Chemical Industry

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Origins

Sulfuric Acid first made in 1736

Bleach in 1799 in St Rollox (Maybe

that is where the word clorox came from)

Top 10

1 BASF
2 Dow
3 Sinopec
4 Sabic
5 Ineos
6 Formosa Plastics
7 ExxonMobil Chemical
8 LyondellBasell Industries
9 Mitsubishi Chemical
10 DuPont

Idea 1 from Basf

https://www.basf.com/global/en/topics/our-plastics-journey.html

Tiles.

Develop process and patent.

Specialization : FEM for Gutter.

Basf Major Areas

Dyes
Soda
Sulfuric acid
Ammonia

Idea 2 from Basf

Low cost and small scale ammonia.

ATRC has two methods to reduce costs.

Pressure reduction.

Cooling and Absorption

Green ammonia is feasible from the energy point of view. Ecosystem required to complete.

Idea 3 from Basf

Low cost sulfuric acid from a preprocess to compete in quantity with other suppliers.

In case high quality only is being supplied currently.

Combination

Robotics and Plastics.

Provide colored (dyes) plastic wire for 3D printing.

Different materials for different applications.

3D Printing

Metal is also printed.

Potash

Potash (especially potassium carbonate) has been used in bleaching textiles, making glass, ceramic, and making soap, since the Bronze Age.

Potash was principally obtained by leaching the ashes of land and sea plants. Beginning in the 14th century potash was mined in Ethiopia. One of the world's largest deposits, 140 to 150 million tons, is located in the Dallol area of the Afar Region.

I do not know much about this. But if y'all are interested we can maybe do some research into this area.

Engineering Plastics

A thermoplastic, or thermosoftening plastic, is a plastic polymer material that becomes pliable or moldable at a certain elevated temperature and solidifies upon cooling.

Foams : Polyurethane PUF Insulated Panels

Plastics : Polyamides

A polyamide is a polymer with repeating units linked by amide bonds.

Polyamides occur both naturally and artificially. Examples of naturally occurring polyamides are proteins, such as wool and silk. Artificially made polyamides can be made through step-growth polymerization or solid-phase synthesis yielding materials such as nylons, aramids, and sodium poly(aspartate). Synthetic polyamides are commonly used in textiles, automotive industry, carpets, kitchen utensils and sportswear due to their high durability and strength. The transportation manufacturing industry is the major consumer, accounting for 35% of polyamide (PA) consumption.

Plastics : Polyamides

Polyamide family	Main chain	Examples of polyamides	Examples of commercial products
Aliphatic polyamides	Aliphatic	Nylon PA 6 and PA 66	Zytel from DuPont, Technyl from Solvay, Rilsan and Rilsamid from Arkema, Radipol from Radici Group
Polyphthalamides	Semi-aromatic	PA 6T = hexamethylenediamine + terephthalic acid	Trogamid T from Evonik Industries, Amodel from Solvay
Aromatic polyamides, or aramids	Aromatic	Paraphenylenediamine + terephthalic acid	Kevlar and Nomex from DuPont, Teijinconex, Twaron and Technora from Teijin, Kermel from Kermel.

Kevlar

This reminds of the interleaved low cost bullet proof vests idea.

Also one way bullet proof glass.

Simple bullet proof glass.

Coke. Not the drink.

Coke is a grey, hard, and porous fuel with a high carbon content and few impurities, made by heating coal or oil in the absence of air—a destructive distillation process. It is an important industrial product, used mainly in iron ore smelting, but also as a fuel in stoves and forges when air pollution is a concern.

Coke. Not the drink.

The unqualified term "coke" usually refers to the product derived from low-ash and low-sulphur bituminous coal by a process called coking. A similar product called petroleum coke, or pet coke, is obtained from crude oil in oil refineries. Coke may also be formed naturally by geologic processes.

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Thar Coal

Lignite, often referred to as brown coal, is a soft, brown, combustible, sedimentary rock formed from naturally compressed peat. It has a carbon content around 25 to 35 percent, and is considered the lowest rank of coal due to its relatively low heat content. Lignite is mined all around the world and is used almost exclusively as a fuel for steam-electric power generation.

Thar Coal

The energy content of lignite ranges from 10 to 20 MJ/kg (9–17 million BTU per short ton) on a moist, mineral-matter-free basis. The energy content of lignite consumed in the United States averages 15 MJ/kg (13 million BTU/ton), on the as-received basis. The energy content of lignite consumed in Victoria, Australia, averages 8.6 MJ/kg (8.2 million BTU/ton) on a net wet basis.

Sindh Coal

The total coal resources of Sindh have been estimated to 184.6 billion tonnes whereas the coal deposits of Thar alone are estimated at 175.5 billion tonnes, which can ideally be utilized for power generation. In addition to Thar, the other coalfields of Sindh are at Lakhra, Sonda, Jherruck and Indus East (Map 2). The Lakhra coalfield is fully developed, and contains mineable coal reserves of 146 million tonnes. Sindh coal is classified as 'Lignite' with calorific value ranging from 5,219 to 13,555 Btu/lb. Thar coal has low sulfur and low ash content but high moisture, whereas Lakhra coal contains high sulfur. The feasibility study conducted by John T. Boyd & Co. of USA has confirmed mineability and suitability of Lakhra coal for power generation. The feasibility study of Thar coal is yet to be completed to confirm its mineability and suitability for large scale power generation. The Sonda coalfield, including Indus East, is the second largest coalfield of Sindh. The feasibility study of Sonda coal for power generation is yet to be initiated.

Coal Reserves in Million tonnes in the Four Blocks of Thar Coalfield

Blocks	Measured	Indicated	Inferred	Total
Block I	620	1,918	1,028	3,566
Block II	640	944	-	1,584
Block III	413	1,337	258	2,008
Block IV	684	1,711	76	2,471
Total:	2357	5,910	1,362	9,629

Table 2: THAR COAL QUALITY & RESERVES

Moisture (%)	29.60 – 55.50
Ash content (%)	02.90 – 11.50
Volatile Matter (%)	23.10 – 36.60
Fixed Carbon (%)	14.20 – 34.00
Sulfur (%)	00.40 – 02.90
Heating Value (Btu/lb)	
As received	6,244 – 11,045
Dry Basis	10,723 - 11,353

The quality of coal is Lignite-B to Lignite-A

10.1 WAPDA 150 MW Lakhra Coal Power Plant

As a result of the Lakhra experience, WAPDA has set-up in 1994, with Chinese Assistance, three units of 50 MW each, power plants based on Lakhra coal using FBC technology near Khanot in the Dadu District of Sindh. While operating the plant, WAPDA faced several problems such as boiler tube leakage, air pollution etc. due to supply of coal below the designed specification. At present, the plant is shut down due to running at de-rated capacity. The plant was consuming about half a million tonnes of lignite coal annually. The coal was supplied from the Lakhra mines of PMDC and LCDC on daily basis. The generation cost of the plant was Rs 2.61 per kWh, including the cost of coal and lime stone. The plant is expected to resume operations after eliminating the problems, failing which, it will be privatized through open tender.

Thar Coal

The Thar coalfield is located in the south-eastern part of Sindh. The first indication of the presence of coal beneath the sands of the Thar Desert was reported while drilling water wells by the British Overseas Development Agency (ODA) in coordination with the Sindh Arid Zone Development Authority (SAZDA), in 1991. The Thar coalfield, with a resource potential of 175.5 million tonnes of coal, covers an area of 9000 sq. km. in the Tharparkar Desert. The mineable coal reserves are estimated to be 1,620 million tonnes. The coal-bearing area is covered by stable sand dunes. In order to establish the coal resources in the selected four blocks (Map 3), a total of 167 holes were drilled at one kilometer spacing. Coal resources of the four blocks are estimated at 9,629 million tonnes, as shown below.

Thar Coal

Conclusion: CNCDC and its partner Oracle Power PLC are pushing forward the Integrated Coal-electricity Project in Thar Block VI, Pakistan. CNCDC hopes to establish a cooperative relationship with the Ministry for Energy Government of Sindh and CPEC of Pakistan to provide overall planning services for coal development in Thar area of Pakistan, including but not limited to coal mining, coal power and coal chemical integration project development, coal mine groundwater resource treatment and utilization, etc. Due to the impact of the global COVID-19, the project is progressing slowly. However, the business team and professional technical team of China Coal Group are ready to go to Pakistan for business negotiation and technical research whenever possible.

Process

5.2 GE Energy

GE Energy acquired its gasification technology from Chevron in 2004, and has units operating commercially worldwide using a wide variety of feedstocks such as natural gas, heavy oil, coal and petcoke. The GE coal gasifier comprises a single-stage, downward-feed, entrained-flow refractory-lined reactor to produce syngas. Coal/water slurry (~ 60% in weight for Chinese applications) is pumped into the top of the gasifier, which together with oxygen is introduced through a single burner, Figure 17. The coal reacts exothermically with the oxygen at high temperature (1200–1480 °C) to form syngas, which contains mostly H_2 and CO, and slag (NETL, 2013b). The latter flows downwards, is quenched and then removed from the bottom of the gasifier via a lock-hopper arrangement. The water leaving the lock-hopper is separated from the slag and sent to a scrubbing unit after which it can be recycled for slurry preparation.

Now back to chemicals

Areas of potential for Karachi and Pakistan and the world.

Water treatment.

Oilgae

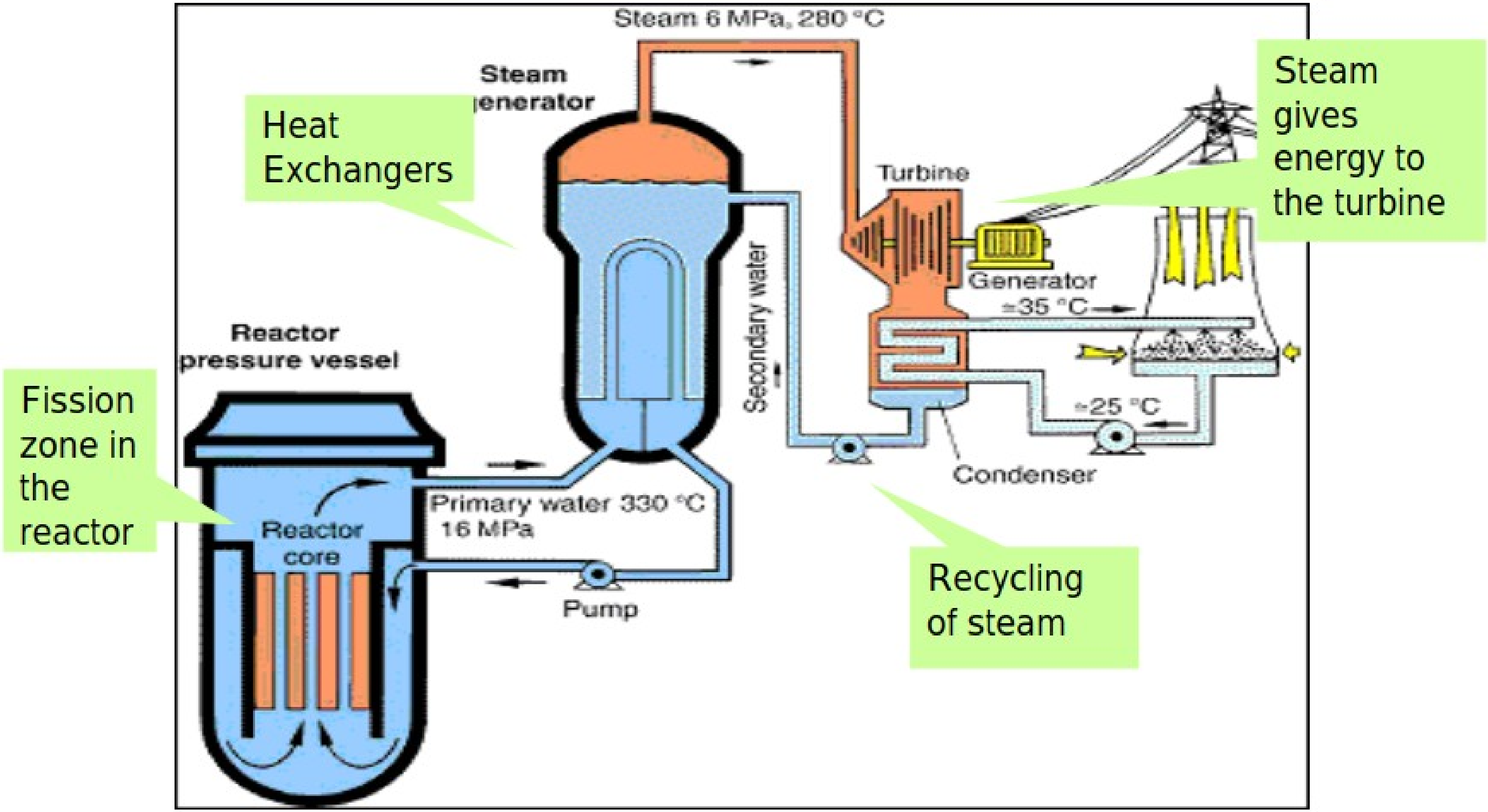
Biodiesel

Synthetic Petrol and diesel from solar energy.

Materials for nuclear.

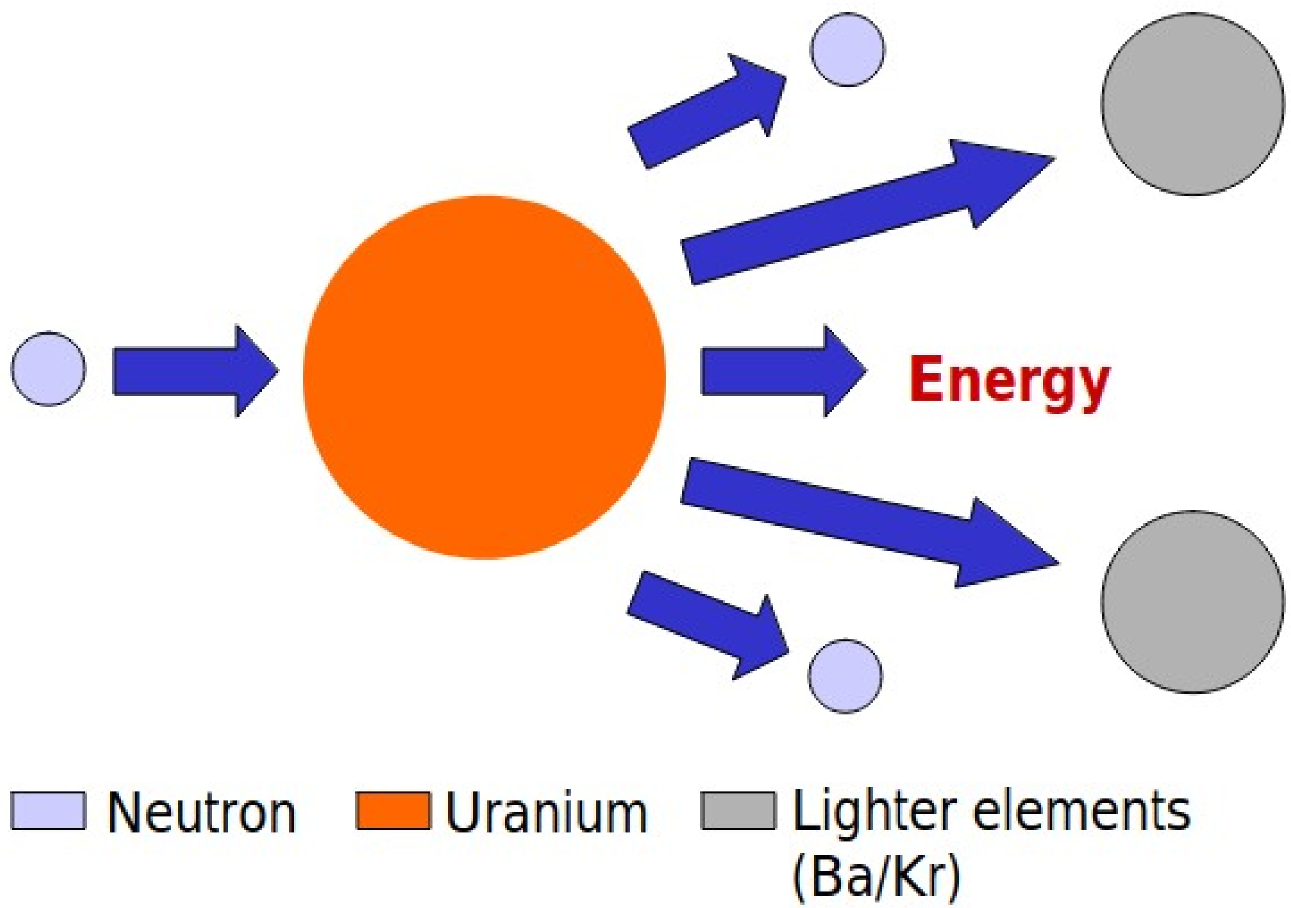
Next Generation Nuclear plant design will require significant Chemical Engineering Knowledge

Production of Nuclear Energy in a Pressurized Water Reactor[1]



… Particularly in recycling of Spent Fuel

Challenges in Nuclear Fission[1,2]



The lighter elements in **Spent Fuel** are radioactive
Need new forms reuse of fuel and chemical treatment processes before disposal

Nuclear

Our current spent fuel is stored in steel drums on the ground.

But we ain’t worried about that. Should we ?

Nuclear Better

There was a good reactor idea which was closed due to politics.

It was a complete cycle and can be dug up from our old research.

Nuclear Future

The next levels in nuclear are as follows :

3.5 Gen in progress.

4th Gen in semi implementation.

SMR

LFTR

Unconventional energy. (>1 multiplier)

Really unconventional (>0 generation)

Storage methods.

Nuclear

This is the future.

Some chemistry and methods are used to separate the different elements.
If people are too scared of politics, we shall not discuss this further.

Methane Hydrate processing.

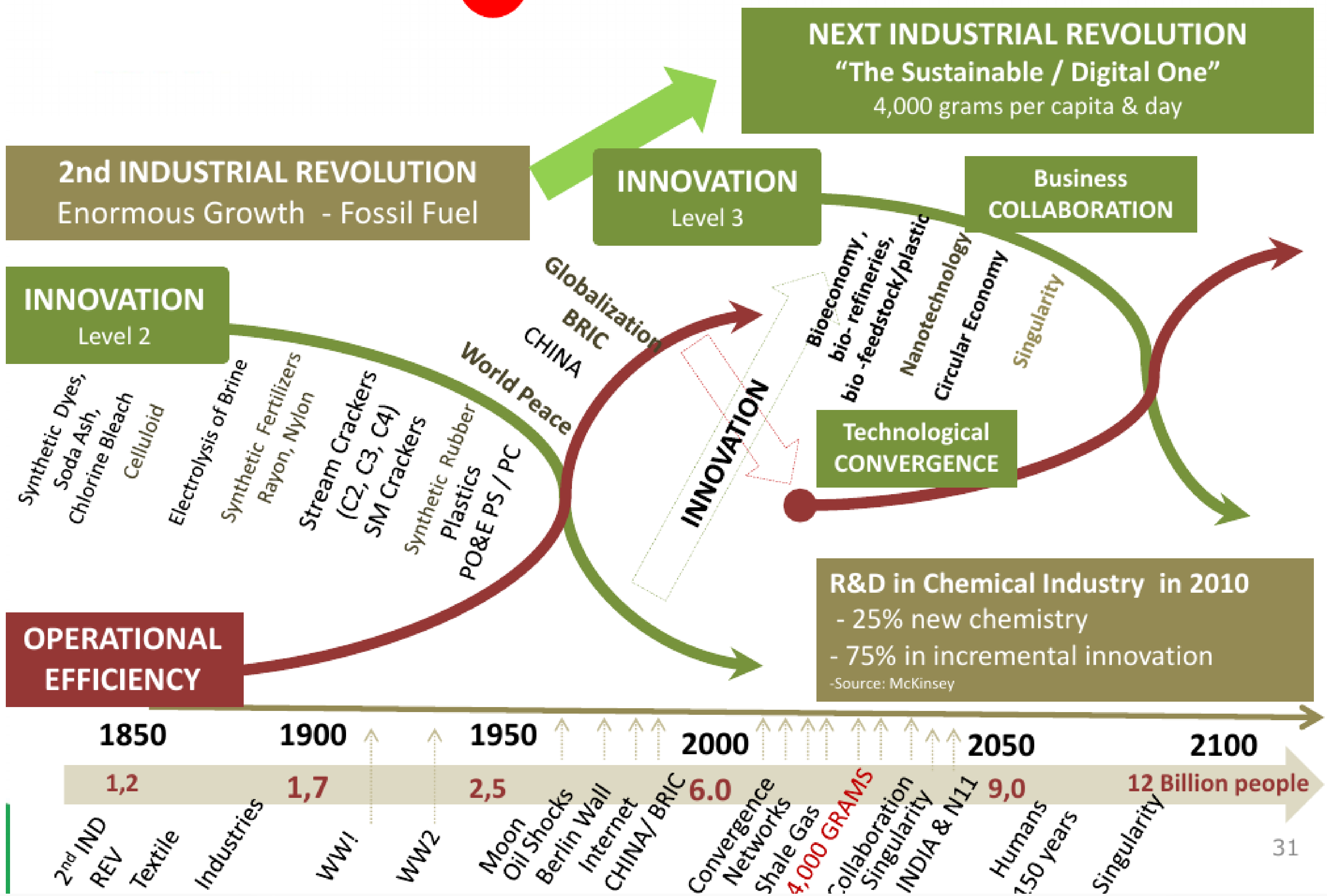
Level 4 extraction chemicals for oil.

Conversion of Naptha idea from Nigeria.

5

INNOVATION – Technology

THE 3rd INDUSTRIAL REVOLUTION

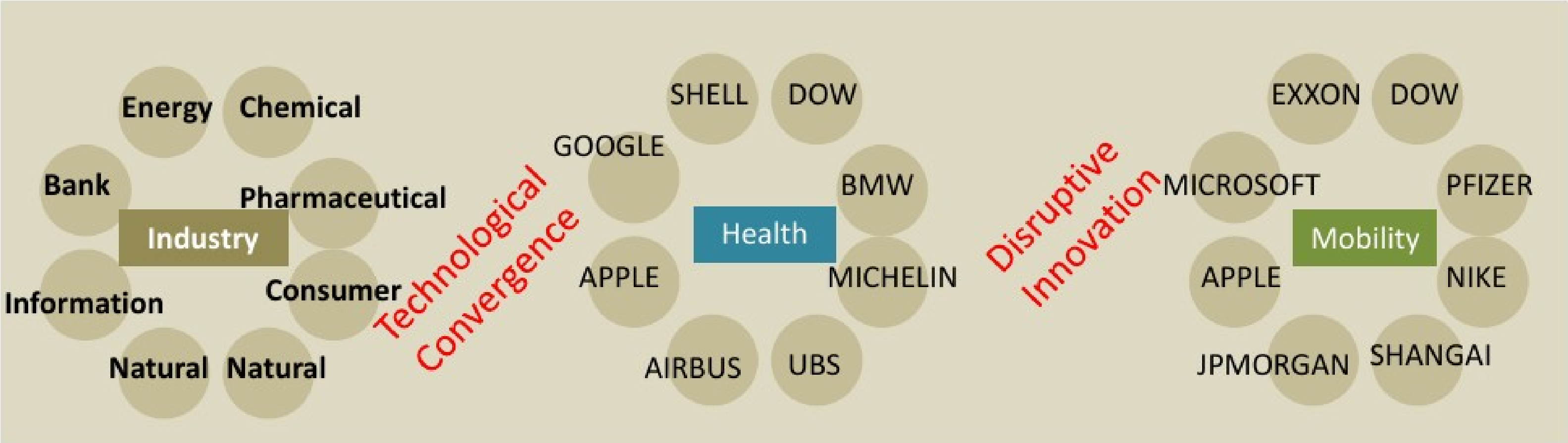


5

INNOVATION – Technology

THE 3rd INDUSTRIAL REVOLUTION

- **Circular Economy, Technological Convergence and Collaboration** will be at the core of the next industrial revolution.
- **This require new biz models, new skills** (employees/leaders), regulatory systems (IP protection, patents, antitrust) and technological frameworks.



- **Companies will be valued by the innovation pipeline of its value chain;** not only by their own innovation, financials or R&D pipeline.

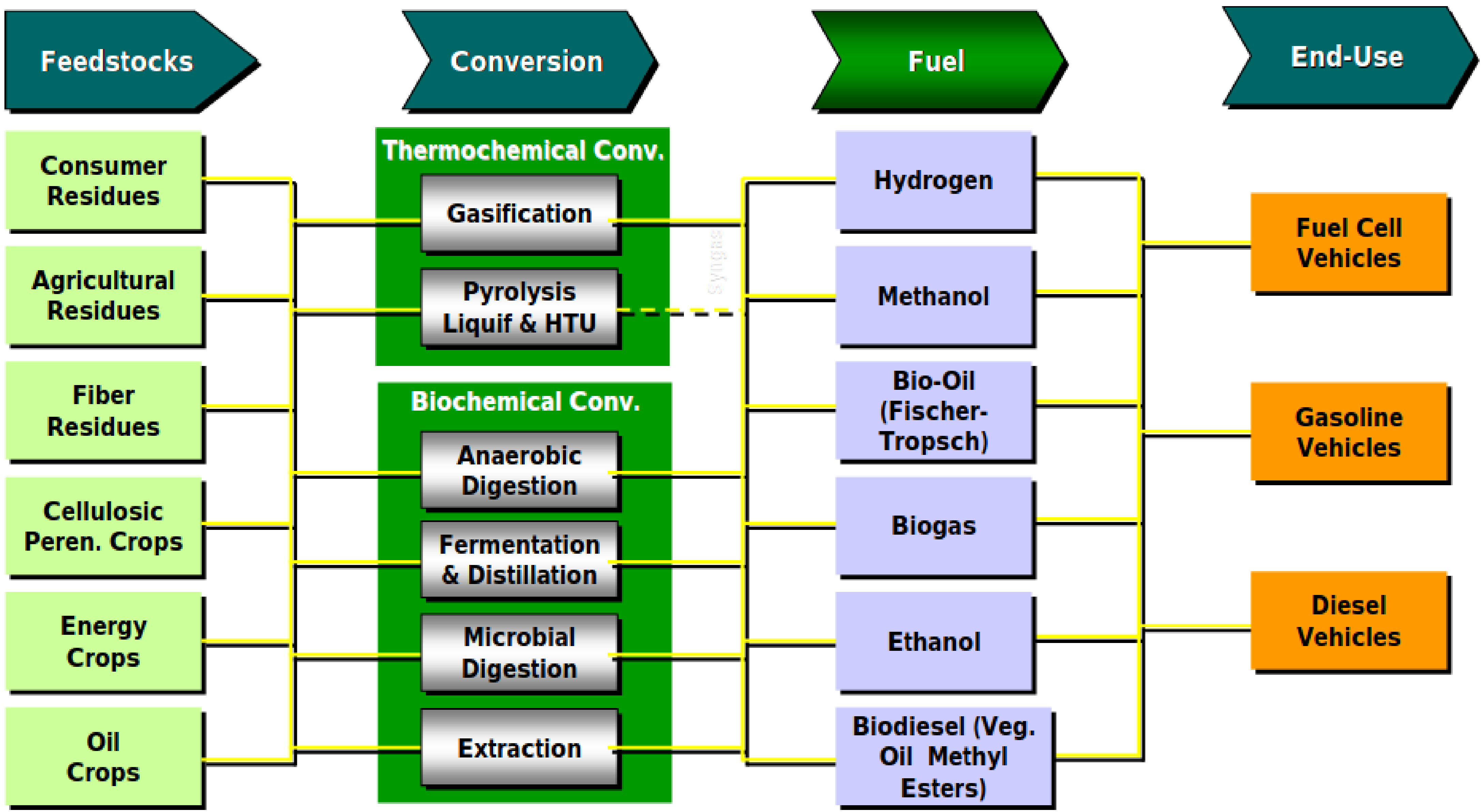
- **Innovation will become disruptive** and exponential rather than incremental (Singularity)

For Example: *An Agro Complex*?

Resource	Industry	Critical Issues
Cereal Crops, Fruits, Tea, Vegetables, Aqua Products	Food and Beverage	• Increase in yield (kg / hectare) • Quality and consistency? • Distribution system? • Down stream value addition and branding?
Cotton, Silk, Jute	Fiber, Fabric and Fashion	• Cost Effectiveness? • Quality consistency? • Familiarity with fashion trends? • New application on development?
Bio-mass, Wind Farming, Seed Oils, Starches	Energy	• Knowledge sharing • Low cost equipment development? • Promotional activities?
Specialty Chemical Industry		
Herbs, Medical Plants, Algae / Azola	Pharmaceuticals and Ayurvedics	• Awareness building? • Involvement of university professionals? • Incentives for corporate sector? • Venture funds "bottom up" development?
Algae / Azola, Vegetable Oil, Flowers	Perfume Personal Care	(as above)

Resource	Industry	Critical Issues
Chemical Industry		
Vegetables, Flowers, Algae	Dyes and Pigments	• Knowledge sharing and awareness building? • Development of low cost process equipment and controls? • Storage and distribution system? • Economics of scale and cost competitiveness?
Natural Rubber, Starch, Lignins	Polymers and Epoxy Glues	(as above)
Alcohol, Starches	Solvent and Chemicals	(as above)
Jute Stick Board, Chip Board, Renewable Wood	Furniture / Constrn.	• Knowledge sharing application development? • Machinery development for rural use? • Development of hot stamping technology?
Sugar Cane, Straw, Jute, Waste Woof Pulp	Paper, Paper Board and Packaging	• Knowledge Sharing and application? • Low cost machinery development? • Incentives for corporate sector?
Rapeseed, Lequerella, Castor Seed	Oil and Lubricants	• Promotion of new application based on agro? • Availability of venture funds? • Creation of down stream pillars?

Development and fine tuning of Biofuels Technologies could open up new vistas



Cellulosic ethanol is on the horizon

Process	Description	Pilot plants
Fermentation	Conventional ethanol from sugars (corn, sugarcane) are marginally energy positive. 100-110 gal/ton	2% of U.S. gasoline demand currently comes from ethanol made this way from 7% of corn
Acid hydrolysis	Strong acids are used to break down cellulose into sugars.	Commercial plants in operation. Used mainly in niche markets for waste disposal.
Thermal gasification	High temperatures convert biomass into synthesis gas of carbon oxides and hydrogen. In the presence of a catalyst, these gases are converted to ethanol.	Arkansas and Colorado
Enzymatic reduction	Enzymes turn woody biomass into sugars.	Ontario

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Biomass Energy development will require a full range of conventional Chemical Technologies

Different Technologies to Harness Biomass Energy[1,2]

Biomass Combustion	Combustion of biomass to produce electricity
Biomass Gasification	Gasification is meant to convert solid carbon fuels into gaseous fuels
Biomass Carbonization	Carbonization converts biomass into biofuels / biocarbons (charcoal and carbonized charcoal)
Biomass Densification	Biomass densification converts the loose biomass (agricultural and agro – industrial wastes) into a densified fuel called briquettes
Biogas Production	Biogas production involves the fermentation of cowdung, crop residue and kitchen waste in the absence of oxygen to produce biogas (mainly CH_4, CO_2 and other gases)

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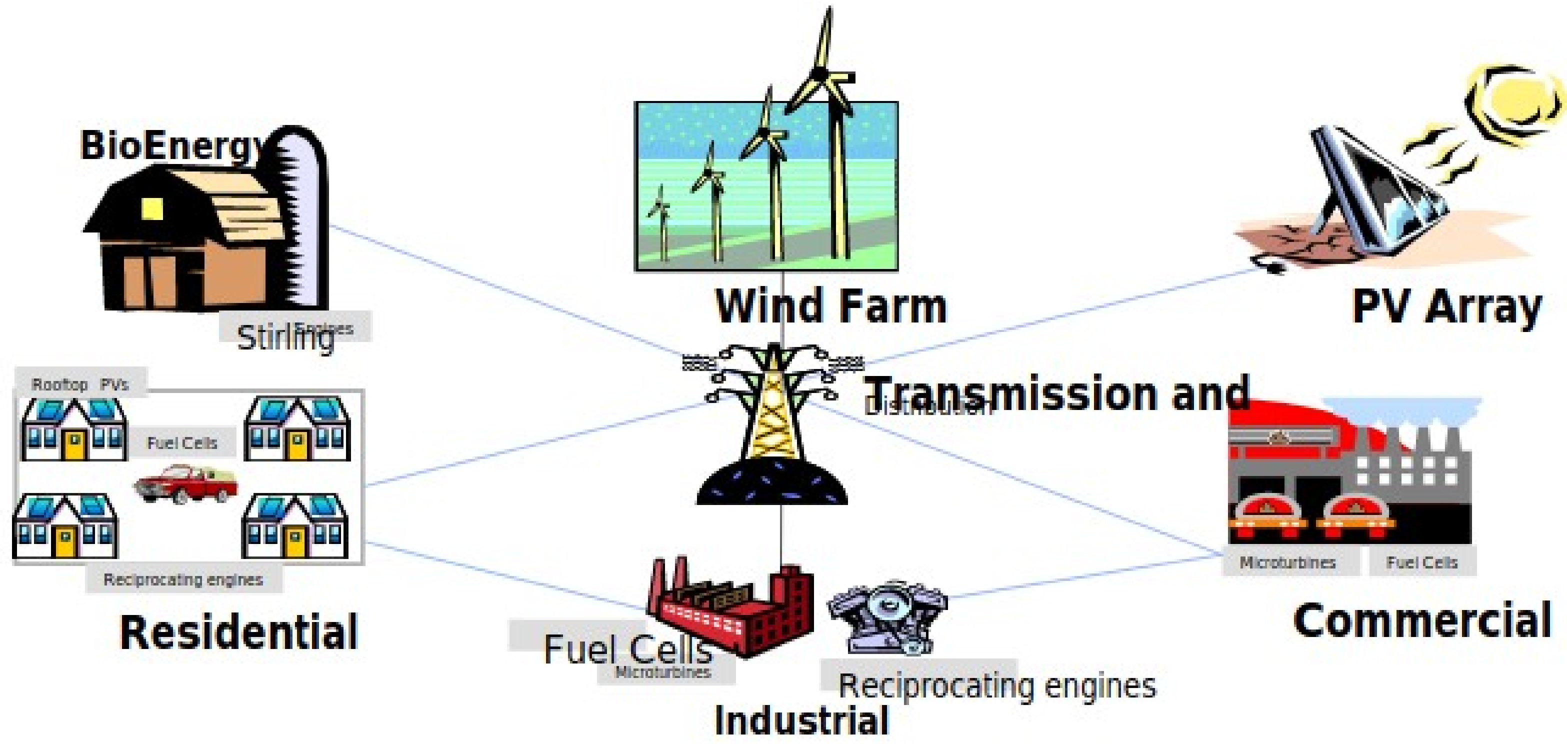
Power & Energy: *Large Scale Engineering systems thinking is essential*



The Virtual Power Plant

- *Aggregates the output of thousands of micropower technologies*
- *Peak shaving becomes power trading on the wholesale market*
- *Coordination and control through a new communications infrastructure*

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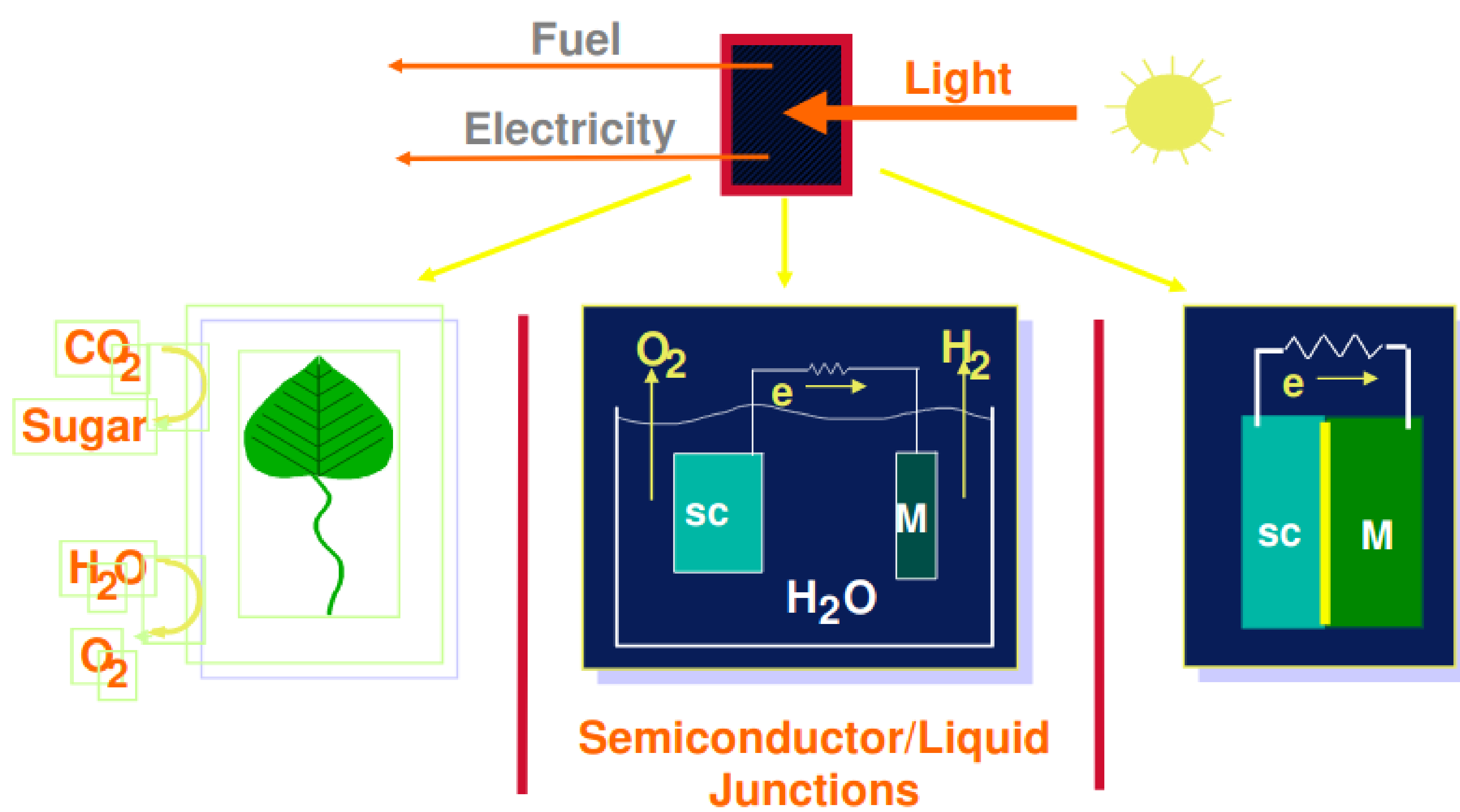
Solar Energy has the potential to address our growing energy needs in an environmentally-friendly way

Basic Mechanisms of Solar Energy Conversion[1]



Boston Analytics Research

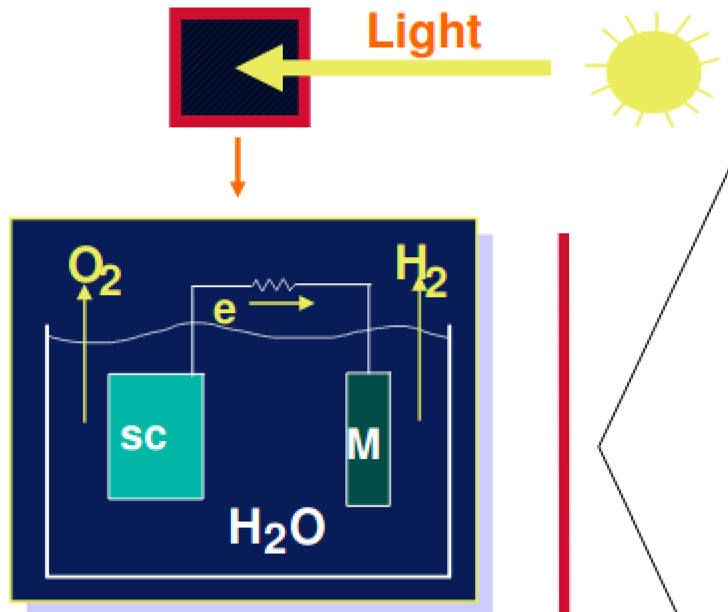
1."Global Energy Perspective", Nathan S. Lewis, California Institute of Technology, Pasadena, CA

Poor efficiency and intricate material processing techniques are major issues with the solar cell

Major Issues with a Photovoltaic (PV) Cell [1,2,3]

Photovoltaic (PV) cells provide efficiencies as low as 25%

Require: New electrolytes and catalysts to improve efficiency of the PV cell



Semiconductor/Liquid Junctions/Photovoltaic

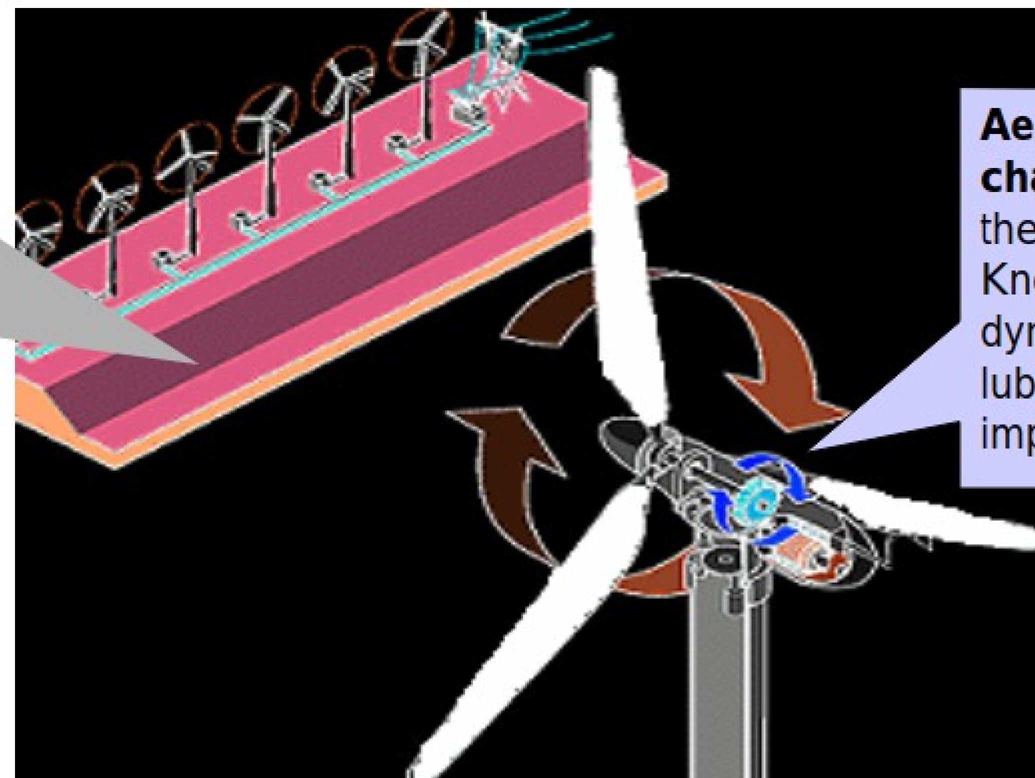
Polycrystalline Si technology in semiconductors is relatively complex.

Flat Plate Si crystalline is better but yet significant development will be required

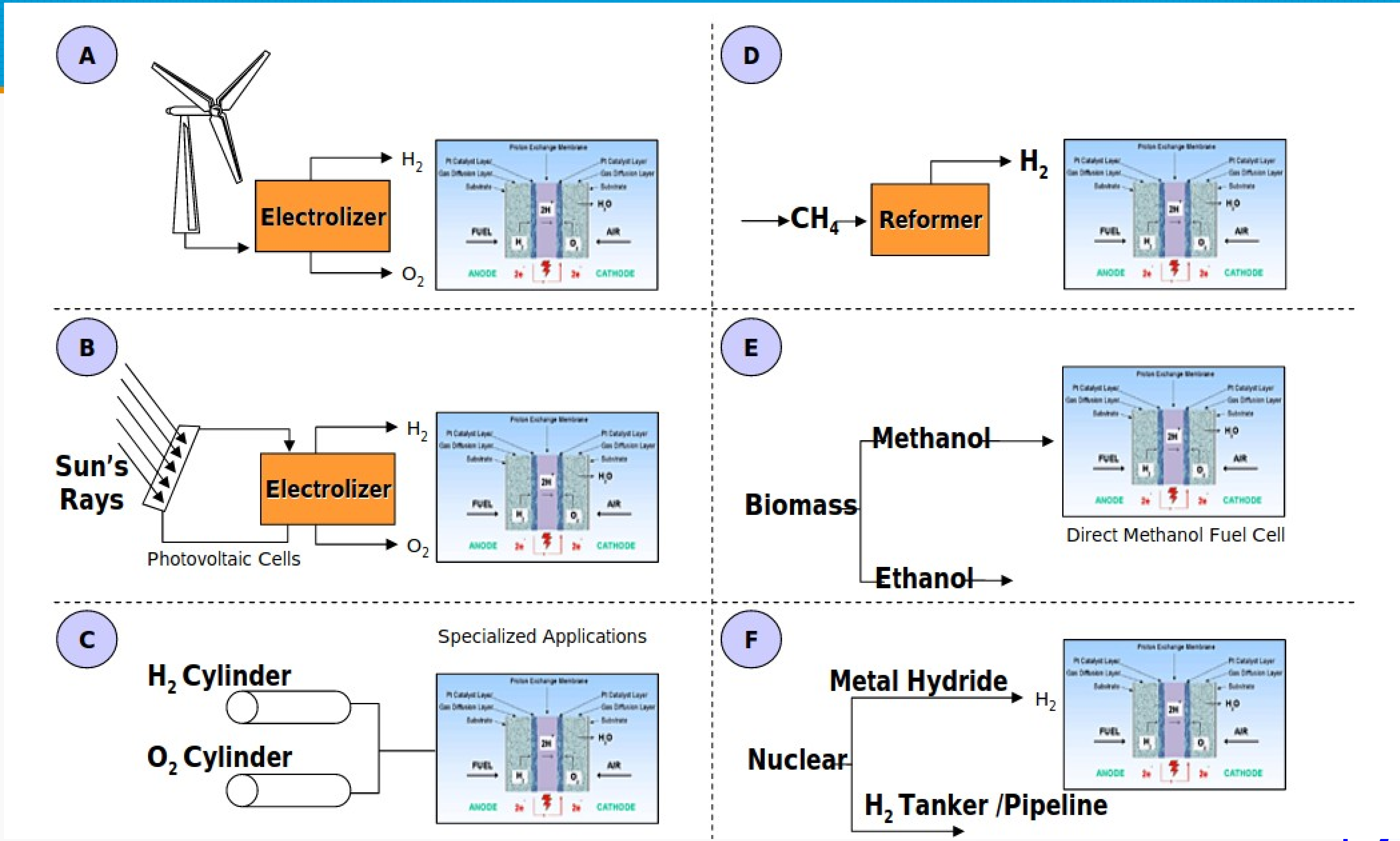
Reducing cost of production of electricity by wind turbines could be a significant challenge

Challenges in Using Wind as a Source of Power[1,2,3,4]

Varying wind supply require **innovative storage solutions**

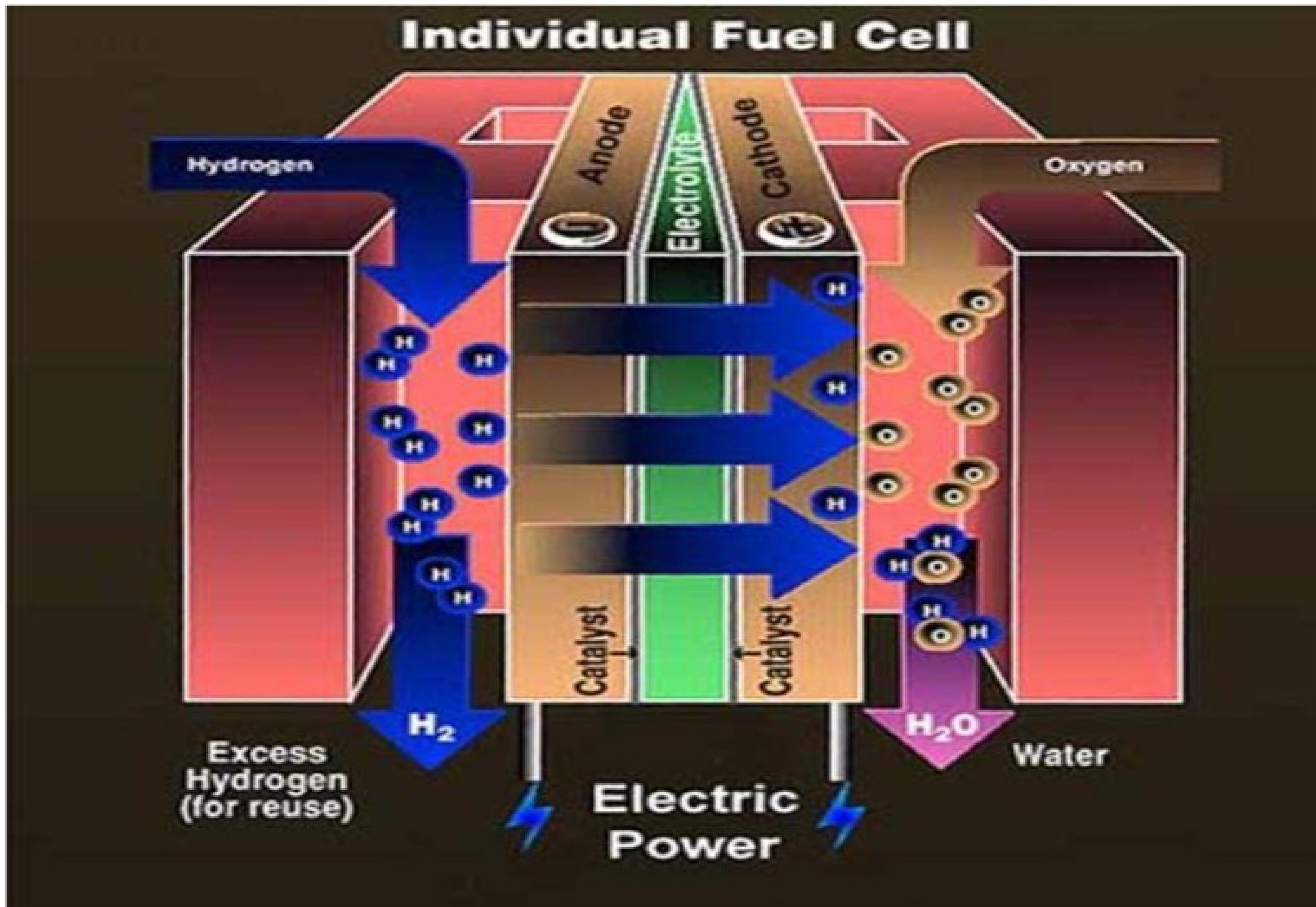


Aerodynamic characteristics of the blade: Knowledge of fluid dynamics and lubrication to improve efficiencies


A
Electrolizer
H_2
O_2
D
CH_4
Reformer
H_2
B
Sun's Rays
Electrolizer
H_2
O_2
Photovoltaic Cells
E
Methanol
Biomass
Ethanol
Direct Methanol Fuel Cell
C
Specialized Applications
H_2 Cylinder
O_2 Cylinder
F
Metal Hydride
H_2
Nuclear
H_2 Tanker /Pipeline

Fuel Cells works by converting chemical energy to electrical energy **On Demand**

Basic Mechanism of a Fuel Cell[1]

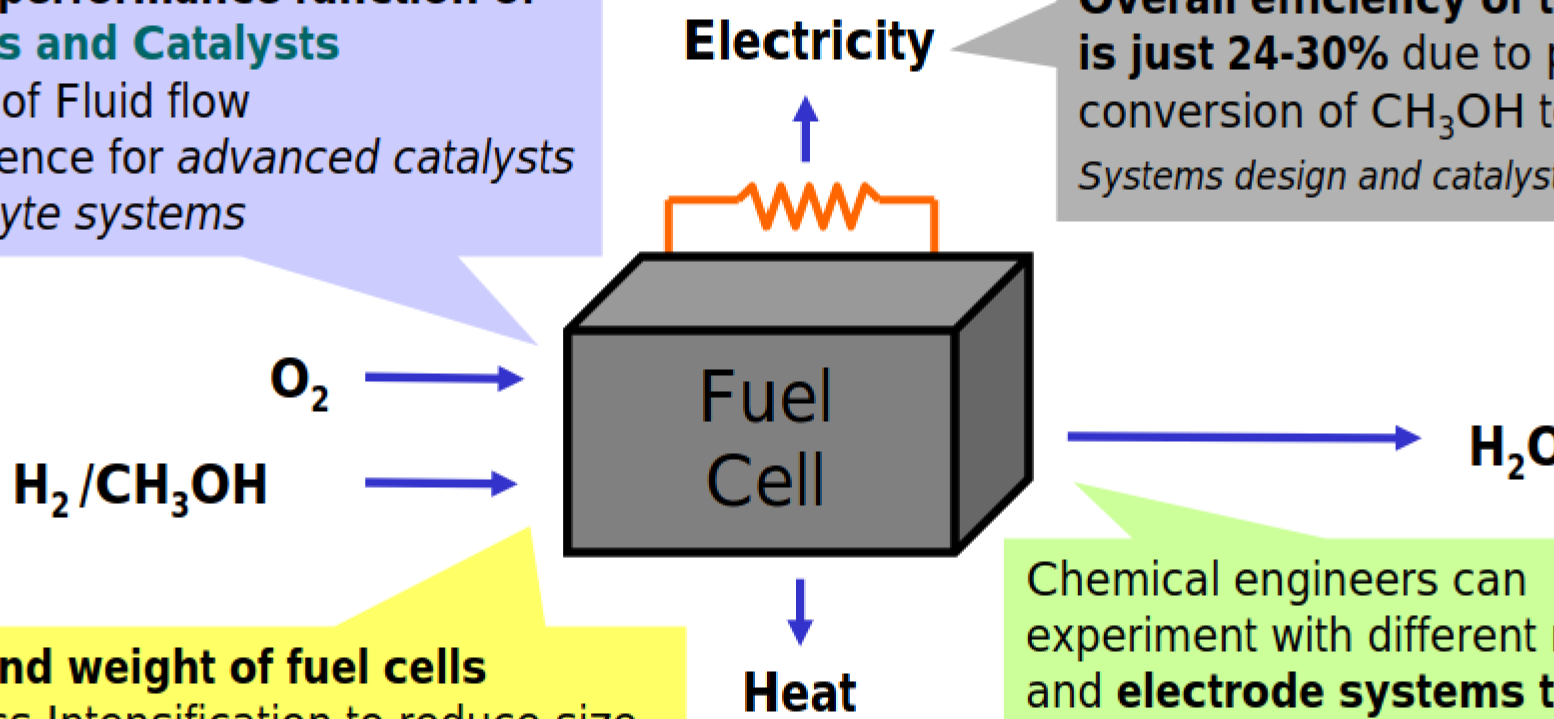


Fuel Cells have been around since the 19th century:
Could we take on the Challenge of commercialization ?

Major Challenges in Using a Fuel Cell[1,2,3]

Fuel cell's performance function of
Electrolytes and Catalysts
Knowledge of Fluid flow
Material science for *advanced catalysts and electrolyte systems*

Overall efficiency of the cell is just 24-30% due to poor conversion of CH_3OH to H_2
Systems design and catalysts



Size and weight of fuel cells
Process Intensification to reduce size and weight of cell

Chemical engineers can experiment with different materials and **electrode systems to come up with cost-effective solutions**

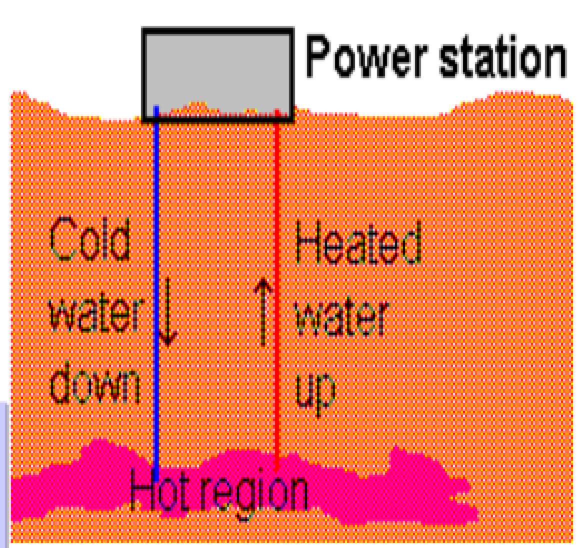
Heat Mining: Health & safety concerns due to materials ejecting from the Earth are issues that will need attention

Challenges in Harnessing Geothermal Energy[1,2,3,4]

The steam coming out needs to be purified before it drives the turbine
Chemical engineers can design a steam purification plant

Injection well → **Injecting water** → **Hydro fracture** → **Doublet**

Many-a-times, hazardous gases and minerals may be released during heat extraction
Engineers can develop a safety systems by which the toxic substances would not harm the surroundings – just like SHE mechanisms are evolved for chemical plants

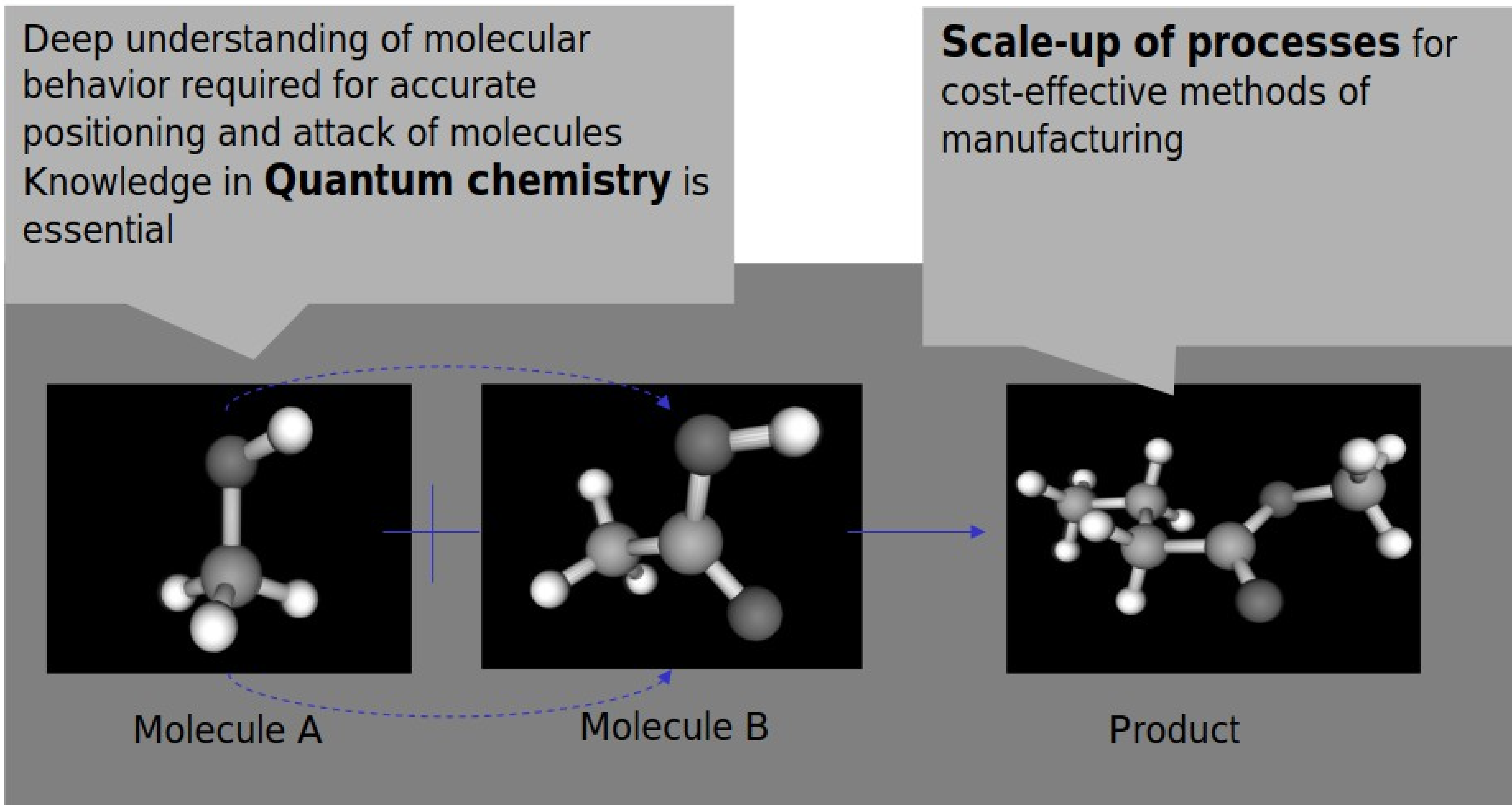


Heat mining

This reminds me of fracking.

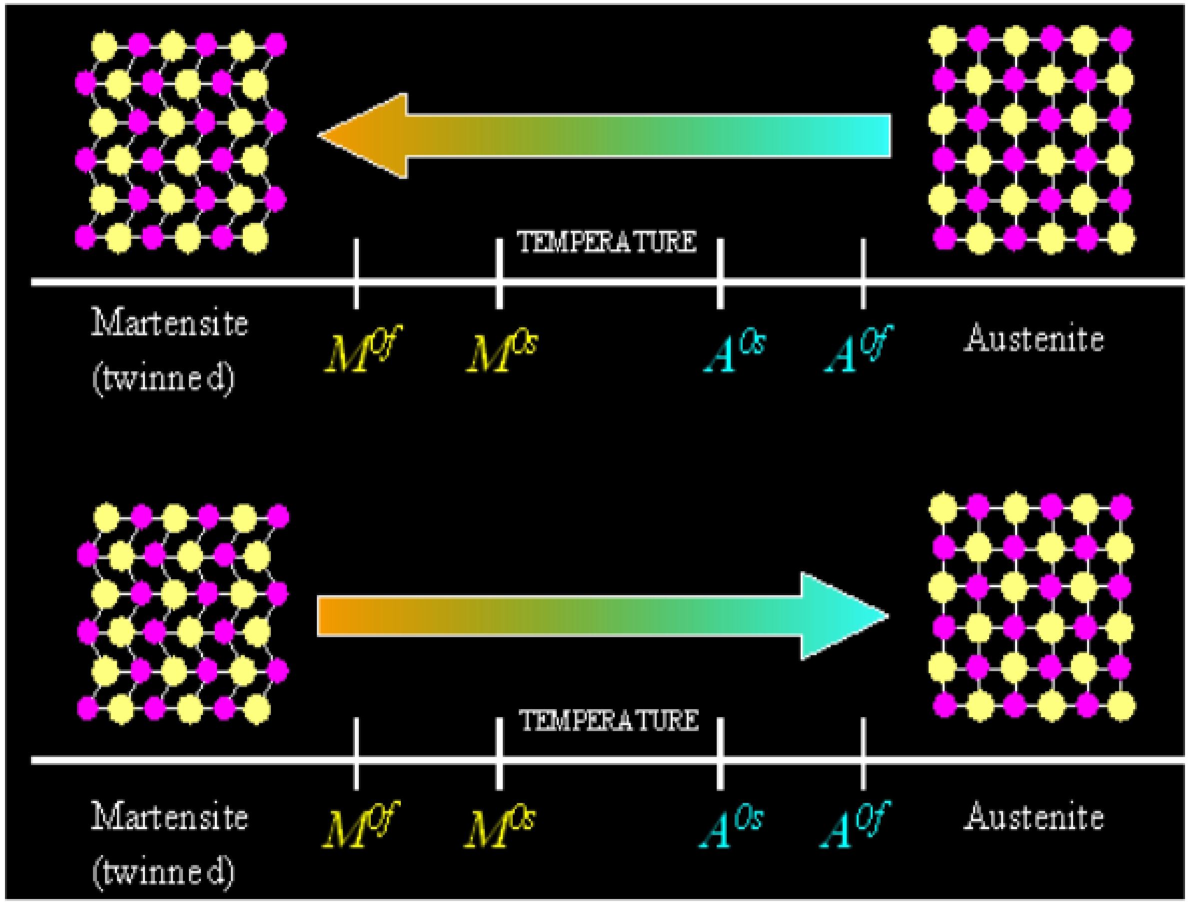
An Opportunity in search of Creativity: Nano manufacturing will need committed work

Challenges of Nano-Manufacturing[1,2,3]



Shape Memory Alloys (SMAs) are materials that can recover from strain when they are heated above a certain temperature

Basic Mechanism of SMAs[1]



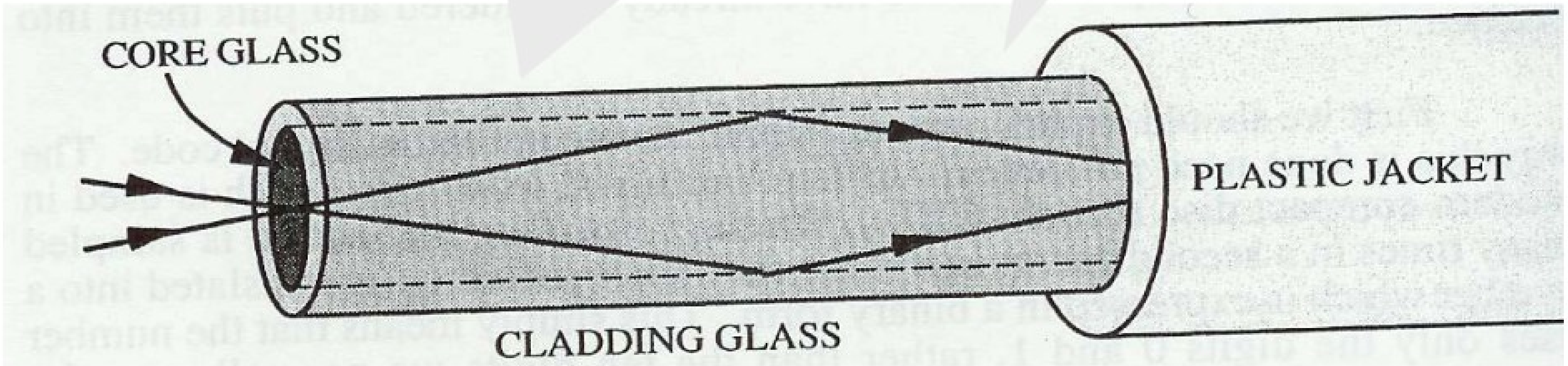
- The SMAs have two phases - the high-temperature phase, **austenite** (hard, inelastic, simple FCC structure) and the low-temperature phase, **martensite** (soft, elastic, complex structure). **Transformation between these two phases** at different temperatures leads to shape memory
- Example: NiTiNol, CuZnAl etc.

Current Research is directed towards improving the data quality and biodegradability of optical fibers

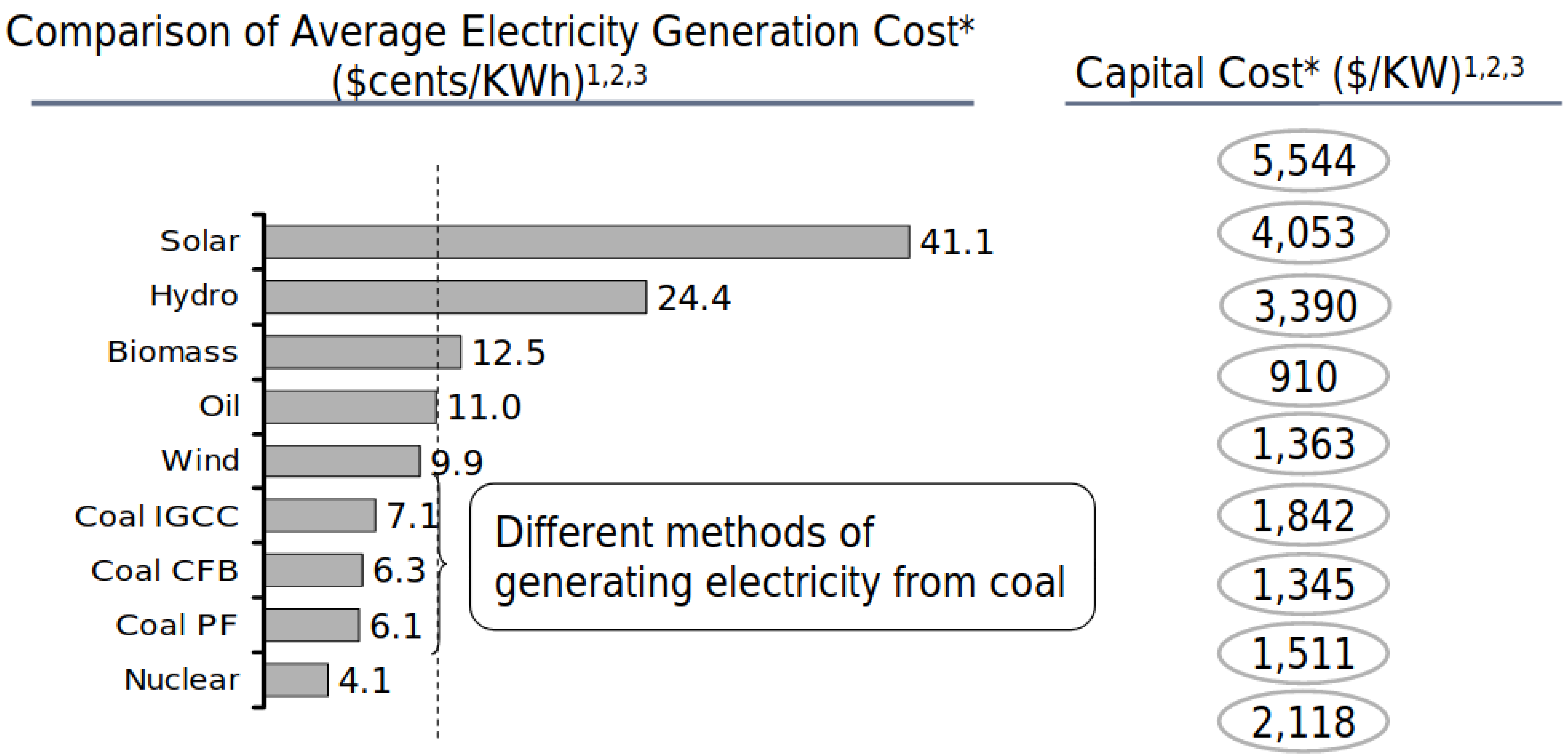
Issues in Transmission[1,2,3]

Research is on to enhance the size and quality of data transfer through a fiber
For example tiny **drops of fluid** inside the fiber in order to improve the flow of data carrying photons resulting in fast transmission and improvement in quality

Improve over systems functionalities of fibers and biodegradability

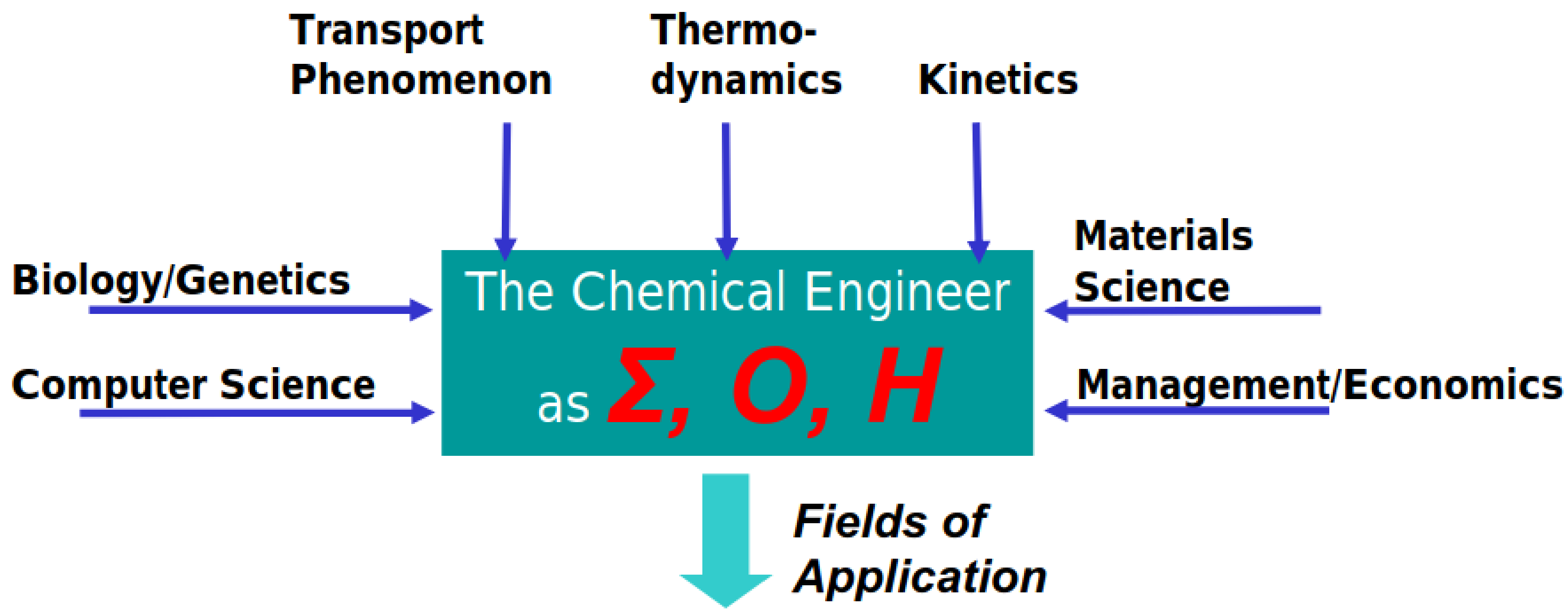


As micro technologies develop macro systems solutions will become more affordable



Note : *These are only indicative figures. Actually, electricity generation cost varies across different territories as per the environmental and technological scenario.

The Chemical Engineer is a multi-disciplinary engineer a Strategic Problem Solver



Design Engineering, Plant Operations, Process Optimization, Engineering balance of Living Systems, Energy Engineering, Material Research, Environmental Engineering, Biotech, Safety Engineering, Nano Engineering

The Essential Points:

1. Indeed Challenging & Interesting times ahead
2. The Process Industry will become more dominant & will be the driver
3. The 2st Century Chemical Engineer
4. **A Vision of the Future**

The New horizons…

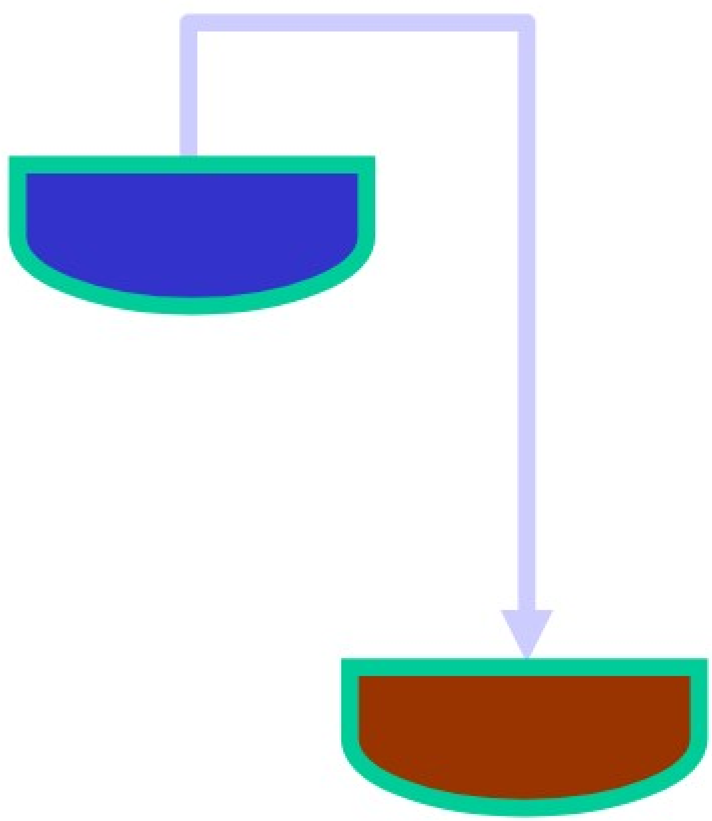
Frontier Areas	Brief Description
Alternative Energy	Ecology friendly, Sustainable and Safe Energy for all
Nano-Manufacturing	Taking a bottom-up approach to manufacturing mechanisms at nanoscale to yield products of high quality with zero wastage
Novel Materials	Efficiency of Usage of Materials e.g. Shape memory alloys, new fibers etc.

... beyond current framework of plant design and engineering

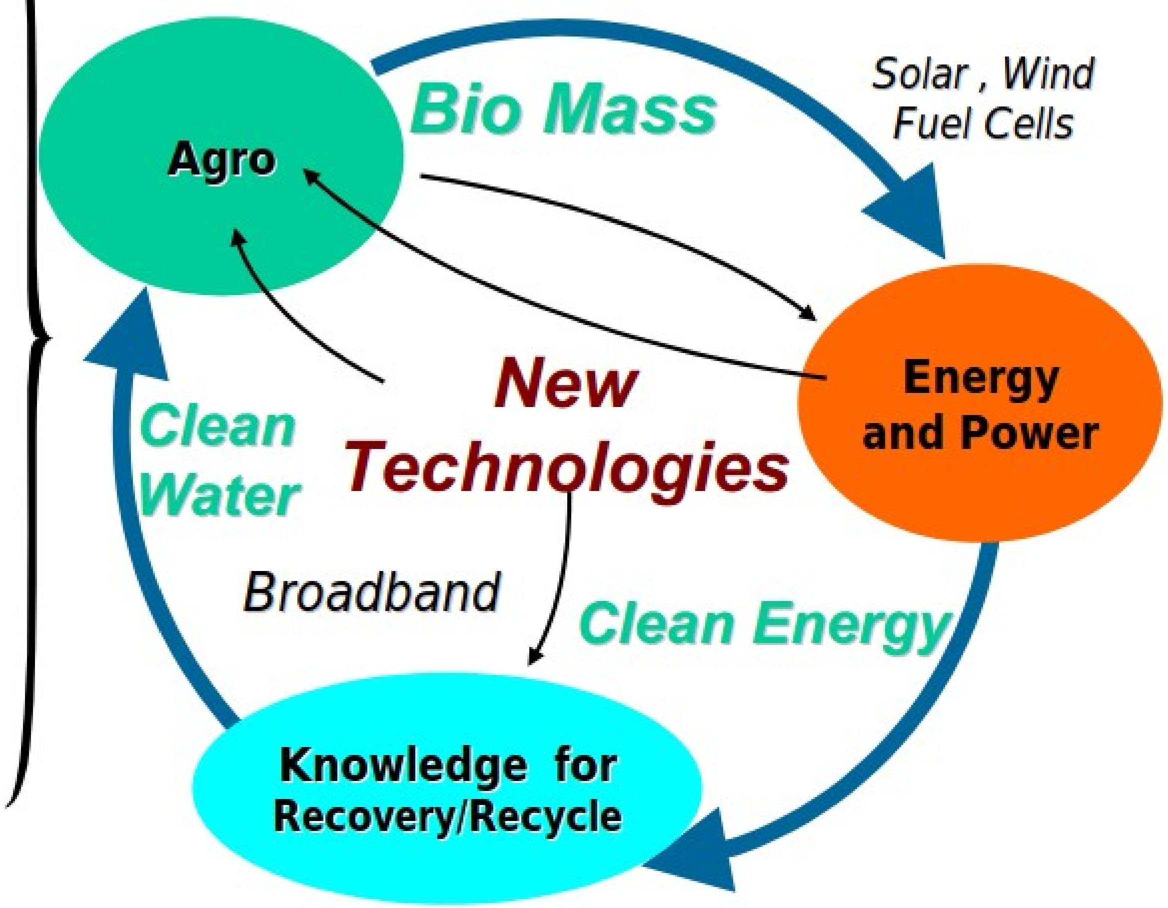
Frontier Areas	Brief Description
Biocatalysis	Microorganisms and enzymes to catalyze reactions such as polymerization – without any harmful or toxic releases and at normal conditions
Genetic Reforestation	Production of healthier and fast-growing trees using principles of genetics and biotechnology
Waste Recycling	Making optimum use of recycling to productively utilize waste materials

Last 5,000 Years... .....Future Possibilities..

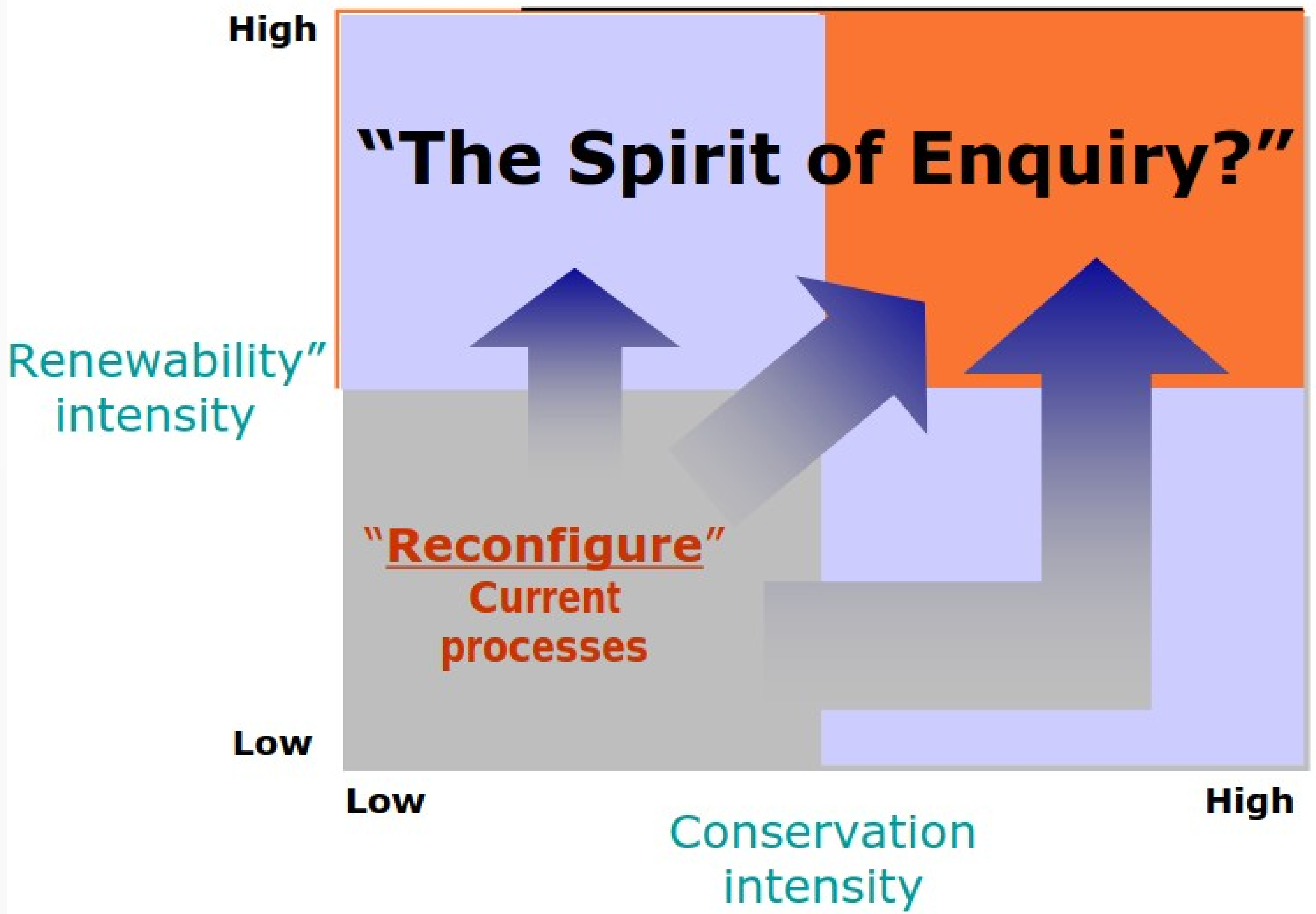
Economics of Linear Mechanics: *Extraction, Exploitation & Experimentation*



Economics of Closed Loop Harmony



.. Chemical Engineering Education & Industry has to ***Rekindle the Sprit of Enquiry***



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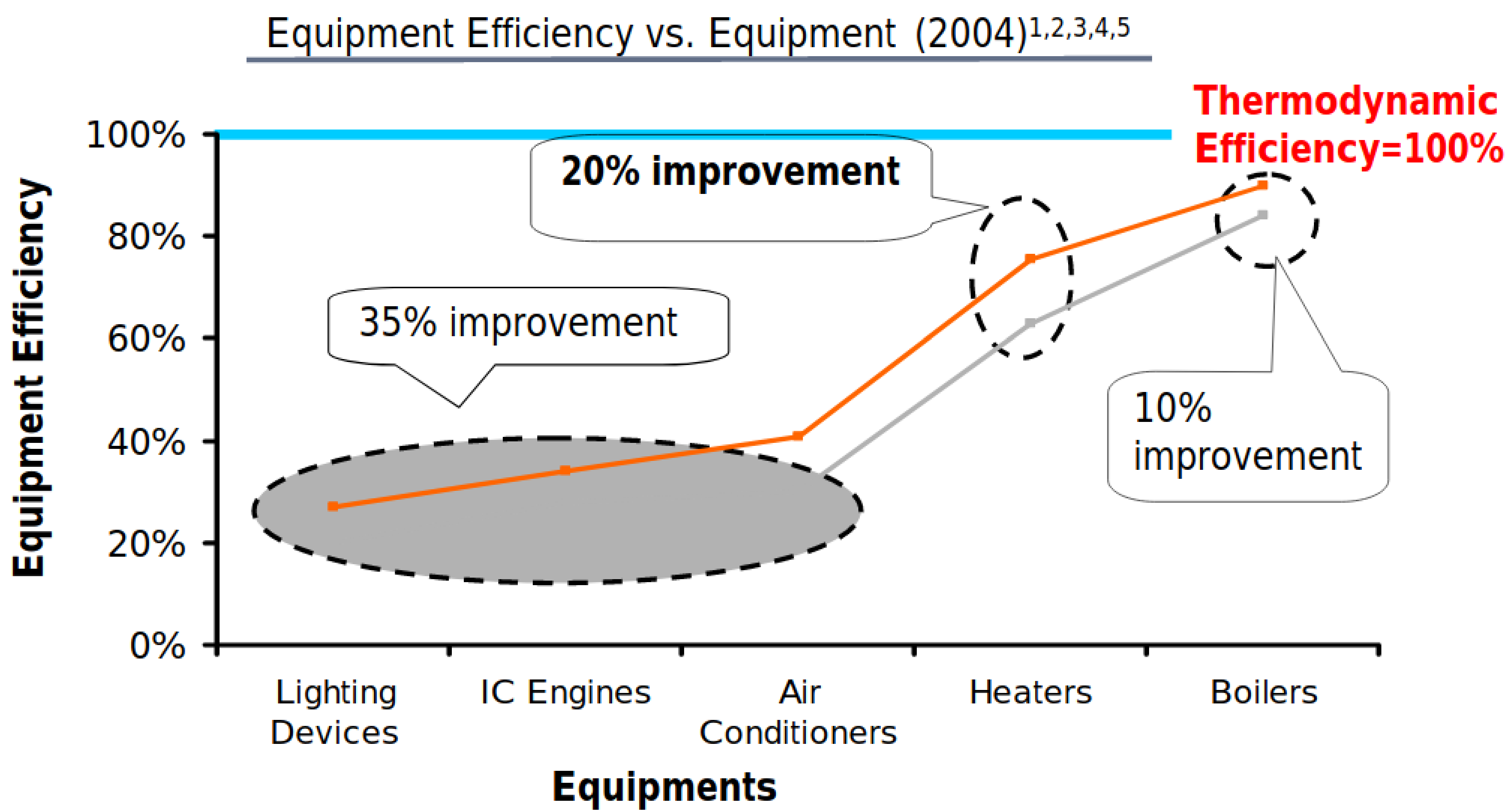
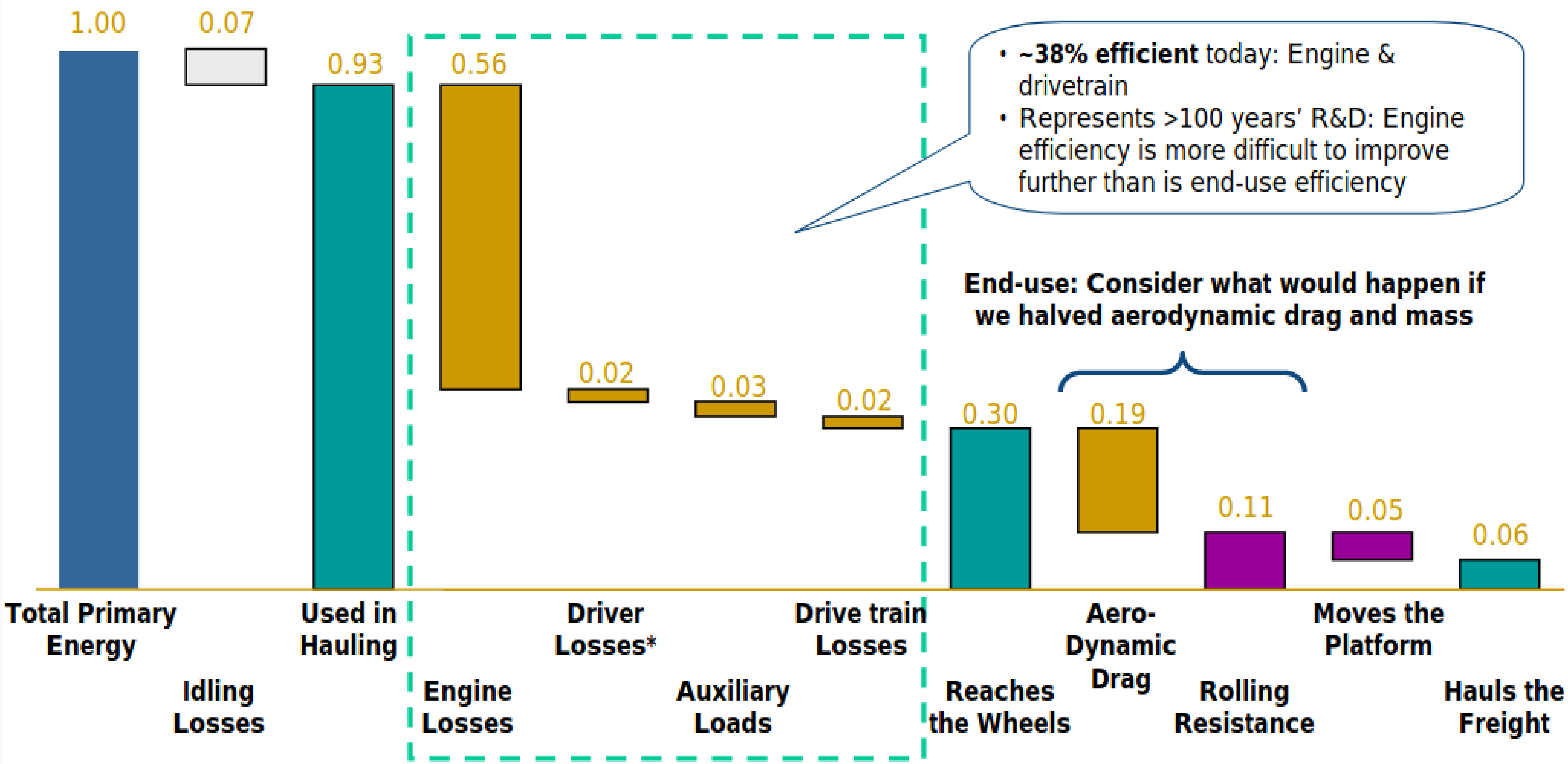
Equipment efficiency?



Where a long-haul Class 8 truck's diesel fuel goes ?

Focus: End of Chain [Fuel] → [Engine] → [Drivetrain] → [Tractive Loads]



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Source: Technology Roadmap for the 21st Century Truck Program (DOE 2000), RMI analysis

For questions and comments. Please email to khawar@atrc.net.pk