R&D in our industry: where do we go from here?

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Outline

- Setting the stage
  - The three main R & D challenges of the 21st century
- The energy challenge
  - Some world-wide energy data
  - Production
  - System integration
  - Public policy
- The role of power engineers in addressing emerging energy challenges
- The role of academia
- The role of the IEEE Power Engineering Society
- Conclusions

Background

- The 19th century saw the dawn of the industrial revolution driven by the steam engine.
- The beginning of the 20th century saw the advent of electricity as the driver of economic development.
- The second half of the 20th century saw the advent of the communication-information revolution enabled by semiconductor technologies.
- The 20th century witnessed the transportation revolution.
- The world has become a village – we can communicate instantly and we can gather from any corner of the world within hours.

21st R & D drivers

- By the year 2050 the world's population will have increased to 9.1 billion an increase of 2.6 billion from the 2005 situation.

  Not only will the population grow dramatically but its geographical distribution will also evolve:

  – Europe's population will decrease to 650 from 730 million at present.
  – Africa's population will explode to 1,940 million from 910 at present.
  – Asia's population will grow to 5.2 billion from 3.9 billion at present.
  – By 2050 India is expected to have a population of 1.6 billion surpassing that of China at 1.4 billion.

21st R & D drivers - 2

- The end of the petroleum era of man's presence on earth will come during the 21st century.

  While we can not predict the exact date, there is broad agreement that the peak production of petroleum will occur some time during the 21st century.

  At $60-$70 per barrel, the cost of petroleum is close to being the highest it has ever been and will encourage the deployment the more expensive extraction technologies.

  The era of inexpensive petroleum is definitely behind us. Indeed, future price structures will be cost driven as opposed to market driven.

Main R & D Challenges of the 21st century

1. Availability and broad access of reliable and affordable health services world-wide.

   While developed countries are rapidly running into a major crisis in terms of the cost of health services, developing countries are struggling to gain access to health services to address immediate and very large scale health crisis.

   The canyon between the “have” and “have-nots” is widened by the fact that most preventative medical services, including medicines, are brought to market by corporations from developed countries and at costs which are often beyond the means of developing countries.

Main R & D Challenges of the 21st century - 2

2. Production and distribution of food world-wide.

   At present, developed countries are generally the largest food producers in the world.

   Increasing standards of living in developed countries, coupled with intensifying competition on the world market, which drives prices down, result in heavy government subsidies provided by developed countries to their farmers.

   In the latest rounds of WTO DOHA negotiations, significant tensions arose between poor countries which are demanding that rich countries stop subsidizing their farmers in an effort to “level the playing field”.

Main R & D Challenges of the 21st century - 3

3. Production, transport and delivery of energy.

   This is probably the one area where humanity will have to consent to the heaviest investments during the second part of this century.

The Energy Challenge of the 21st century

- Production
- System integration
- Public policy

Key energy world-wide data - 1

World-wide energy consumption – quadrillion of BTU

	1982	2002	Δ %
North America	86.8	117.4	35.2
Latin America	11.5	21.2	84.3
Western Europe	55.9	72.3	29.3
Eastern Europe & former USSR	63.4	51.9	-18.1
Middle East	6.4	18.9	195.3
Africa	7.6	12.8	68.4
Asia & Oceania	50.6	116.9	131.0
Total	**282.2**	**411.1**	

Key energy world-wide data - 2

Per Capita world-wide energy consumption – million of BTU

	1982	2002	Δ %
North America	264.9	278.5	5.1
Latin America	37.9	48.8	28.8
Western Europe	127.9	149.0	16.5
Eastern Europe & former USSR	173.1	134.6	-22.2
Middle East	65.1	105.8	62.5
Africa	15.4	15.3	0.0
Asia & Oceania	19.9	33.3	67.3
Total	**61.7**	**65.9**	

Key energy world-wide data - 3

Energy sources – quadrillion of BTU

	1982	2002	Δ %
Petroleum	119.9	153.4	27.9
Natural gas	55.5	95.3	71.7
Coal	75.6	97.4	28.8
Hydro (net)	18.9	26.6	40.7
Nuclear (net)	9.5	26.9	183.2
Geothermal, solar, wind…	0.6	3.3	450.0
US ethanol, geothermal, solar waste, etc…non-electric	2.6	2.2	-15.4

The Energy Challenge of the 21st century

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Present generation mix

- At present, the primary generation technologies are:
  - Hydro, either run-of-the-river facilities or various types of dams.
  - Thermal, using either coal, oil or gas.
  - Nuclear.

Present generation mix

- To-day, the primary generation technologies are:
  - Hydro, either run-of-the-river facilities or various types of dams.
  - Thermal, using either coal, oil or gas.
  - Nuclear.
- The present generation mix already is:
  - Distributed.
  - Significantly renewable.

Hydro

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- In industrialized countries, almost all feasible sites have been developed – the potential incremental capacity is very low.

  The only potential incremental energy capacity is by way of conversion of existing storage facilities to pumped-storage.

Hydro

- Very significant incremental capacities are available in Africa, Asia and Latin America.

  Development will come at heavy ecological and societal impacts. Some of the ecological impact will go beyond regional to become world-wide.

ISSUE: World-wide environmental and ecological public policy – major research needed.

Fossil Fuel - Coal

- Heavy environmental impact.

Fossil Fuel - Coal

- Heavy environmental impact.
- Technologies are available to significantly mitigate the environmental impact; they are also very expensive to implement & operate.

ISSUES: Can industrialized countries impose such technologies on countries with emerging economies?

What is the true potential of coal liquefaction?

Fossil Fuel - Oil

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Fossil Fuel - Oil

- The “lust” of industrialized countries for oil is the major reason for the increasing tensions world wide.
- There is broad agreement that the production of oil will peak sometime during the 21st century.

ISSUES: When do we start focusing on the use of carbon as a material as opposed to as fuel?
What new extraction technologies become feasible as the price per barrel increases?

Fossil Fuel - Gas

- Environmentally more friendly.

Fossil Fuel - Gas

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- Transportation is technologically “cumbersome” and requires heavy infrastructures.

ISSUE: Will we be able to continue to build liquid gas harbor sites close to heavy consumption centers?

Nuclear

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- Countries with emerging economies want to construct nuclear power plants using existing technologies.

ISSUE: How can industrialized countries “monitor” such developments?

Hydro, Fossil & Nuclear

- How do we site the new facilities?

  What organization makes the decision and then assumes it?

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- How do we site the new facilities?

  What organization makes the decision and then assumes it?
- The financing of large generation facilities have reached a scale often beyond the capabilities of the private sector.

- The construction and operation of the required transmission systems are increasingly in “limbo”.

Alternative Generation
Technologies

Renewable

- Solar - photovoltaic and/or thermal
- Wind
- Geothermal
- Ocean - tidal

Alternative Generation
Technologies

Renewable

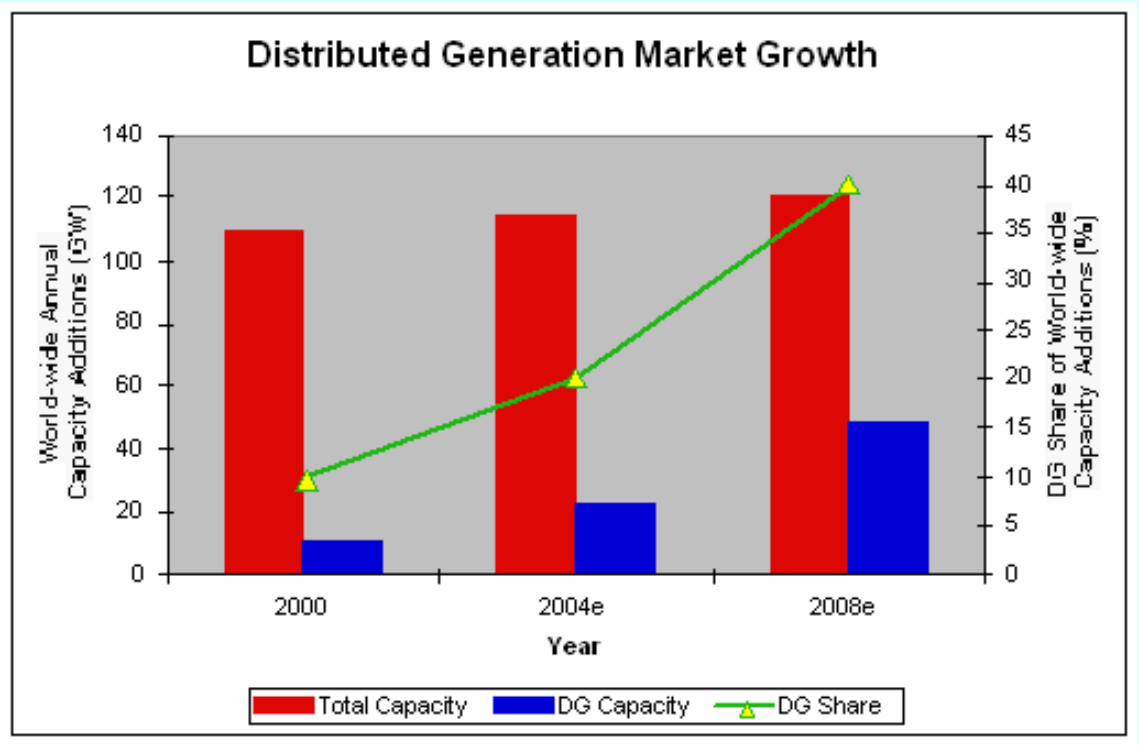
- Solar, photovoltaic or thermal
- Wind
- Geothermal
- Ocean

Non-renewable

- Internal combustion engine, ICE
- Combined cycle
- Combustion turbine
- Micro-turbines
- Fuel cell

Distributed Generation
Market growth

By the year 2010 the Distributed Generation market is expected to reach $10 - $30 billion.



Alternative Generation
Photovoltaic

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- Photovoltaics does not have the potential to displace the need for installed capacity – it may only displace energy production.

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- Installation of large wind farms, while promising, is limited by:
  - Availability of near by back-up power.
  - Availability of reactive power support.

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  Should be implemented in conjunction with large storage systems – pumped hydro?

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ISSUE: Viability of the Hydrogen economy – large scale implementation without nuclear questionable.

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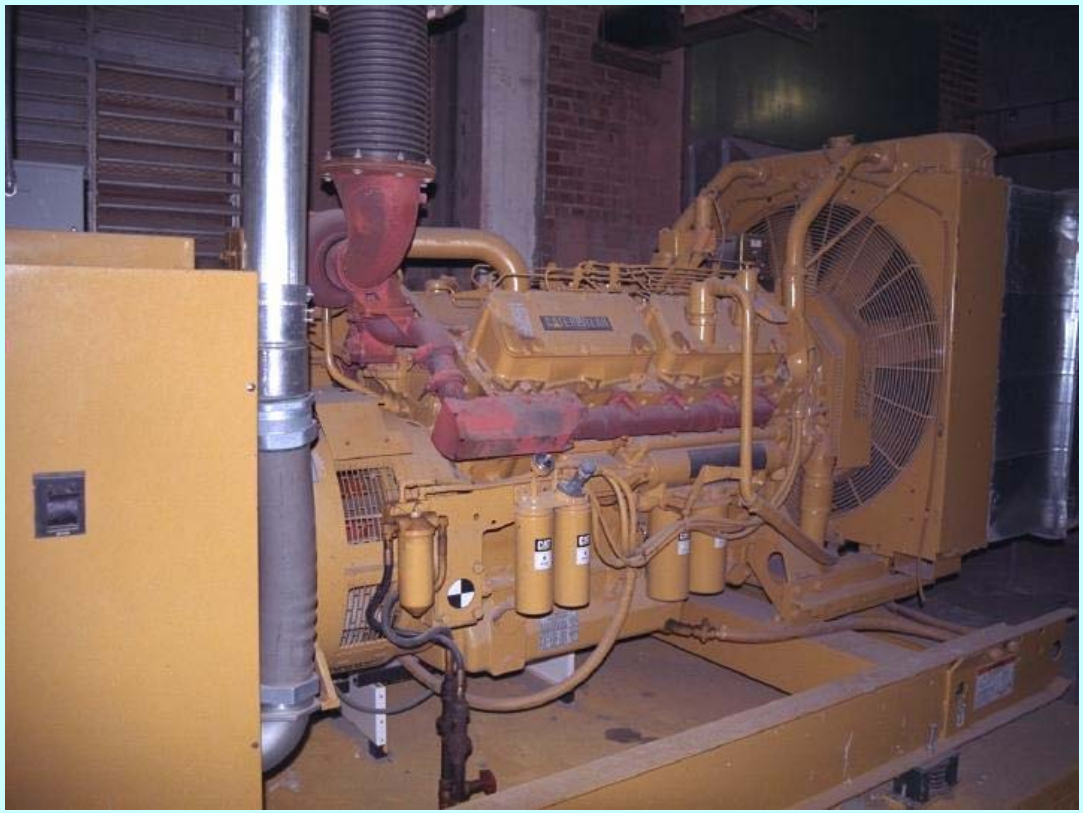
- They are overwhelmingly used for back-up purposes.
- They represent an immediate and huge impact on the need for additional peak power generation.

Alternative Generation
Internal Combustion Engine

ISSUE:

Environmental impact in terms of emissions.



550 kW ICE generator

The Energy Challenge of the 21st century

- Production
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System Integration

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R & D : Need for ultra-fast switching

Need for very high current interruption

System Integration

Technical “opportunities”

- Power quality
  - Impact of various power electronic interface devices.

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- Safety
  - Bi-directional energy flow on distribution systems

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- Power quality
- Reactive power coordination and voltage support.
- Reliability
  - Reserve margin: not all technologies will contribute to the installed capacity
  - Redundancy
- Safety
- Security
  - Protection of the T & D infrastructure against outside threats.
  - Construction of “self-healing” systems.

System Integration
Control systems

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  - As the penetration of alternative generation reaches levels where its installed capacity and/or energy production becomes significant, the need for integrated controls becomes paramount.
- Need for ubiquitous and bi-directional communications
  - Integration of “off the shelve” IT technologies.
  - This is perhaps THE biggest challenge faced by all manufacturers.
  - Security and resiliency against external threats.

System Integration

System concerns

- Asset Management
  - Maximize utilization of existing assets
  - Cost avoidance
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- Diagnostics
  - Non-intrusive and reliable diagnostics
  - Data collection, storage and sorting

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- Superconductivity
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- Conductors
  - Intelligent - variable resistance

The Energy Challenge of the 21st century

- Production
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Public Policy

"It's the economy, stupid"

Bill Clinton's campaign staff overall strategy call

Public Policy

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R & D : Need to create systematic approach to measure the financial and societal impacts of Public Policy proposals.

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- **Successful public policy setting and implementation can not be achieved without electric power engineers – again this is our opportunity to seize.**

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- **We must take the time to clearly outline the risk – benefit trade-offs of proposed exploratory research.**

Role of the Power Engineering Society

- **Fewer but broader conferences at the global level.**
  - **General – annual – meeting**
  - **T&D Conference & Exposition – every odd year**
  - **Power Systems Conference & Exposition – every even year**
- **More regional conferences – such as PowerTech & PowerCon as well as T & D Conference & Exposition.**
- **New tutorials:**
  - **Power systems for non-engineers.**
  - **Communications and business practices for engineers.**

Overall, PES seeks to be more present in YOUR professional environment

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- **They constitute a major infrastructure which is crucial for the prosperity of any country and for the well-being of any population.**
- **One of the key challenges at the dawn of our new century will be the development of energy supply systems which are safe, reliable, sustainable and economical – electric power systems already are and will remain at the core of these systems.**

Conclusions - 2

- **Major challenges must be faced and conquered:**
  - **Integration of alternative energy sources**
  - **Design of electric power delivery systems which are robust against outside actions and economic to operate**
  - **Implementation of end-use systems which are environmentally friendly and cost attractive for the world population at large.**

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- **World wide cooperation will be crucial.**
- **More than ever do we need young engineers who are actively engaged within their profession and society.**

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