



FUTURE POWER SYSTEMS: CHALLENGES AND SOLUTIONS

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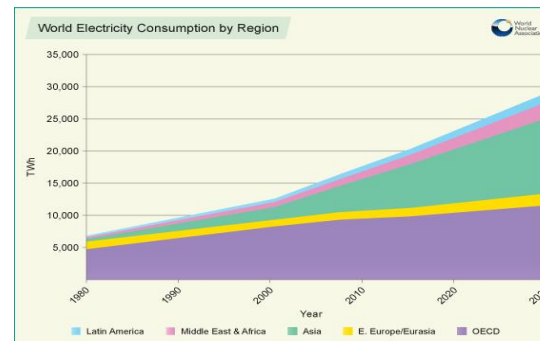
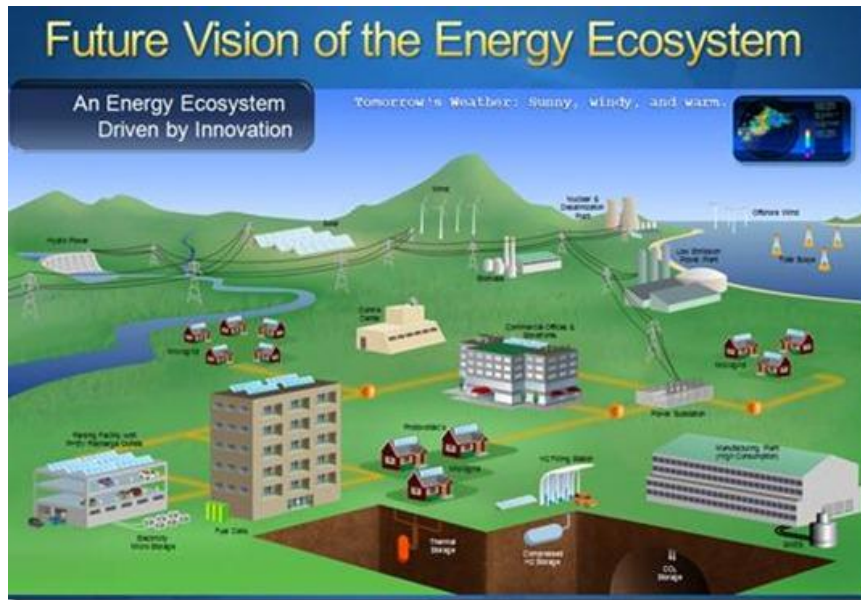
**FUTURE ENERGY
FORUM | 2017**
Building the Future. Saving the Planet.

LOW CARBON TECHNOLOGIES

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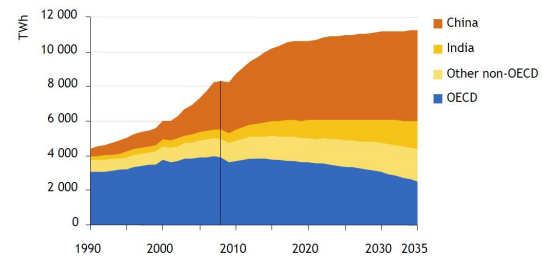
FUTURE ENERGY SYSTEMS

Energy: abundant, reliable, clean, sustainable, safe, cheap

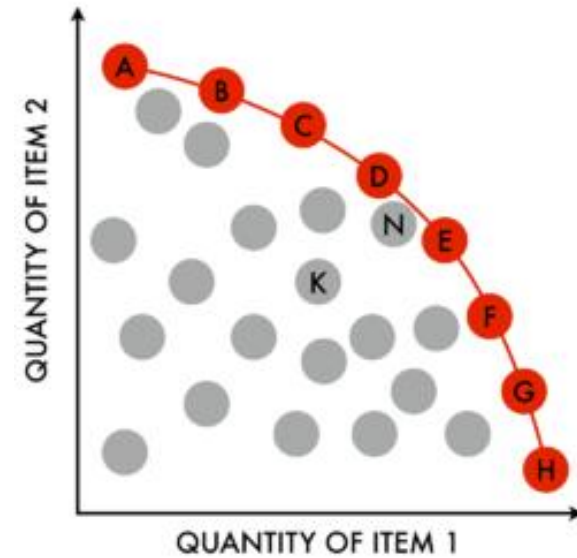
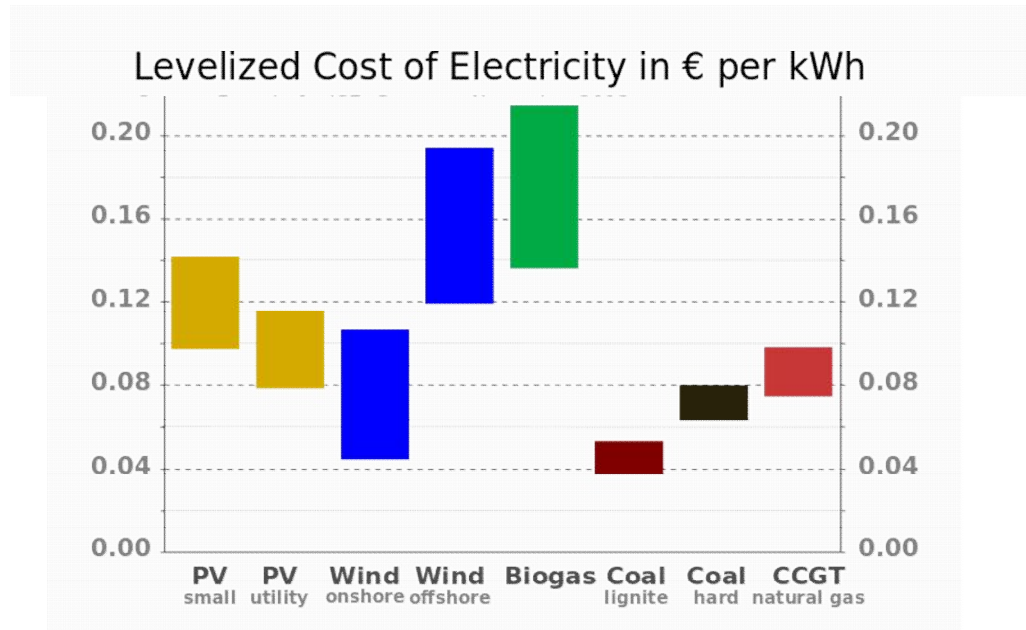


coal 40.8%,
natural gas
21.6%, nuclear
10.6%, hydro
16.4%, oil
4.3%, wind
4%, solar 1%

Coal-fired electricity generation by region in the New Policies Scenario



MULTIOBJECTIVE OPTIMIZATION

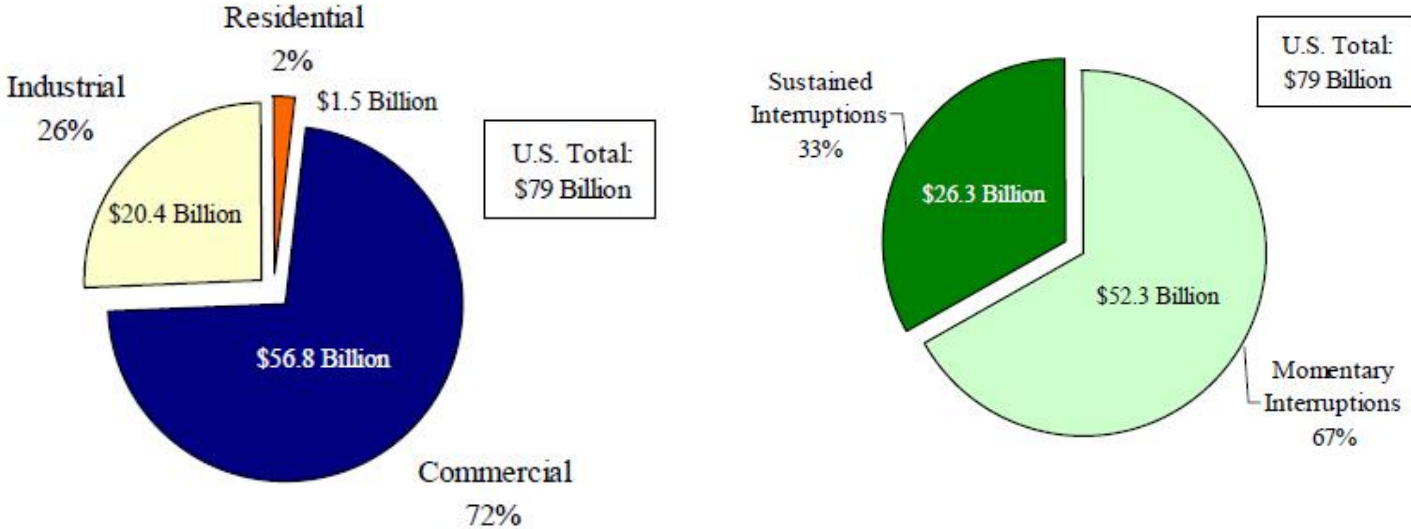


TOP REASONS U.S. SHOULD WITHDRAW FROM PARIS CLIMATE TREATY

- Cost to U.S. taxpayers.
- Increased energy costs for U.S. consumers and businesses. Household electricity costs are projected to increase up to 20%, and an average family of four would see total income loss of over \$20,000.
- Puts U.S. at a competitive disadvantage. This agreement will cost the U.S. an estimated 6.5 million jobs by 2040 and reduce GDP by over \$2.5 trillion, putting the country at a huge disadvantage to countries like China, India, or Russia.
- Paris Climate Treaty will have negligible benefits to the environment. According to the Massachusetts Institute of Technology (MIT), which compiled the combined impacts of the various pledges under the Treaty, it found a global temperature reduction of 0.2 degrees Celsius by 2100.



COST OF POWER INTERRUPTIONS IN THE US.

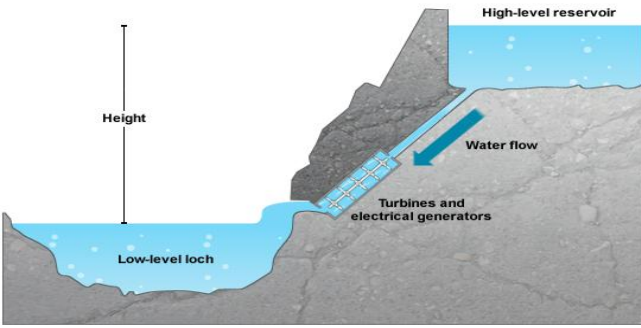


LARGE RENEWABLES PENETRATION

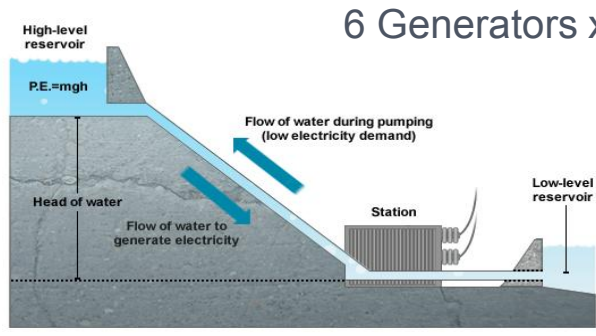
- Increased level of variability and uncertainty in power grid operations enhances hazard that power plants and transmission lines can unexpectedly drop out of service.
- Different options for improvement of efficiency and safety of power system with high renewables penetration are under discussion in technical literature:
 - Energy storage
 - New control systems for transmission and distribution
 - Flexible generation



PUMPED STORAGE NANT DE DRANCE, SWITZERLAND



high power demand

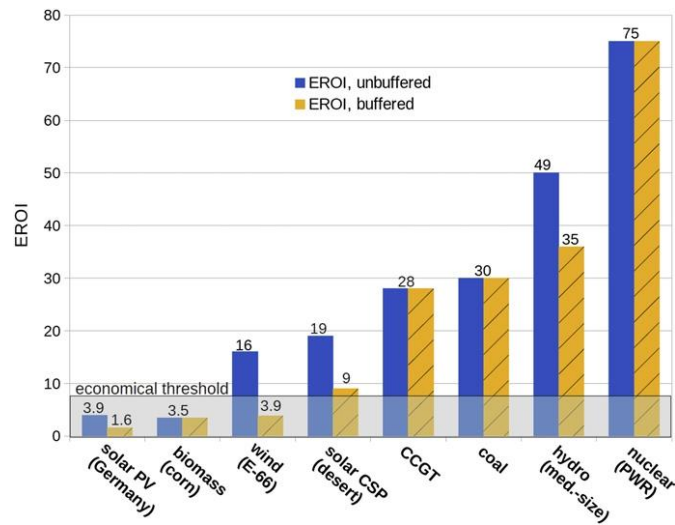


6 Generators x 150 MW

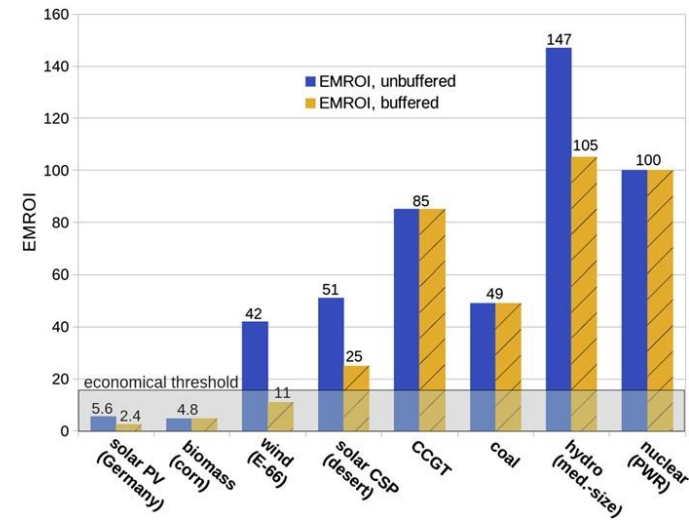
low power demand



RETURN ON INVESTMENT



“Energy Return on Investment” (EROI)

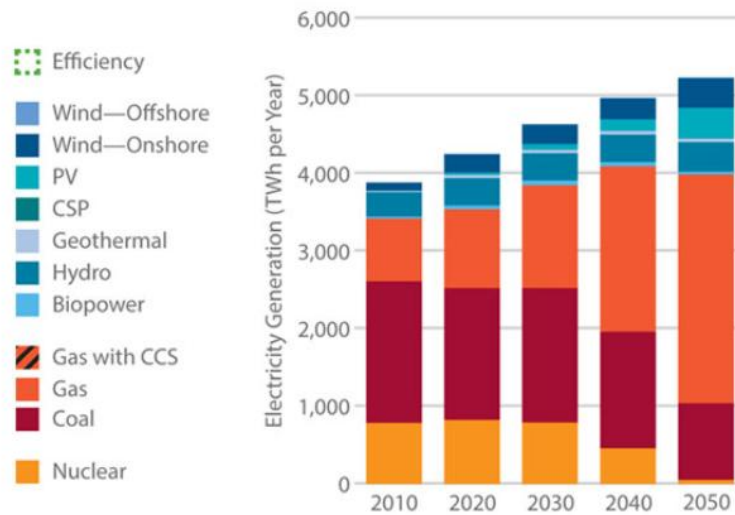


“Energy Money Return on Investment” (EMROI)

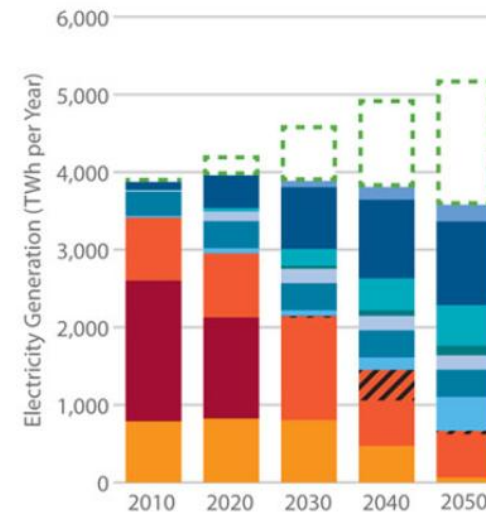


ENERGY EFFICIENCY

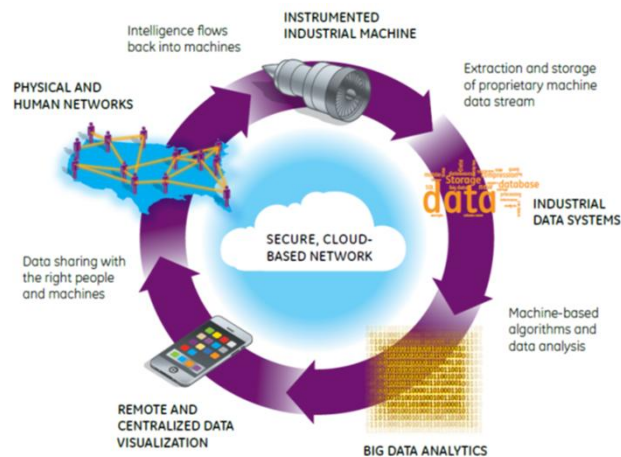
U.S. Electricity Mix under Business as Usual



U.S. Electricity Mix under the Renewables-and-Efficiency Scenario



INDUSTRIAL INTERNET. GE REPORT



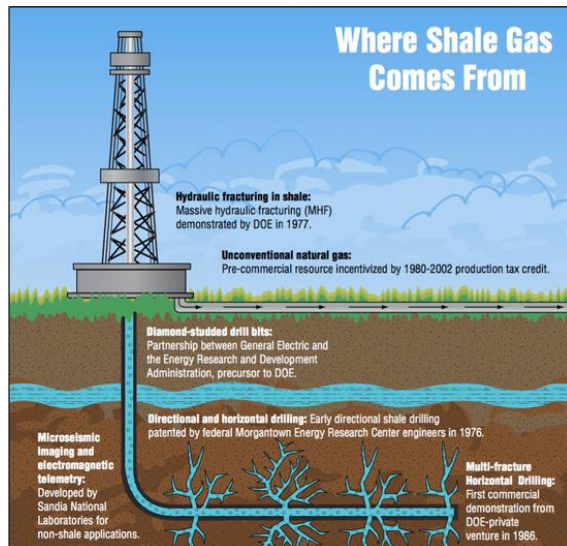
What if... Potential Performance Gains in Key Sectors

Industry	Segment	Type of Savings	Estimated Value Over 15 Years <small>(Billion nominal US dollars)</small>
Aviation	Commercial	1% Fuel Savings	\$30B
Power	Gas-fired Generation	1% Fuel Savings	\$66B
Healthcare	System-wide	1% Reduction in System Inefficiency	\$63B
Rail	Freight	1% Reduction in System Inefficiency	\$27B
Oil & Gas	Exploration & Development	1% Reduction in Capital Expenditures	\$90B

- Future energy systems efficiency can be enhanced by broad implementation of industrial internet solutions.
- These solutions put real-time intelligence in the hands of customers so they can advance assets and networks toward zero unplanned downtime



SHALE GAS REVOLUTION

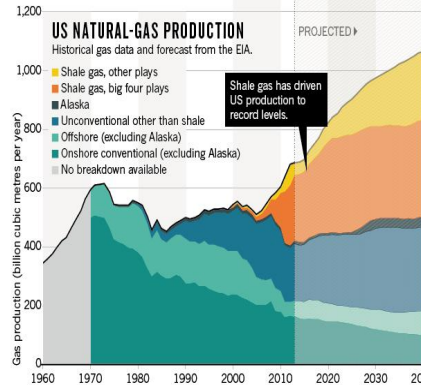
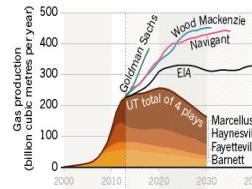


BATTLE OF THE FORECASTS

Production of natural gas in the United States is climbing rapidly, and the US Energy Information Administration (EIA) predicts long-term growth. But studies by the University of Texas (UT) challenge that forecast.

BIG FOUR SOURCES

The Texas team made forecasts for the four most productive shale-gas formations, or plays. Those forecasts suggest that gas production will peak soon and quickly drop, a much more pessimistic outlook than those offered by the EIA and several companies, such as Goldman Sachs.



Pounds of CO₂ emitted per million British thermal units (Btu) of energy for various fuels:

Coal (anthracite)	228.6
Diesel fuel and heating oil	161.3
Gasoline	157.2
Propane	139.0
Natural gas	117.0



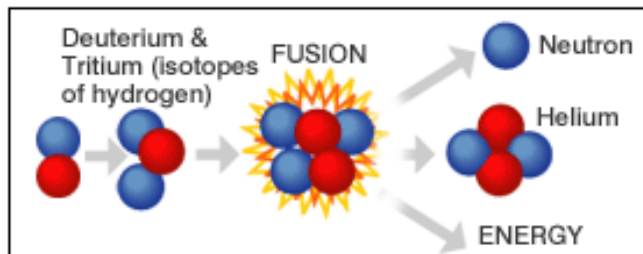
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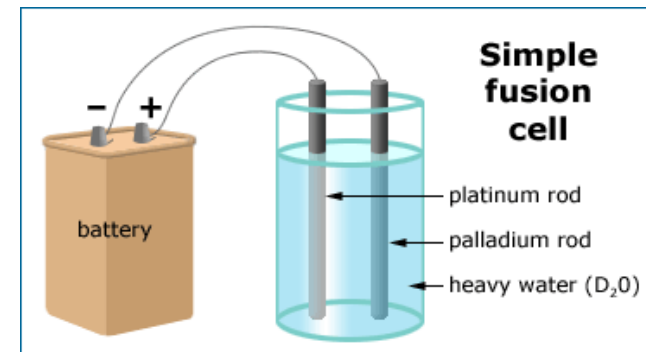
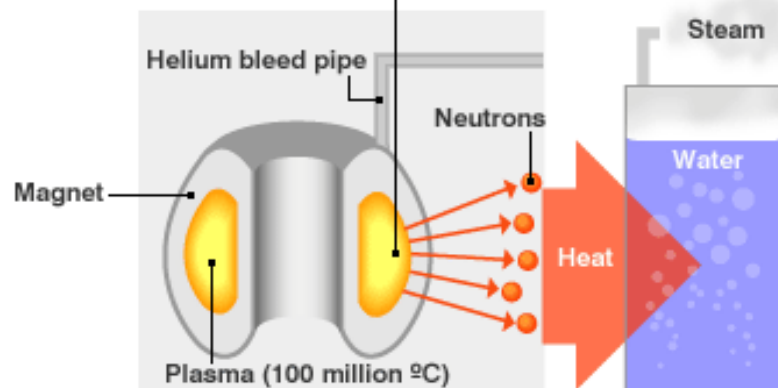


FUSION POWER GENERATION

NUCLEAR FUSION



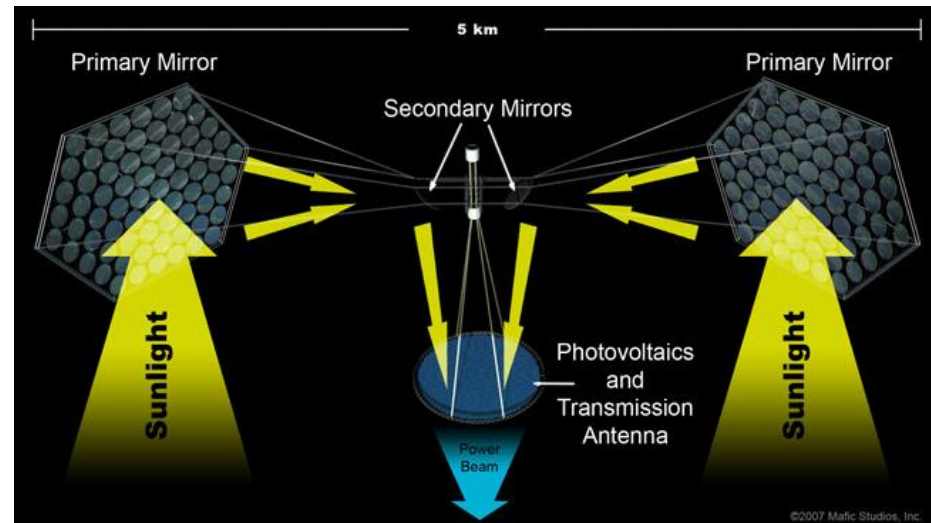
Thermonuclear reactor



Cold fusion is a hypothesized type of nuclear reaction that would occur at, or near, room temperature. This is compared with the "hot" fusion which takes place naturally within stars, under immense pressure and at temperatures of millions of degrees

SPACE-BASED SOLAR POWER (SBSP)

- Basic principle
 - Power satellite equipped with mirrored panels collects continuously energy from the sun
 - The energy is redirected to concentrating photovoltaic arrays to convert it into electrical power
 - The electrical energy is transmitted by microwaves to the ground (collection rectennas) and can be routed into an electrical grid as base-load power



Space Solar Power Station (SSP) in Geosynchronous Earth Orbit (GEO) radius 36000km



THE NEW SOLAR SYSTEM. STANFORD LAW SCHOOL AND STANFORD GRADUATE SCHOOL OF BUSINESS

China and the United States find themselves at an unprecedented moment in the growth of solar power. Their interaction will determine whether solar energy emerges as a mainstream energy source, as an engine of significant economic growth and carbon reductions. There are many reasons to be sceptical that the world's two largest energy consumers and carbon emitters will find the will to work more closely together to scale up solar power to meaningfully address the climate challenge. Yet The New Solar System concludes that each of them has an even more-compelling reason to do so: economic self-interest.



THE NEW SOLAR SYSTEM. STANFORD LAW SCHOOL AND STANFORD GRADUATE SCHOOL OF BUSINESS

- Solar energy has become big business.
- China solar-panel manufacturing-70% of global capacity for manufacturing crystalline-silicon solar panels, the US share -1% percent.
- A more-enlightened United States policy approach to solar to continue slashing solar power's costs — not to prop up types of American solar manufacturing that can't compete globally.
- It is likely to make more sense Focus American solar subsidies more on research and development and deployment than on manufacturing.



SUMMARY

- High renewables penetration needs involvement of innovative solutions:
 - Energy storage
 - Stability and control systems
 - Energy management
 - Industrial internet
- New energy sources are necessary to meet growing power demand



SUMMARY

– An approaching the global problem needs original scientific and engineering solutions which must stimulate profound research in fundamental and applied sciences:

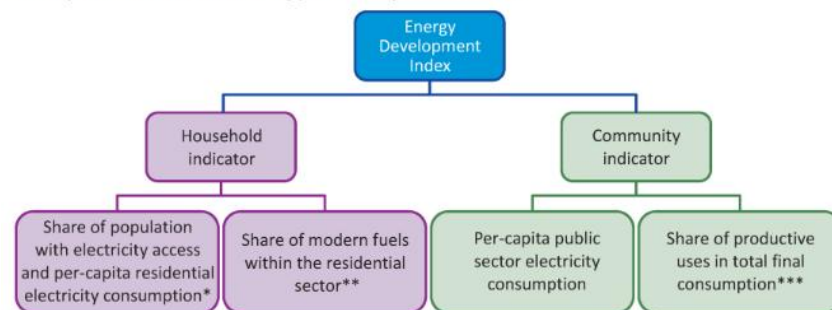
- Mathematics, physics, chemistry
- New materials, catalysts
- Advanced sensors
- Big data
- etc.



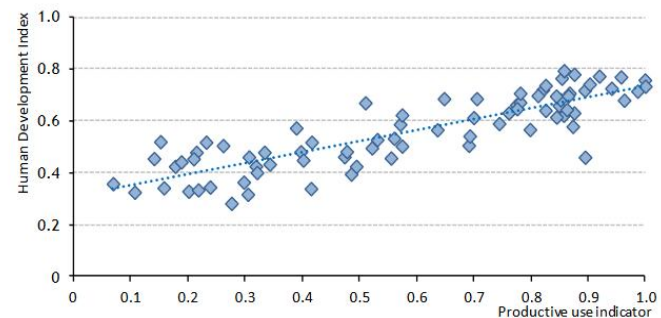
ENERGY AND SOCIETY DEVELOPEMENT

The level of a society development is closely connected to the energy it consumes. The Energy Development Index quantifies country energy consumption both at the household level: electricity and access to clean cooking facilities; and at the community level: modern energy use for public services (e.g. schools, hospitals and clinics, water and sanitation, street lighting) and energy for productive use, which deals with modern energy use as part of economic activity.

Components of the Energy Development Index



HDI and new productive use variable for the EDI (2010)



MICROGRID

A microgrid is a small-scale power grid that can operate independently from area's main electrical grid. Microgrids: bolster the main power grid during periods of heavy demand; often involve multiple energy sources as a way of incorporating renewable power; include reducing costs and enhancing reliability; due to the modular nature could make the main grid less susceptible to localized disaster; allows gradual modernization of the existing grid.

