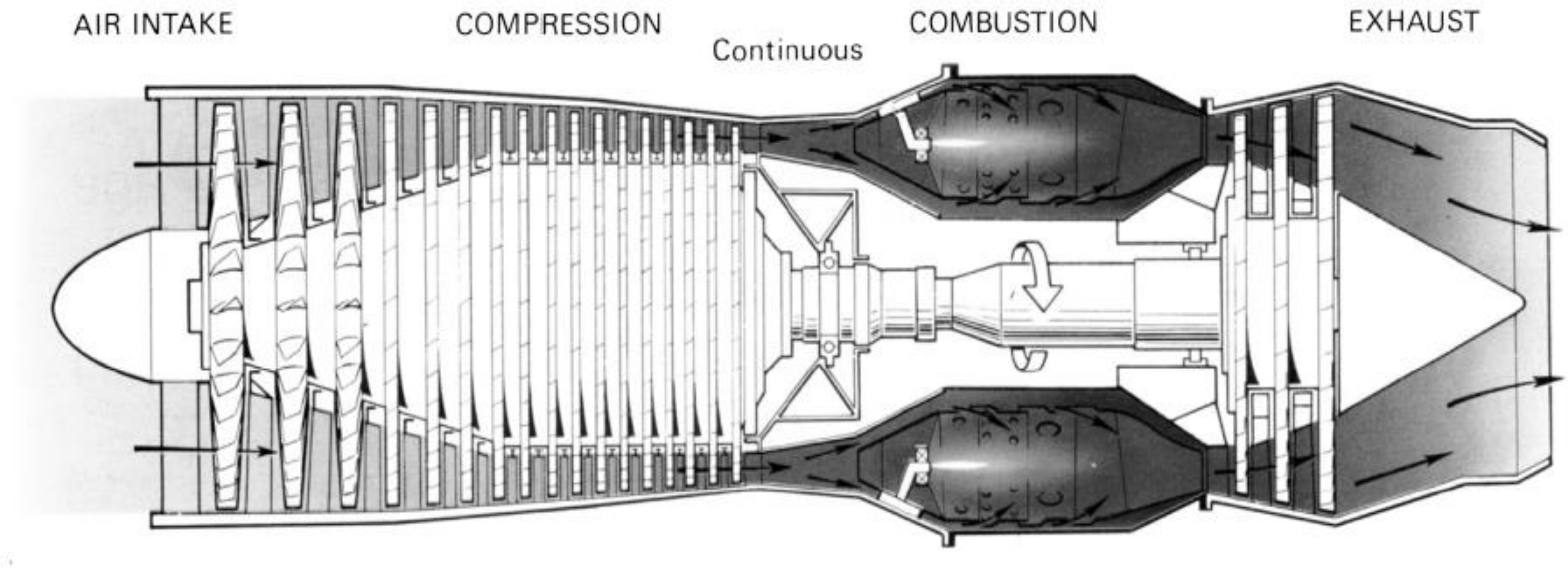


- In 1905, Brown Boveri built the first gas turbine and compressor unit.
- It provided 5,300 kilowatts.

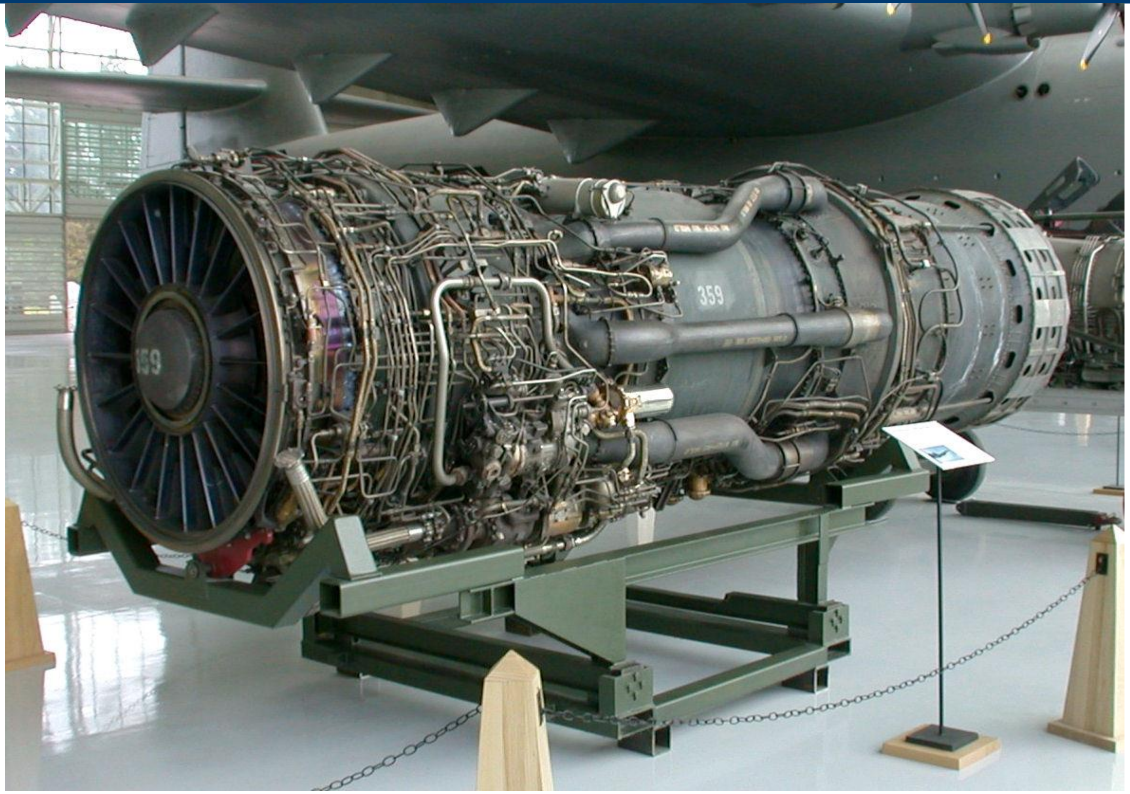
- In 1959, Cooper Bessemer installed the world's first base-load aeroderivative industrial gas turbine, the FT3.
- The unit generated 10,500 brake horsepower (BHP).
- In 1981, that unit had accumulated over 100,000 operating hours.

<u>Source:</u> *Gas Turbine Handbook: Principles and Practices*, Giampaolo, A., 2012

Gas Turbine – 4 Parts to the Cycle



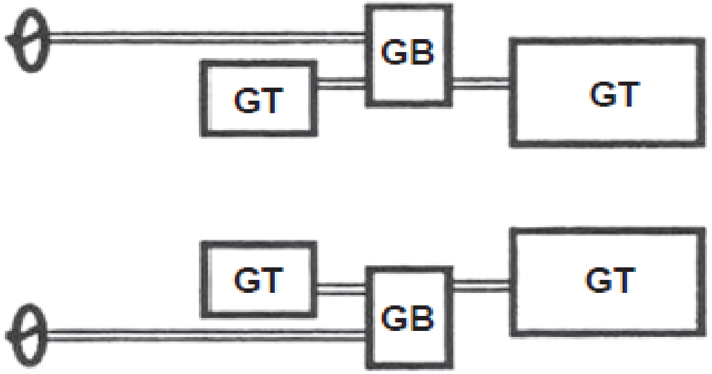
Gas Turbine – 4 Parts to the Cycle



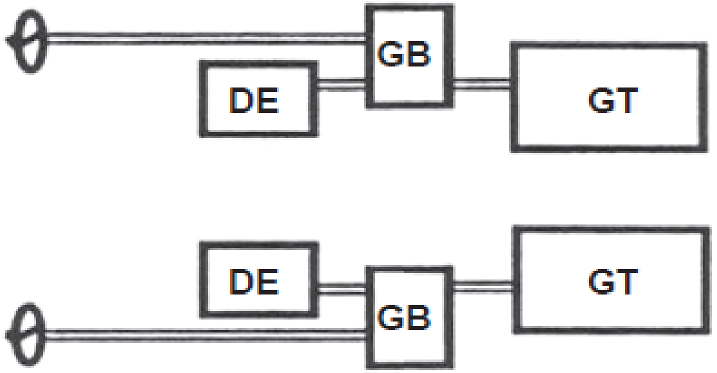
Gas turbines classified into five broad groups:

1. Frame type heavy-duty gas turbines
2. Aircraft-derivative gas turbines
3. Industrial type-gas turbines
4. Small gas turbines
5. Micro-turbines

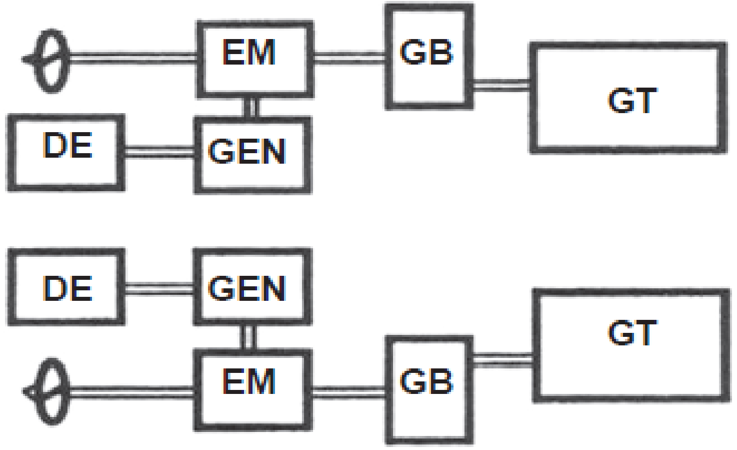
Marine Configurations



(a) Combined gas turbine and/or gas turbine (GOGAG/GOGAG)



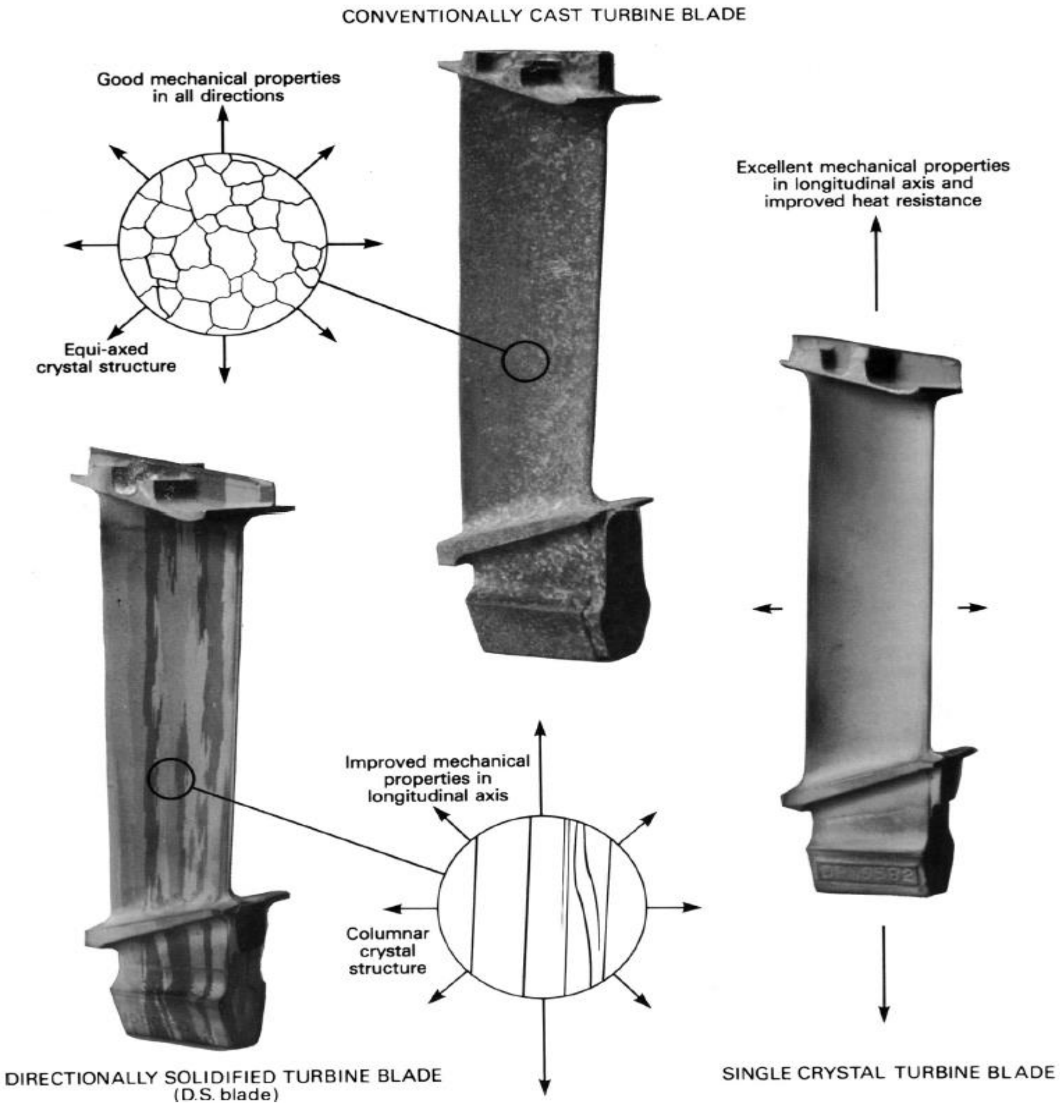
(b) Combined diesel and/or gas turbine (CODAG/CODOG)



(c) Combined diesel -electric and gas turbine (CODLAG)

GT=Gas Turbine, DE=Diesel Engine, EM=Electric Motor, GEN=Generator

Gas Turbine Components



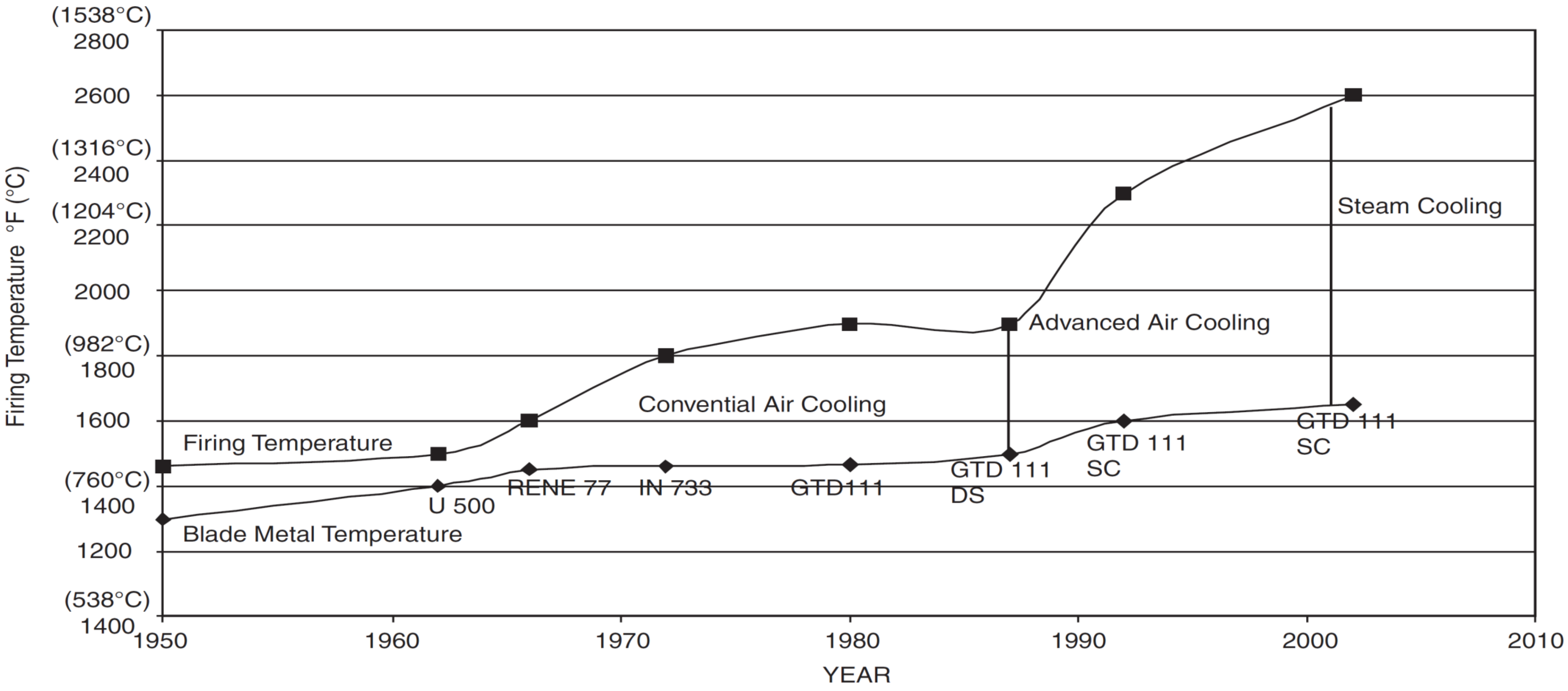
Technical Improvements

Three factors significantly contributed to the growth of gas turbines in recent years.

1. Metallurgical advances
2. The cumulative background of aerodynamic and thermodynamic knowledge
3. The utilisation of computer technology in design and simulations

- This has led to improvements in compressor design, combustor design, turbine design and overall performance.
- Gas turbines now function satisfactorily on gasified coal, wood, syngas, crude oil
- Computers govern operations, report on the unit's health (diagnostics), and predict future failures (prognostics).

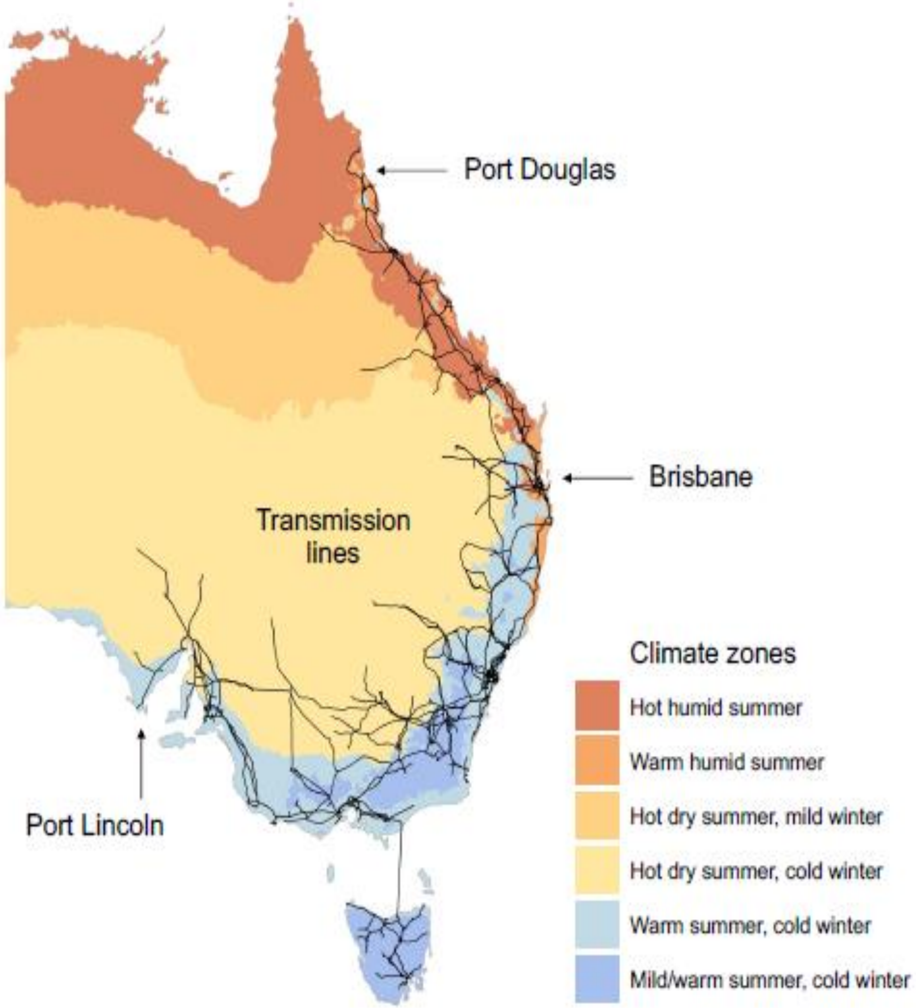
Gas Turbine Materials



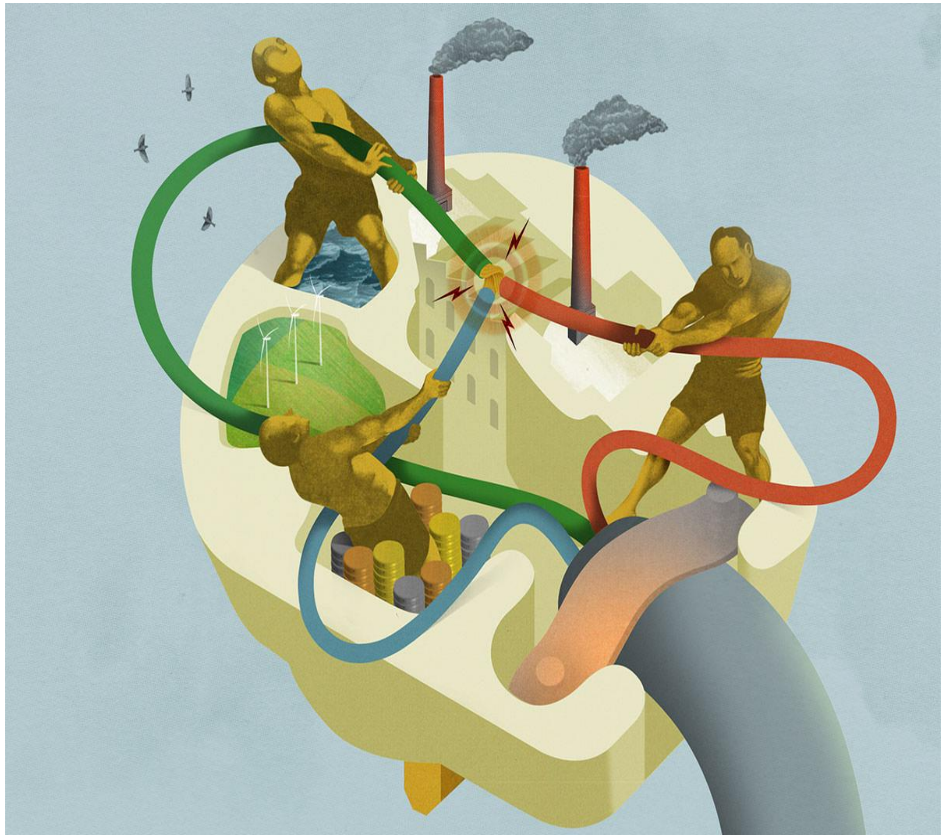
Firing temperature increase with blade material improvement

Source: *Gas Turbine Engineering Handbook, Boyce M., 2012*

Challenges for Existing Power Generation Technologies



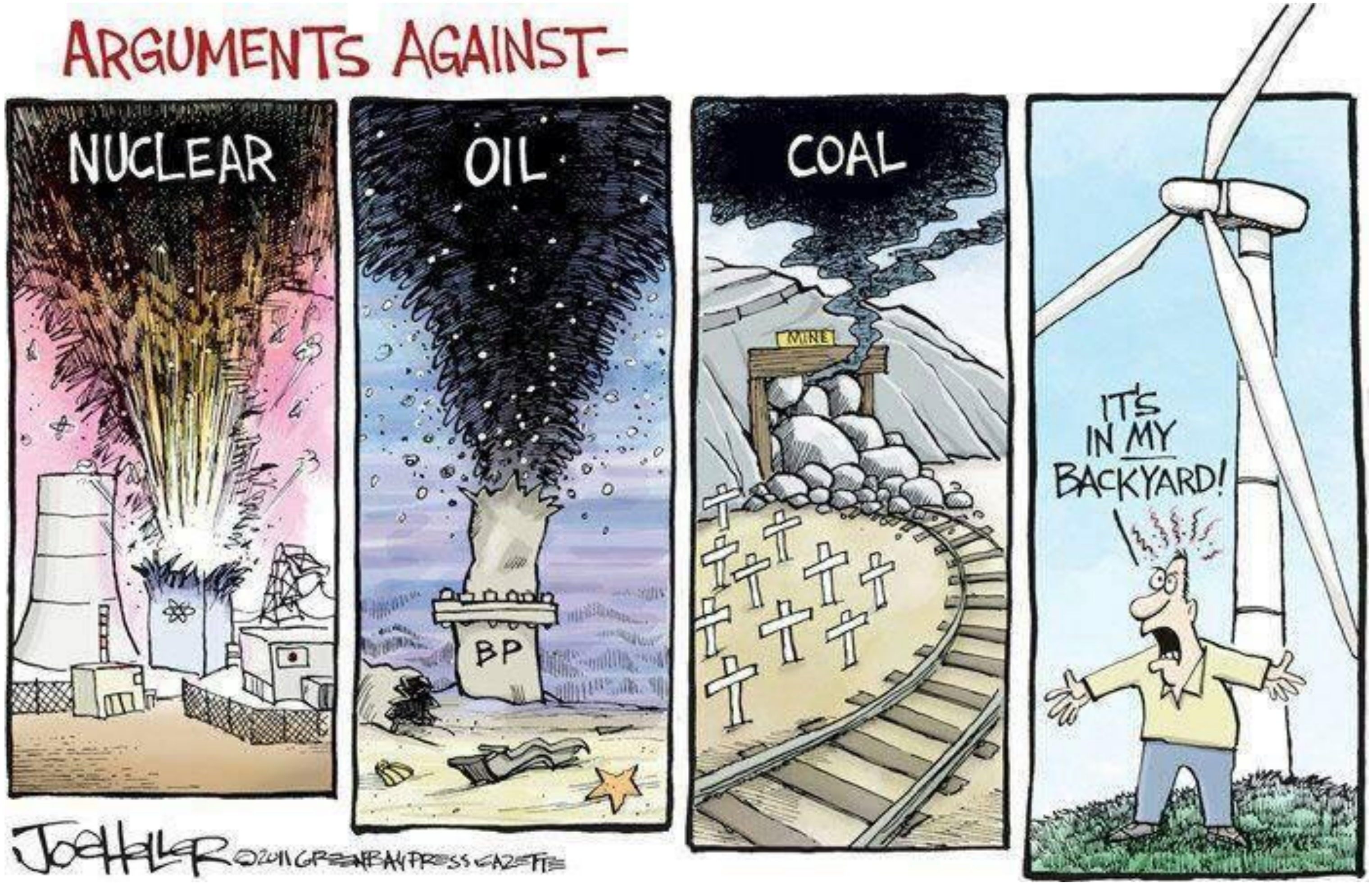
Energy Demands over the Whole Life-Cycle



- ✓ Affordable Electricity **(Cost)**
- ✓ Secure and Reliable Electricity **(24/7 Capacity)**
- ✓ Zero / low-carbon electricity **(Carbon)**

'An Energy Trilemma that cannot be reconciled simultaneously …'
– Michael Pollitt, 2014

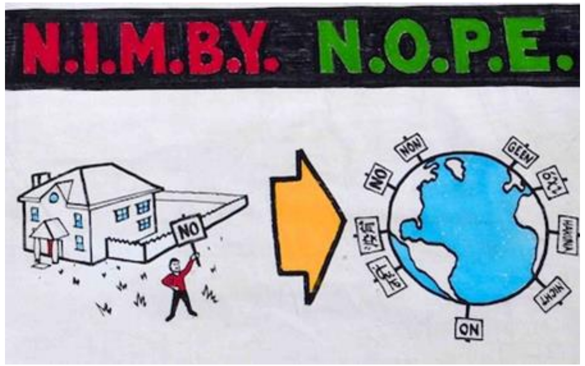
Everyone has a View – who is Correct?

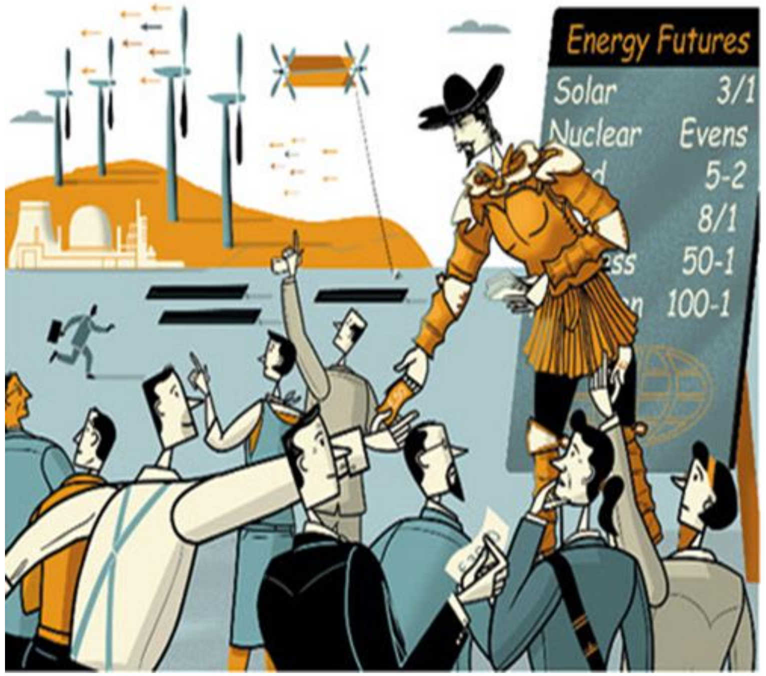


Your View of the Energy Future, please enter in Chat

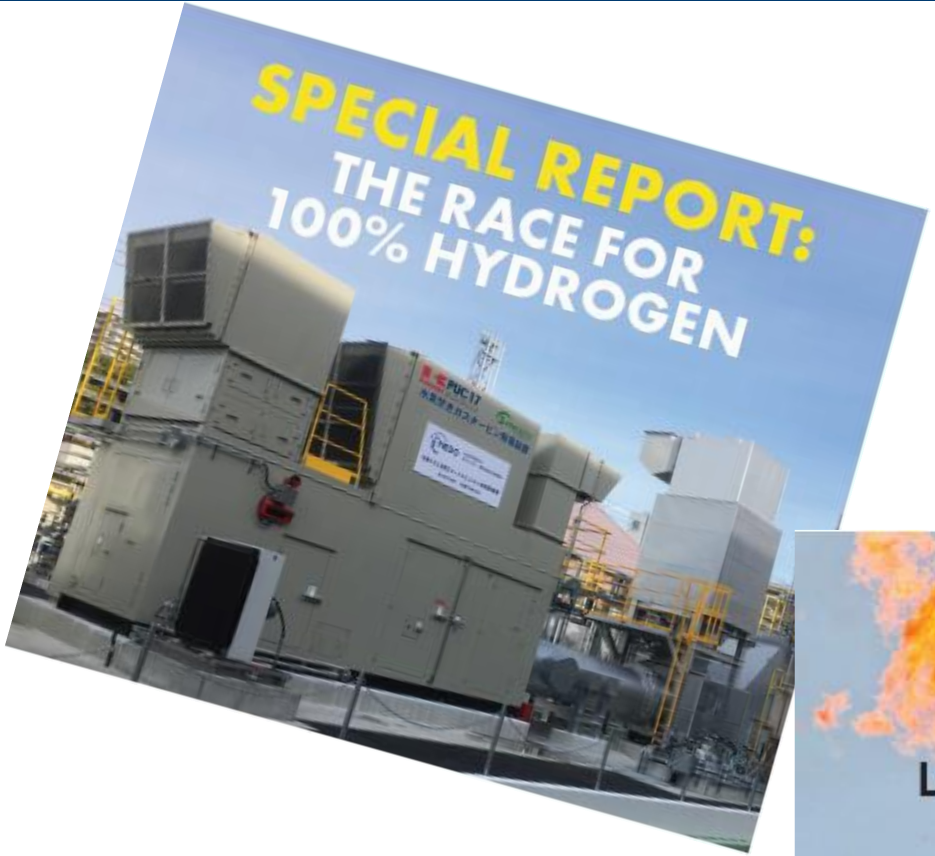
Mark Edwards/Peter Arnold, Inc.

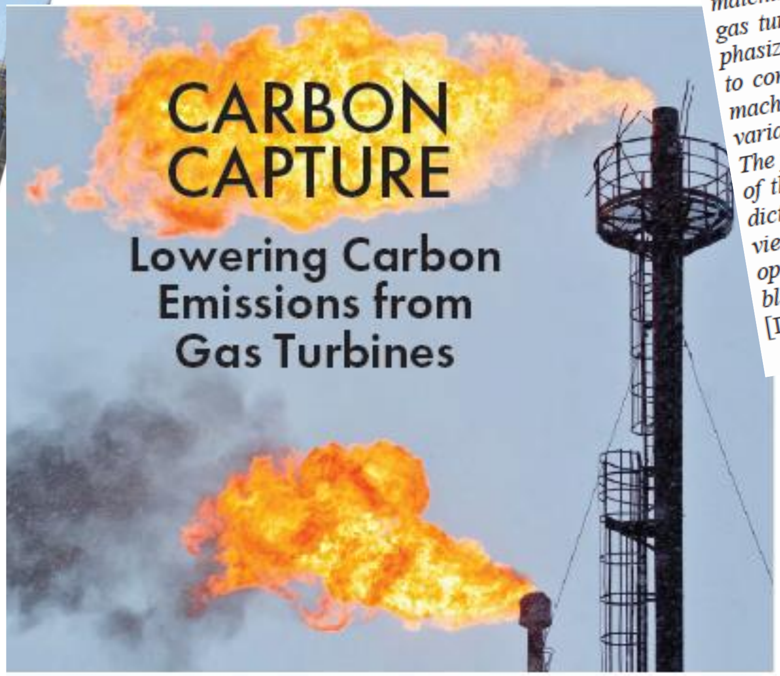
Figure 16-16 **Solutions:** woman in India uses a solar cooker to prepare a meal for her family.





Decarbonisation – H_2



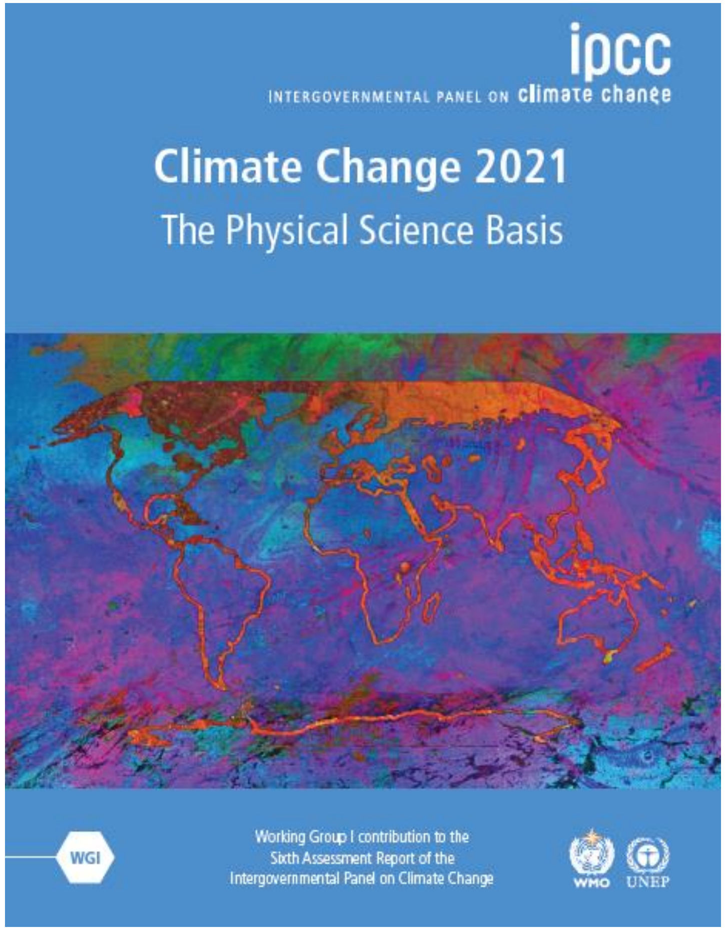


Using Hydrogen as Gas Turbine Fuel

This paper addresses the possibility to burn hydrogen in a large size, heavy-duty gas turbine designed to run on natural gas as a possible short-term measure to reduce greenhouse emissions of the power industry. The process used to produce hydrogen is not discussed here: we mainly focus on the behavior of the gas turbine by analyzing the main operational aspects related to switching from natural gas to hydrogen. We will consider the effects of variations of volume flow rate and of thermophysical properties on the matching between turbine and compressor and on the blade cooling of the hot rows of the gas turbine. In the analysis we will take into account that those effects are largely emphasized by the abundant dilution of the fuel by inert gases (steam or nitrogen), necessary to control the NO_x emissions. Three strategies will be considered to adapt the original machine, designed to run on natural gas, to operate properly with diluted hydrogen: variable guide vane (VGV) operations, increased pressure ratio, re-engineered machine. The performance analysis, carried out by a calculation method including a detailed model of the cooled gas turbine expansion, shows that moderate efficiency decays can be predicted with elevated dilution rates (nitrogen is preferable to steam under this point of view). The combined cycle power output substantially increases if not controlled by VGV operations. It represents an opportunity if some moderate re-design is accepted (turbine blade height modifications or high-pressure compressor stages addition).
[DOI: 10.1115/1.1787513]

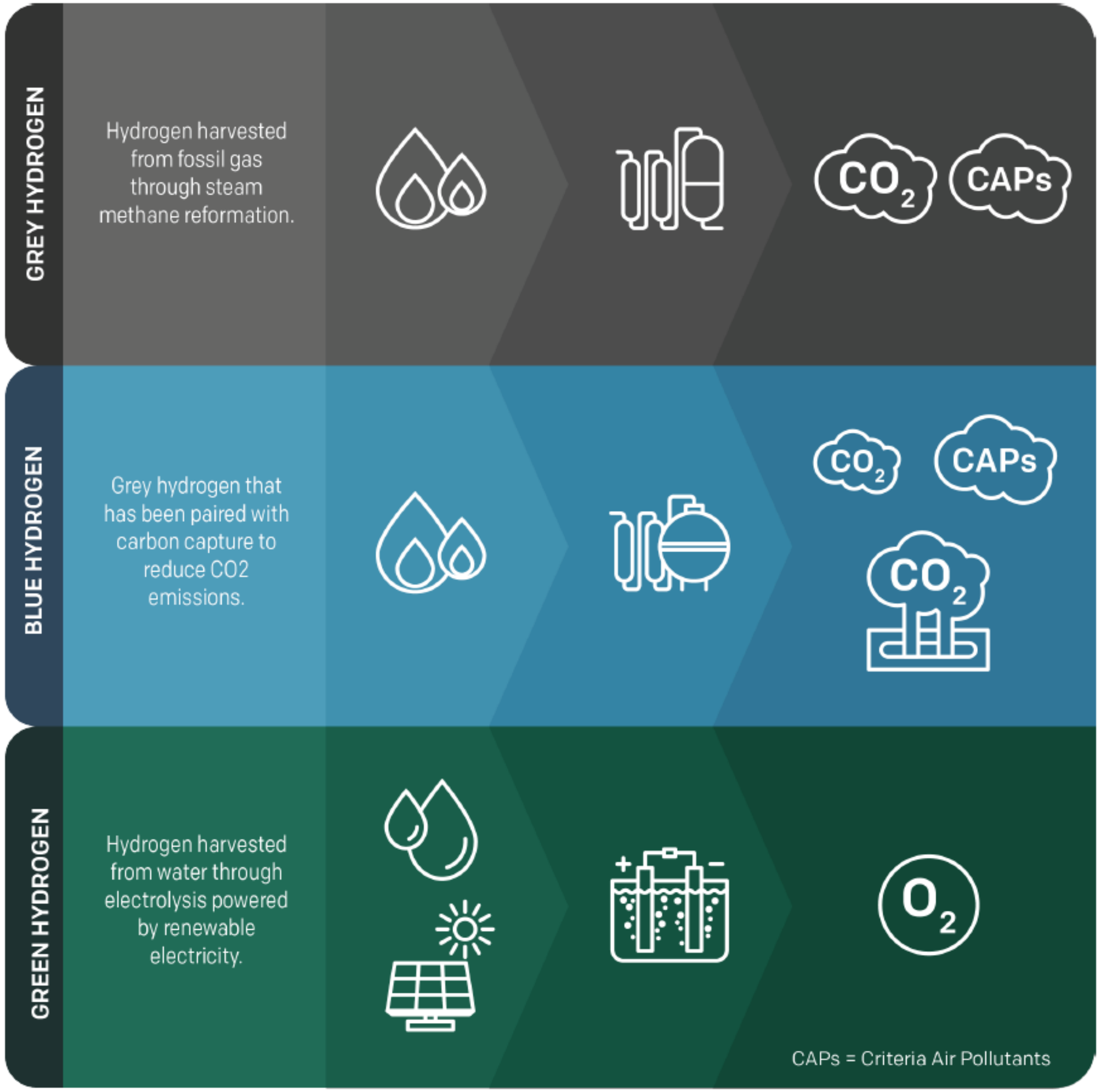
A Quick Poll

<u>Poll:</u> Is Hydrogen the answer to low-emission gas turbine power plants?

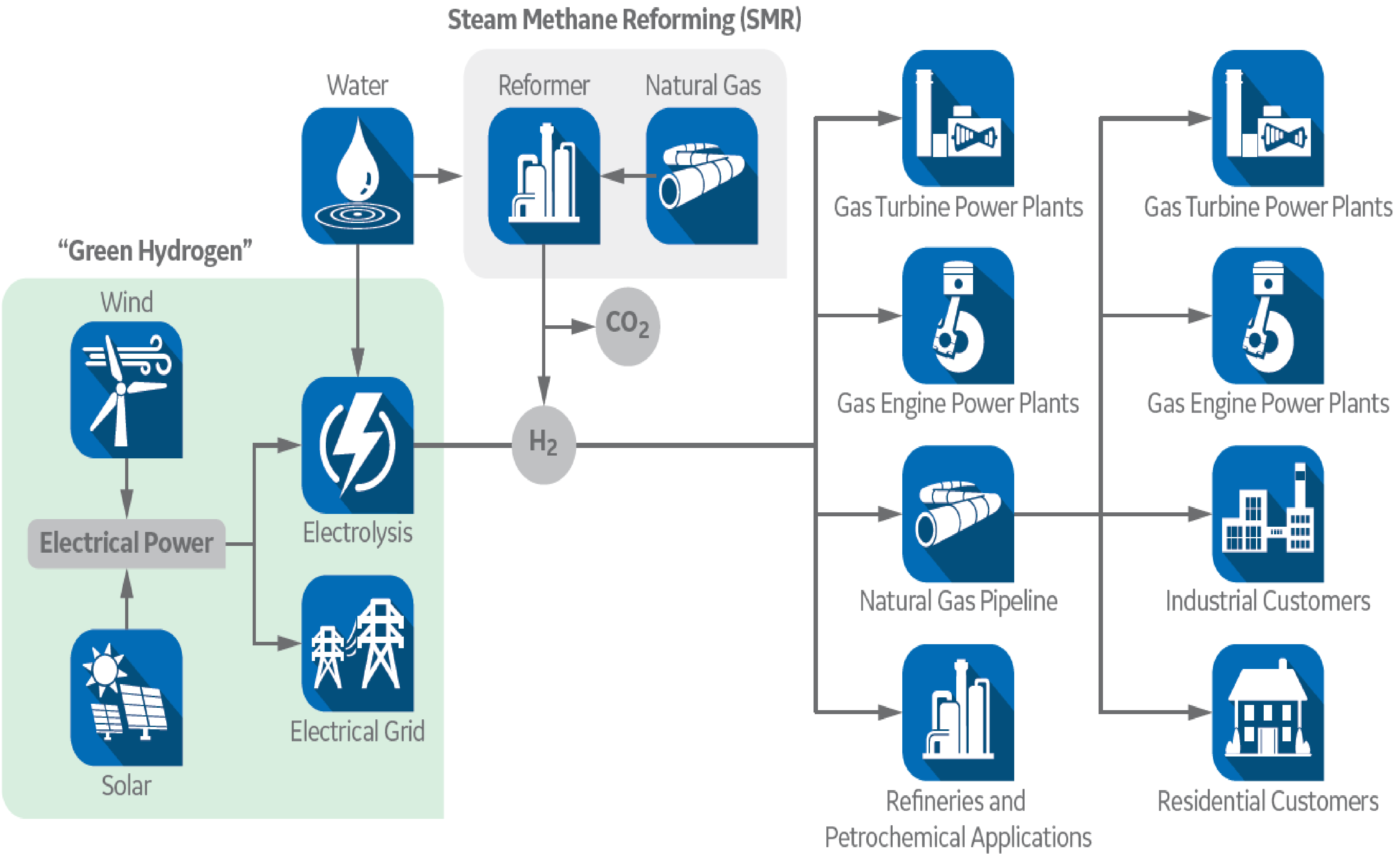


Producing Hydrogen

- **Grey (or black):** Gasification of coal or reforming of natural gas without carbon capture
- **Blue:** Reforming of methane (SMR) with carbon capture and storage
- **Green:** Electrolysis of water using renewable power
- **Pink (Red):** Electrolysis of water using nuclear power
- **Turquoise:** Pyrolysis of methane which produces hydrogen and solid carbon as a by-product
- **White:** Gasification or other process using 100% biomass as a feedstock



Hydrogen as a GT Fuel



Hydrogen as a GT Fuel

Engineering Institute of Technology.

Challenges of Hydrogen

1) Heating Value
   a) On a volume basis H_2 is 1/3 less dense than CH_4 (larger pipelines)

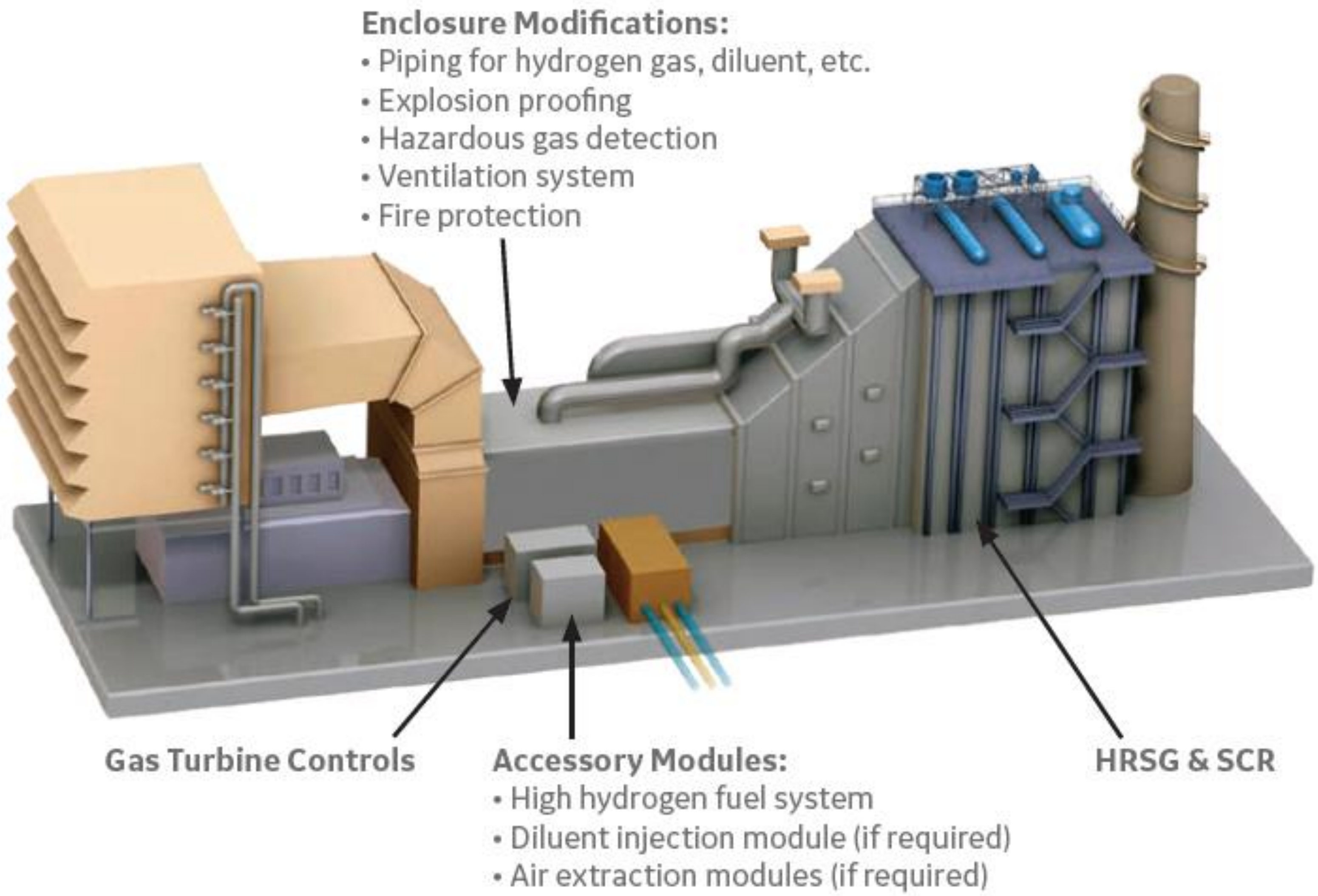
2) Flame Speed
   a) H_2 has a much faster flames than other fuels (combustor design)

3) Safety
   a) H_2 is hard to see as a flame
   b) It can diffuse through seals much easier than other gases / air
   c) It is more flammable than CH_4
   d) Hazardous Ratings

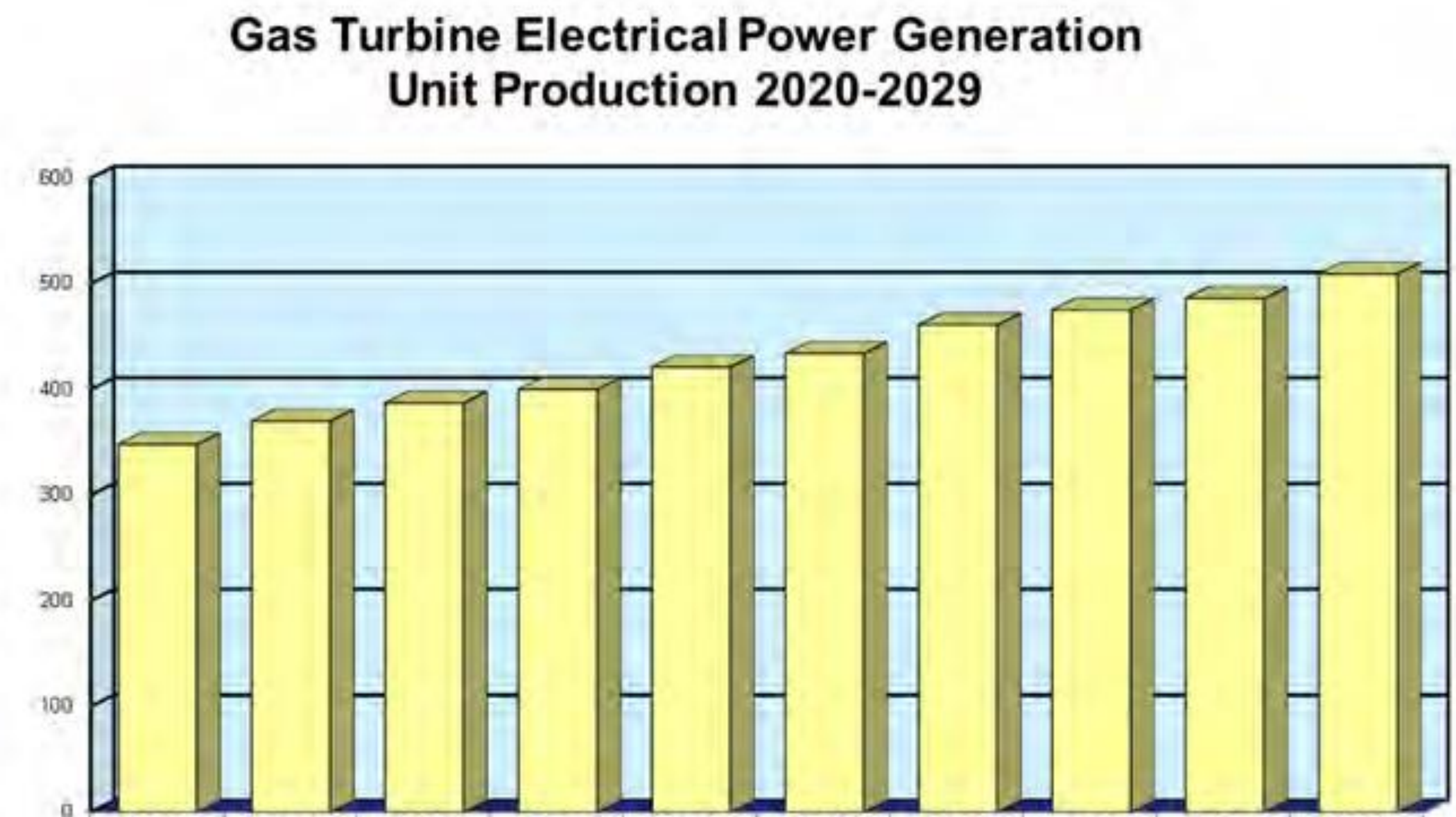
100% NG 100% H2

<u>NOTE!</u> **Gas Turbine burning 100% (by volume) H_2 sees a ~99% relative reduction in CO_2 emissions compared to burning CH_4**

Hydrogen as a GT Fuel



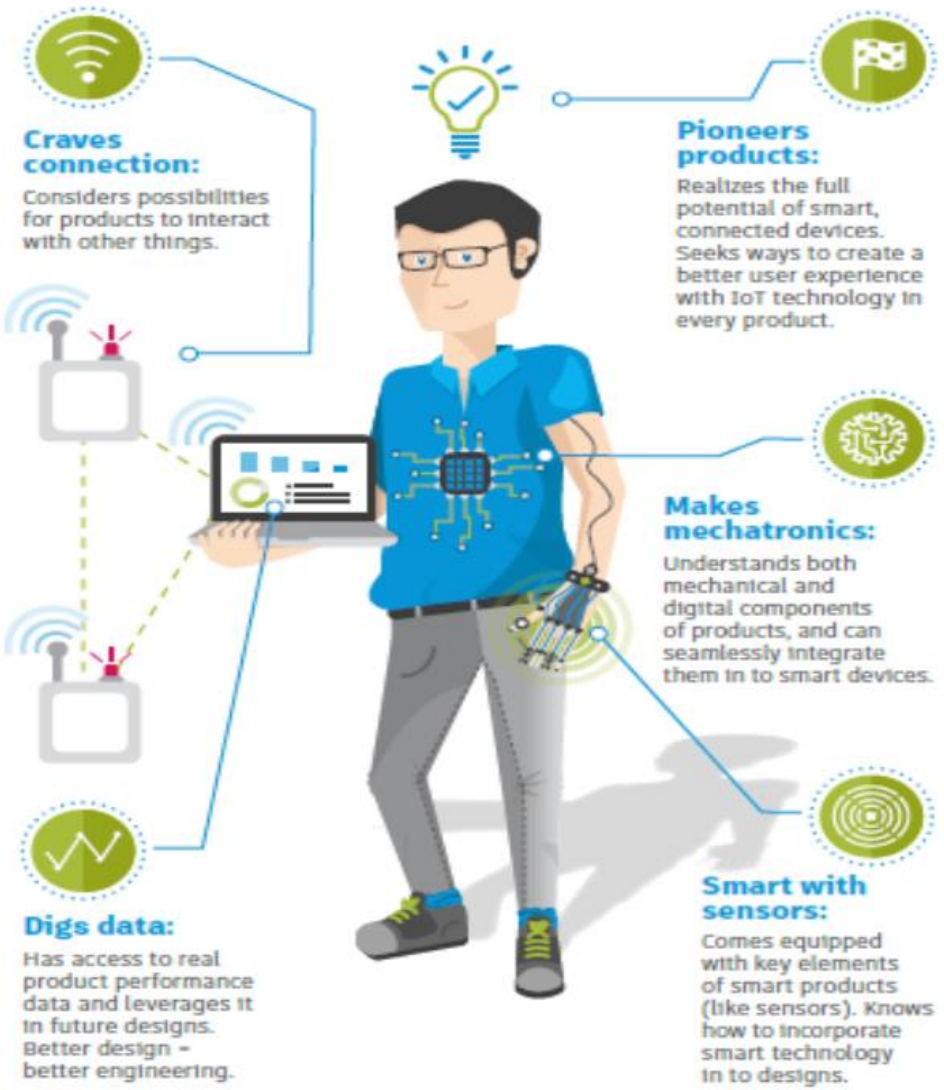
Gas Turbines for Power Generation to 2029

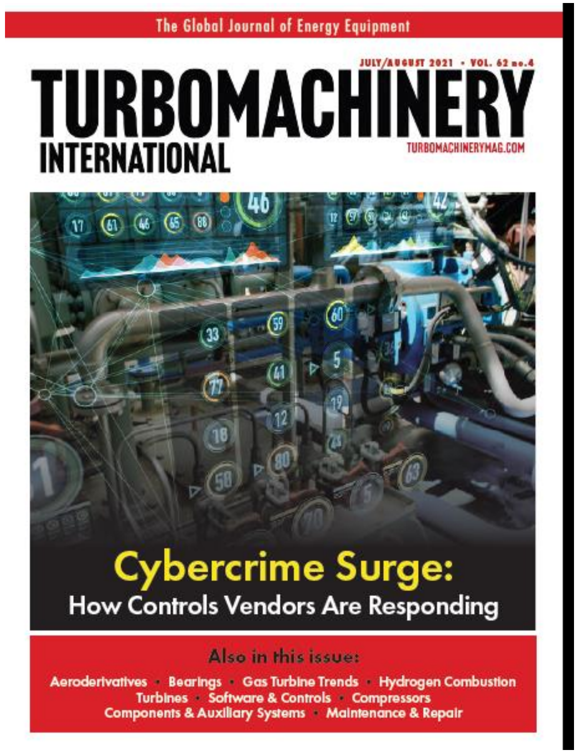


	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029
Units	348	370	387	400	421	434	461	475	486	509

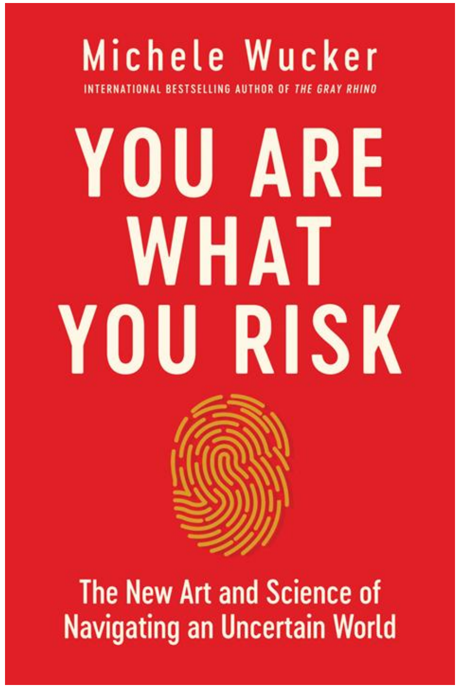
Aviation Initiatives

The People, Skills … $





Summary



"Okay – it's agreed; we announce – 'to do nothing is not an option!' then we wait and see how things pan out..."

"Look – it's Low Carbon Emission Man"

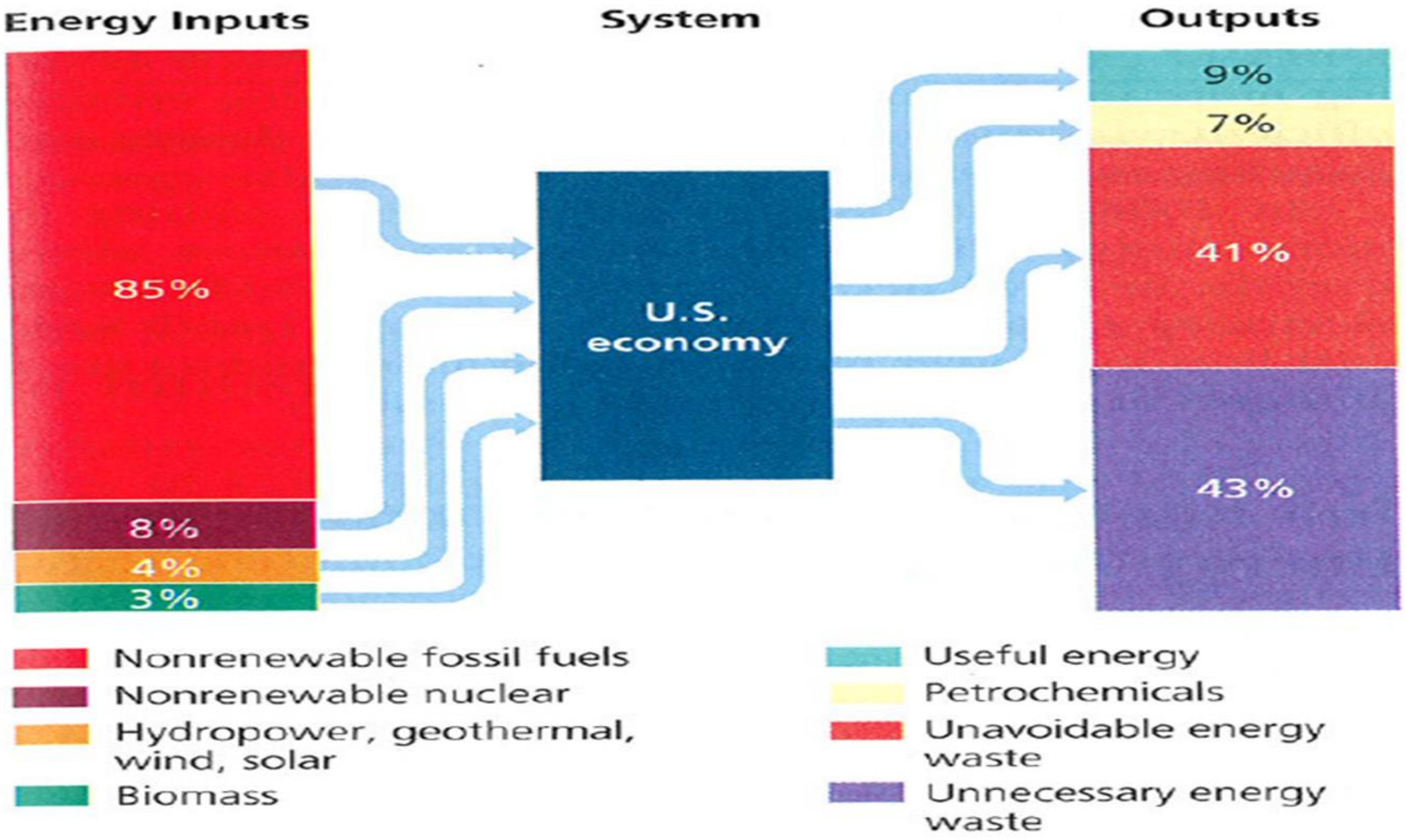


Figure 16-2 Flow of commercial energy through the U.S. economy. Only 16% of all commercial energy used in the United States ends up performing useful tasks or being converted to petrochemicals; the rest is unavoidably wasted because of the second law of thermodynamics (41%) or is wasted unnecessarily (43%). **Questions:** What is an example of unavoidable energy waste? What is an example of unnecessary energy waste? (Data from U.S. Department of Energy)

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Q&A

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