Energy: Its Sources, Uses & Impact
Part 2

Osher Lifelong Learning Institute

At Tufts University

Winter 2018

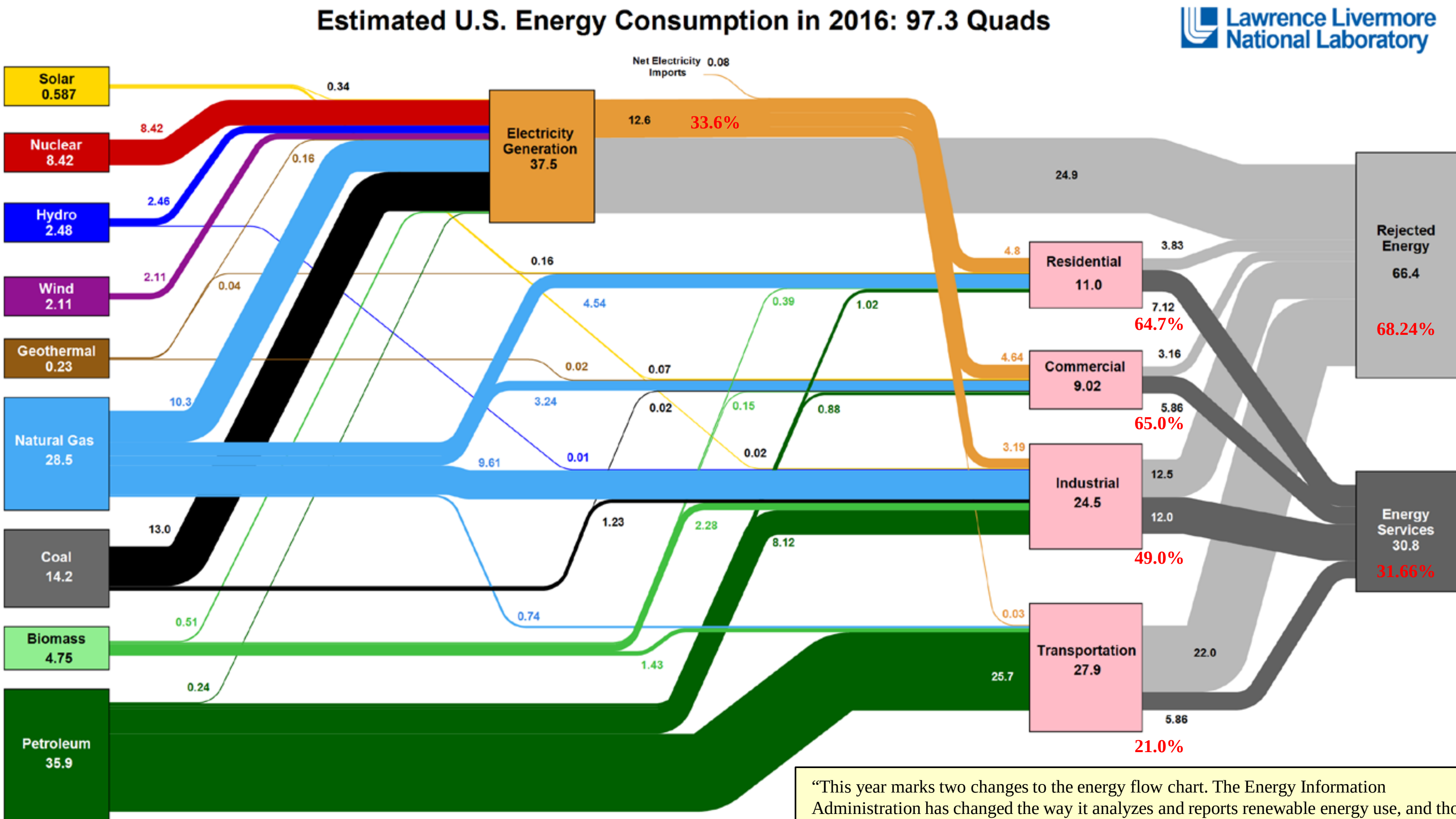
Peter Baldwin

617-306-7419

pete_baldwin@base-e.net

"Practical Strategies for Emerging Energy Technologies"

U.S. 2016 Energy Flow – 97.3Quads



base®e

"Practical Strategies for Emerging Energy Technologies"

"This year marks two changes to the energy flow chart. The Energy Information Administration has changed the way it analyzes and reports renewable energy use, and those changes are reflected in the 2016 chart as well as a revision to the 2015 analysis. Additionally, the estimate of efficiency of the industrial sector has been reduced from 80 percent to 49 percent to align with recent analysis at the DOE's Advanced Manufacturing Office. LLNL reports all year-over-year changes on a consistent basis with the new methodology."
https://energy.gov/eere/amo/energy-analysis-sector

Actions within Reach

- **Use the "waste/reject" heat**
  - Natural Gas Combined Cycle (NGCC)
  - Combined Heat & Power (CHP)
  - Increase Efficiency
- **Demand Management**
- **Fuel Switching**
  - Renewables
    - Enabling Energy Storage Technologies
    - Renewable Portfolio Standards (RPS)
  - New Nuclear
    - SMR
  - Hydro and Geothermal
- **Carbon Capture & Storage on Natural Gas Fired Power Plants**
- **Plant trees**
- **Air Capture (☺!)**

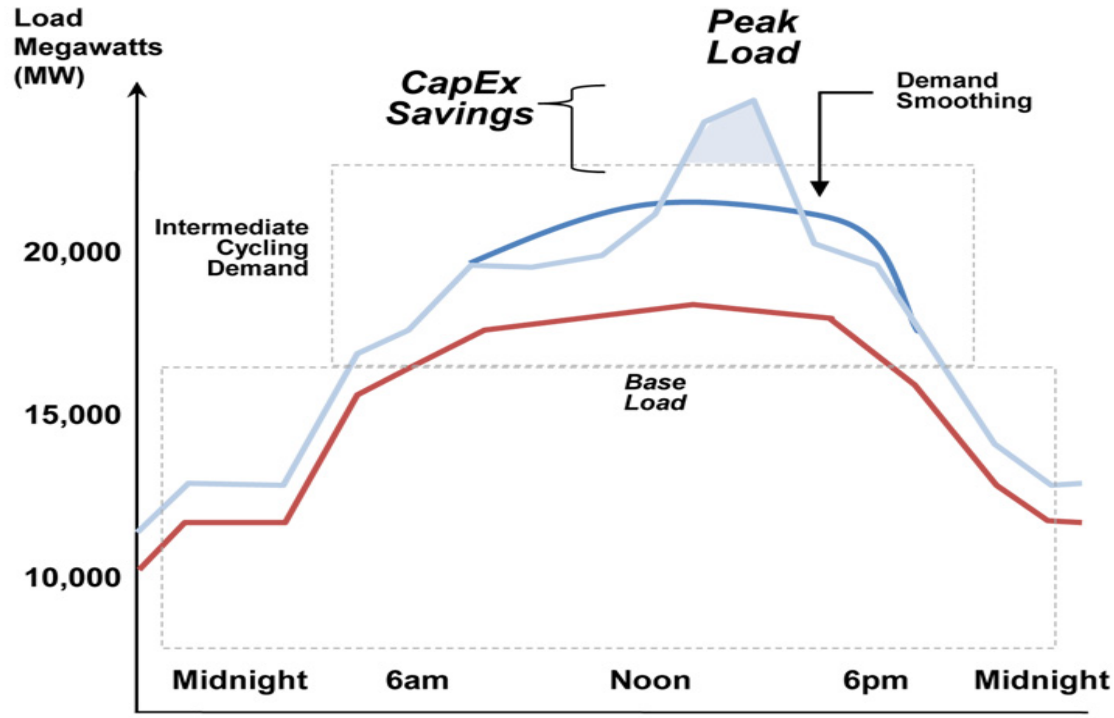
Demand Response

Demand Response

– DR as changes (usually reductions) in electricity **usage by end-use customers from their normal** consumption patterns.

– In response to **changes in the price of electricity or to direct incentives**, typically at times of high wholesale market prices or when system reliability is jeopardized.

– An important distinction for DR is that it must be **dispatchable by a utility or system operator** or be initiated by a customer in response to a non-fixed price signal.



Demand Response is an important component of "Smart Grid"

Time of Day Rates Encourage Customer DR

Summer

	On-Peak	Mid-Peak	Off-Peak	Total
Annual Operating Hours	650	975	2015	3640
Electric Demand Charge - $/kW/month	16.50	2.45	3.30	5.43
Electric Rate - $/kWh	0.1445	0.0680	0.0430	0.0678
Demand Charge - $/kWh	0.1269	0.0126	0.0082	0.0306
Average Electric Rate - $/kWh	0.2714	0.0806	0.0512	0.0984

Months of Operation-Summer: 5

Winter

	On-Peak	Mid-Peak	Off-Peak	Total
Annual Operating Hours	0	1972	3124	5096
Electric Demand Charge - $/kW/month	0.00	0.00	3.30	2.02
Electric Rate - $/kWh	0.0000	0.0800	0.0460	0.0592
Demand Charge - $/kWh	0.0000	0.0000	0.0074	0.0045
Average Electric Rate - $/kWh	0.0000	0.0800	0.0534	0.0637

Months of Operation-Winter: 7

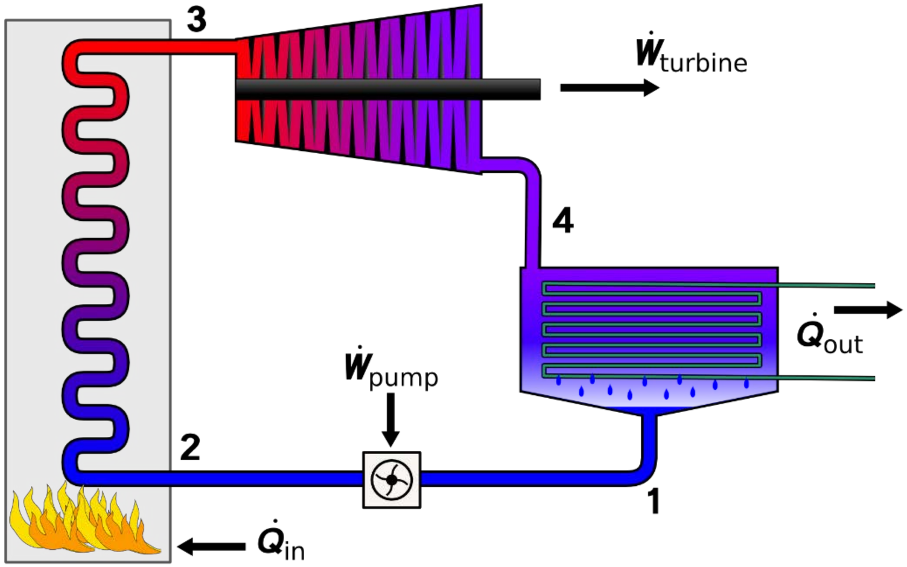
Total

	On-Peak	Mid-Peak	Off-Peak	Total
Annual Operating Hours	650	2947	5139	8736
Electric Demand Charge - $/kW/month	16.50	0.81	3.30	3.44
Electric Rate - $/kWh	0.1445	0.0760	0.0448	0.0628
Demand Charge - $/kWh	0.1269	0.0042	0.0077	0.0154
Average Electric Rate - $/kWh	0.2714	0.0802	0.0525	0.0781

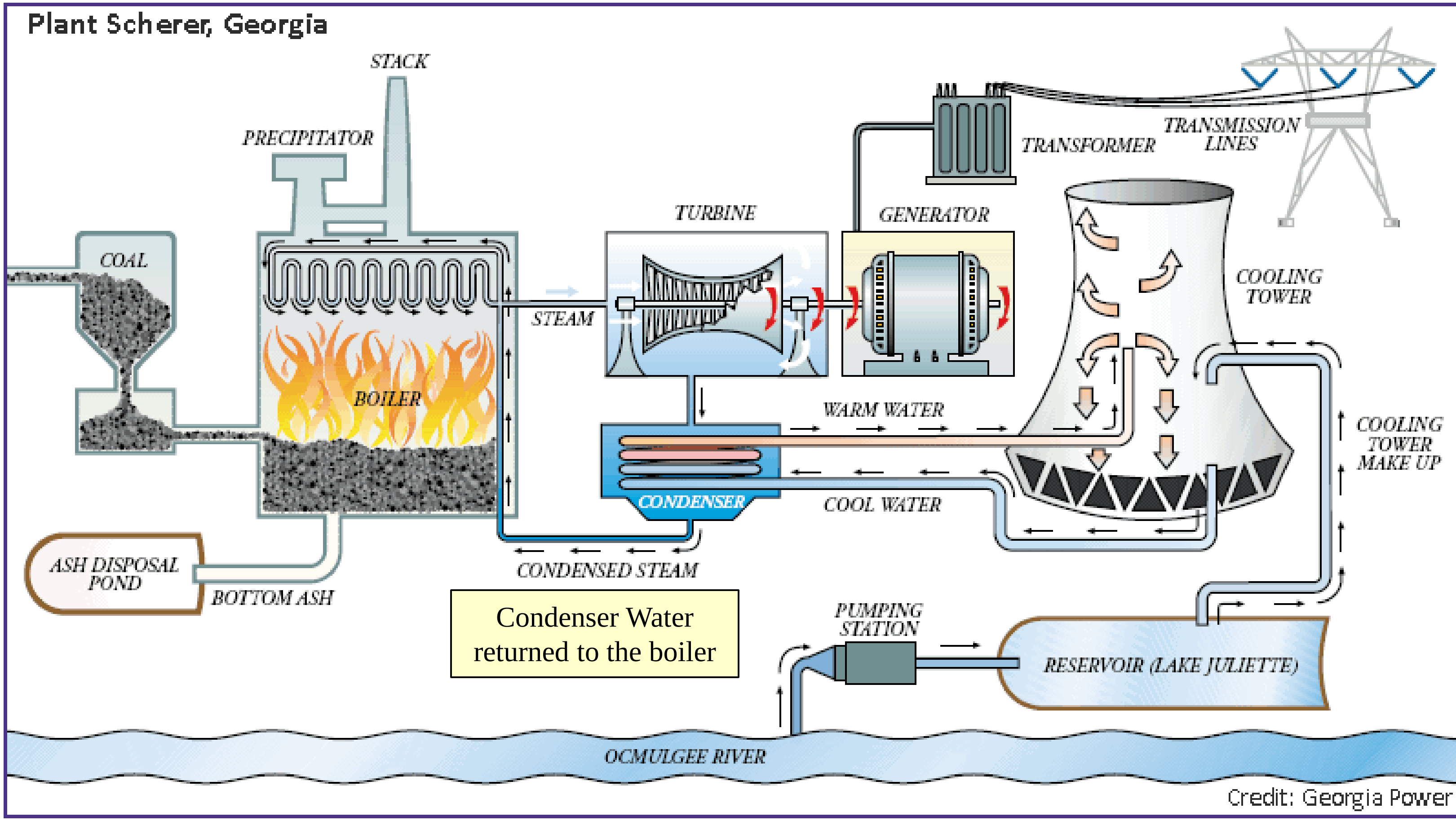
Months of Operation-Total: 12

The Rankine Cycle

- **Steam**
  - Supercritical (SCPC)
  - Ultra-supercritical Pulverized Coal (USCPC)
  - Nuclear
  - Geothermal
  - Concentrated Solar
- **Organic Fluid**
  - Organic Rankine Cycle (ORC)
  - Ocean Thermal–Ammonia
  - Geothermal

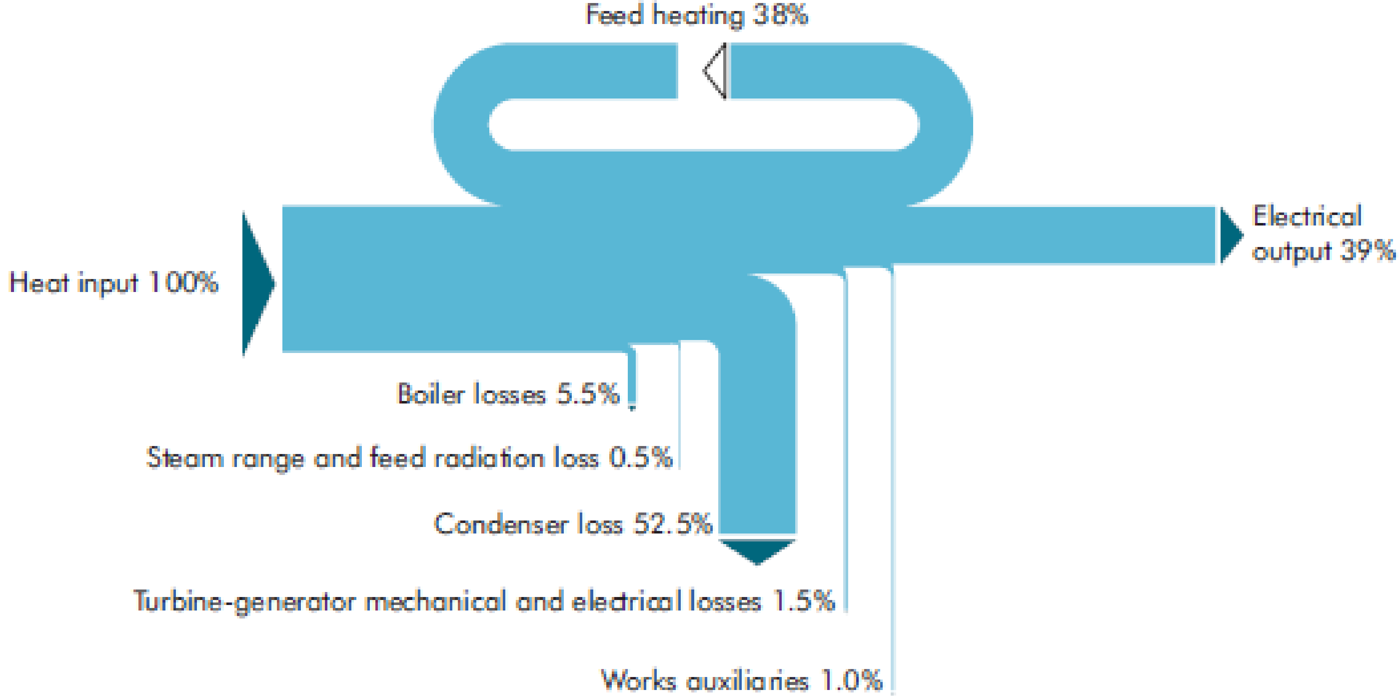


Closed Rankine Cycle



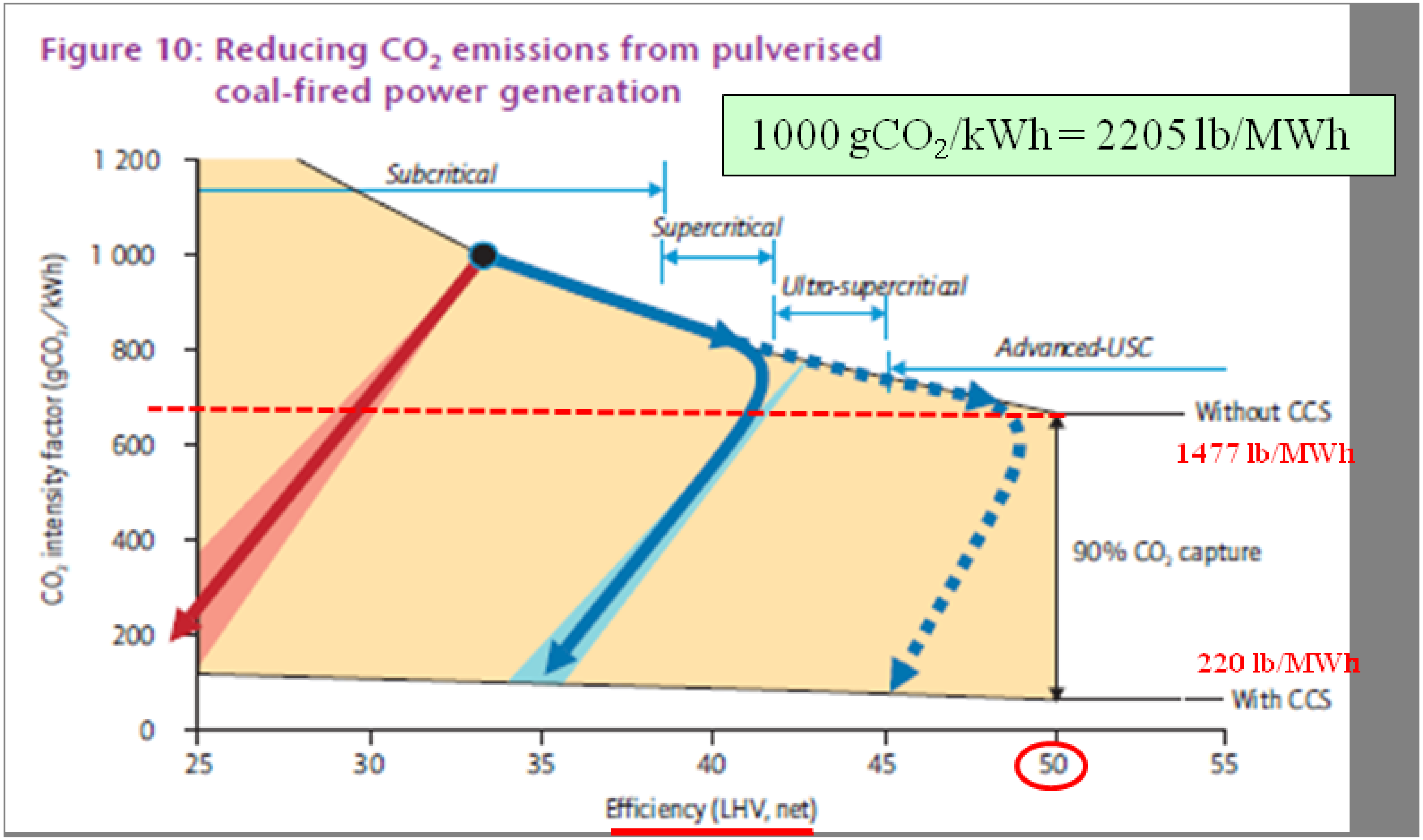
Power Cycle – 500MW Pulverized Coal

Figure 2.3: Example energy flows in a typical 500 MW subcritical pulverised coal-fired boiler

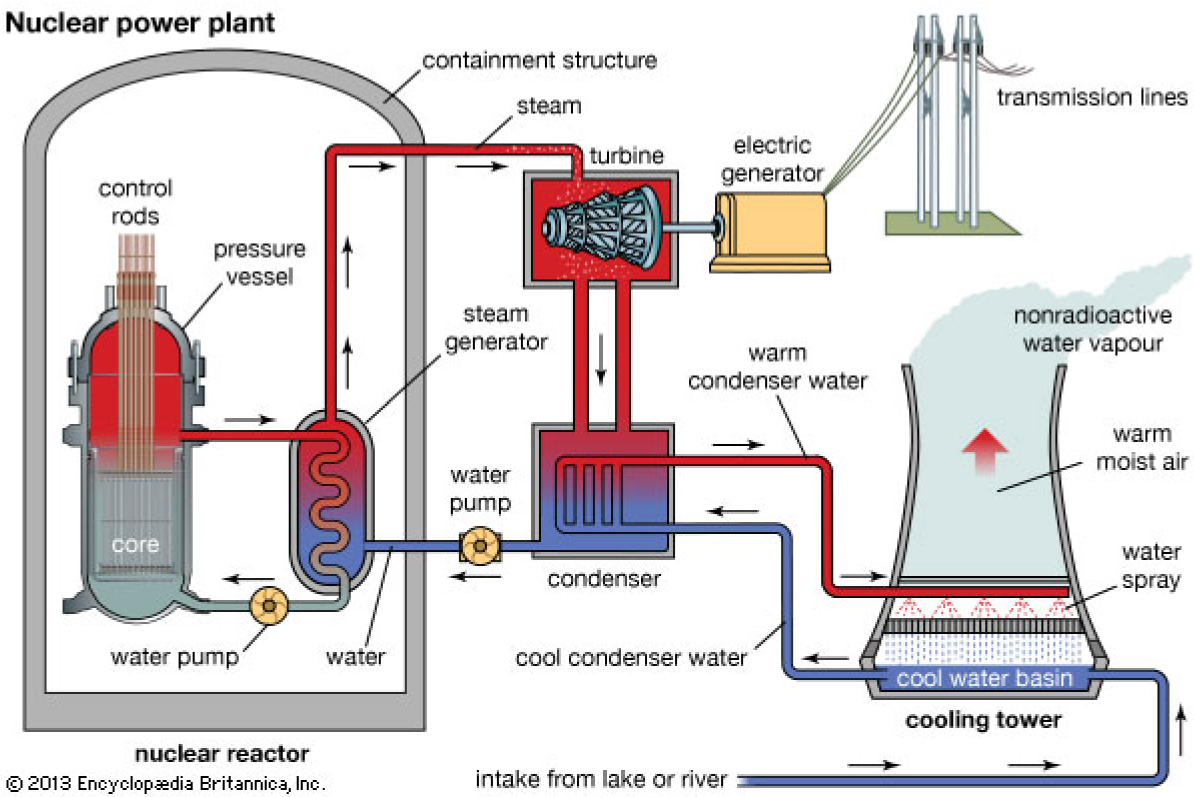


Source: White (1991). Reprinted by permission of the publisher. © Elsevier, 1991.

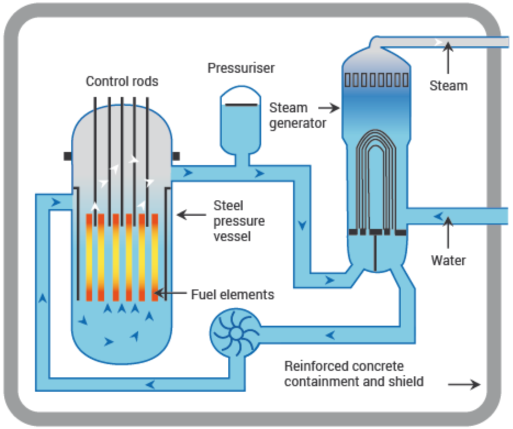
DOE Advanced Coal Power Generation



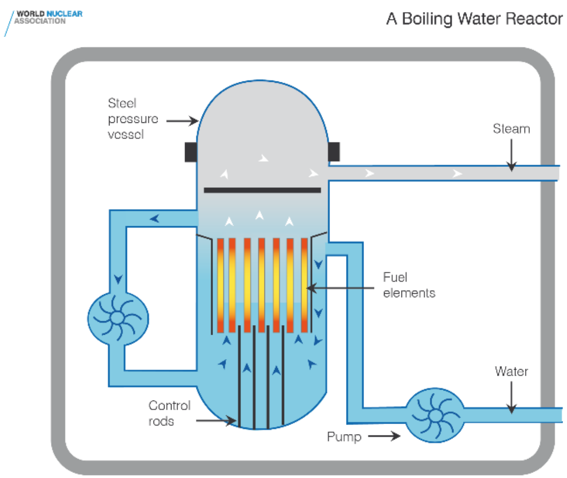
Nuclear Power Plant



A Pressurized Water Reactor (PWR)

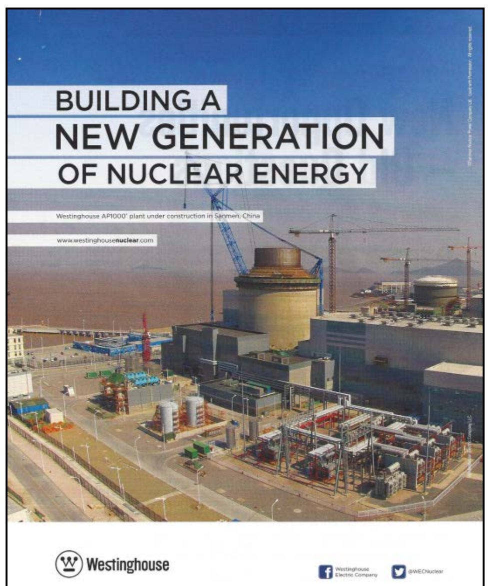


A Boiling Water Reactor (BWR)

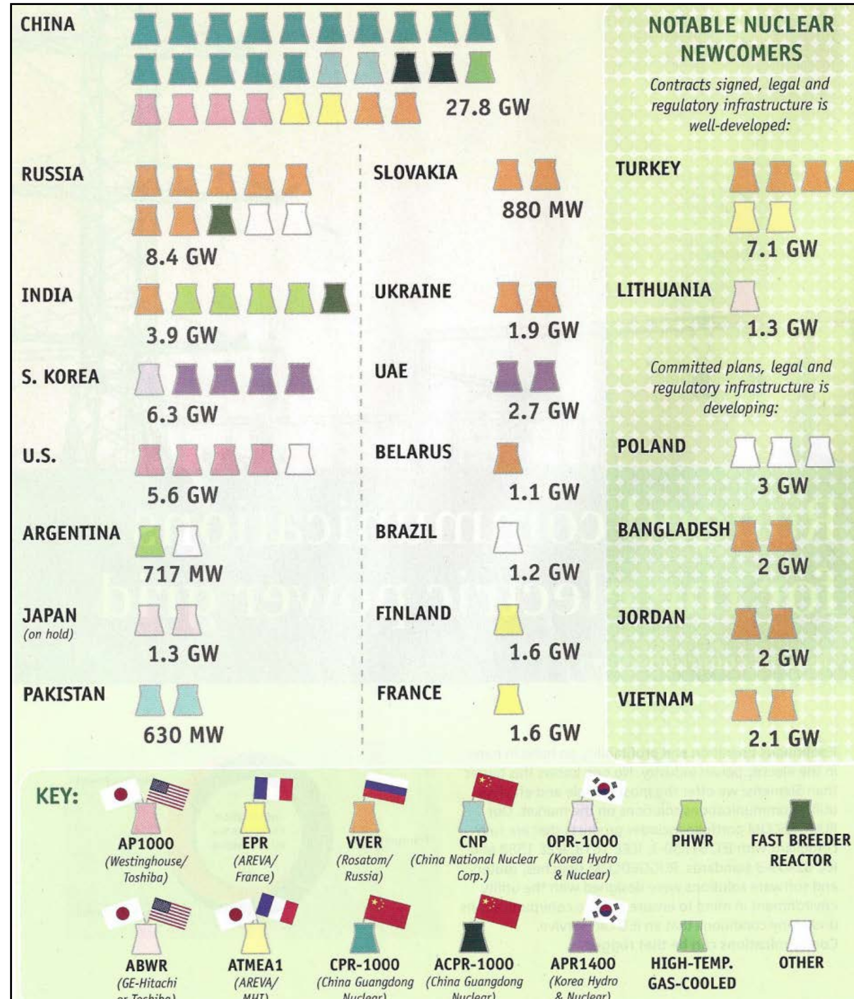


“The Big Picture: Next-Gen Nuclear”

- Compliments of Power magazine April 2014
- 72 mostly advanced nuclear reactions under construction
- A total of 68GW (12% of installed base)
- China represents 40% of the total
- France will cap nuclear capacity at the current 63.2GW, forcing closures w/capacity additions
  - Currently at 75% share of generation
  - Goal is 50% by 2025



Westinghouse AP1000® plant under construction in Sanmen, China



Installed Generating Capacity (2012) = 5,550 GW

France Walks Back Nuclear Commitment

- PARIS (AP) — France's environment minister is backing down on promises to sharply reduce nuclear Power Production so that the government can concentrate on reducing fossil fuels instead.
- Nicolas Hulot told reporters Tuesday that it's too "brutal and unrealistic" to meet earlier pledges to cap the amount of France's electricity produced by nuclear plants at 50 percent by 2025.
- Hulot said President Emmanuel Macron's government remains committed to reducing nuclear energy and ordered his ministry to produce a new timetable.
- But Hulot made clear his priority is weaning France's economy from fuel that contributes to global warming. His ambitious goals include banning all sales of gasoline and diesel cars by 2040.
- France depends more on nuclear energy than any other country, getting about three-quarters of its electricity from its 58 nuclear plants.

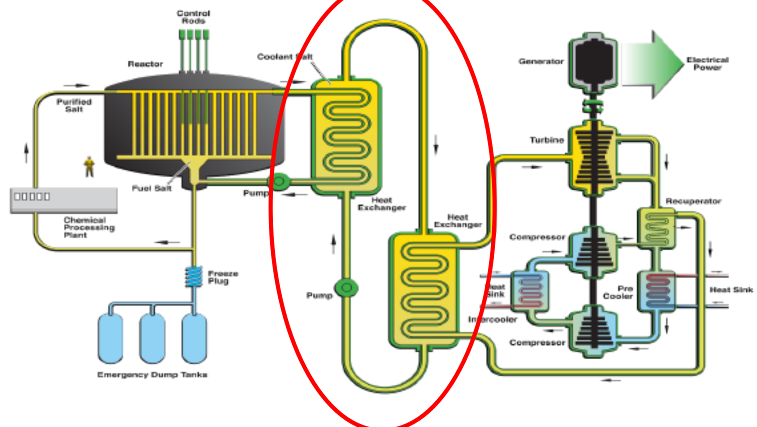
November 7, 2017

Advanced Nuclear

Heat Exchangers are a Challenge

MSR: FROM THORIUM TO ENERGY

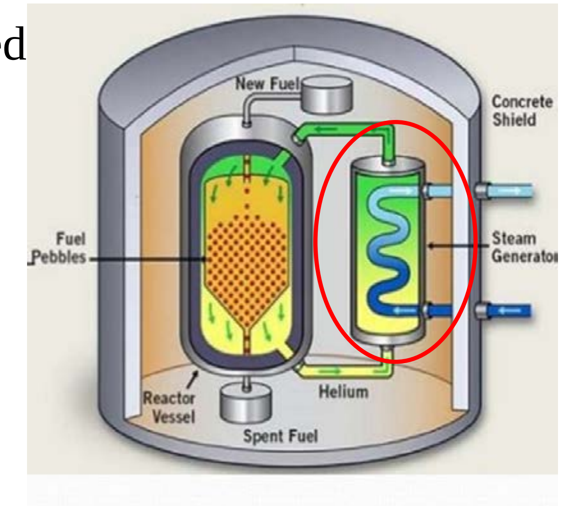
This ongoing decay (from Thorium to Uranium) **will generate large amounts of energy in the form of heat.** This heat can be transported through a gas in a heat exchanger and transferred to a turbine connected to a generator **which will produce electricity.**

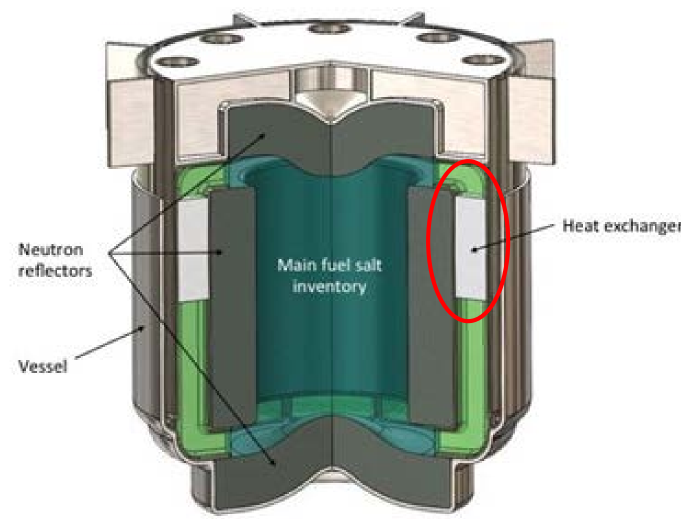


ELYSIUM INDUSTRIES | TECHNICAL DECK

Fission fuel produces fission products and actinides. Fission products only stay toxic for about 200 years while many actinides stay toxic for over 30 000 years. Molten Salt Reactors can fully recycle actinide wastes and only emit fission product wastes. This results in nuclear waste remaining toxic for only about 200 years as opposed to thousands of years for other nuclear reactors.

Pebble Bed

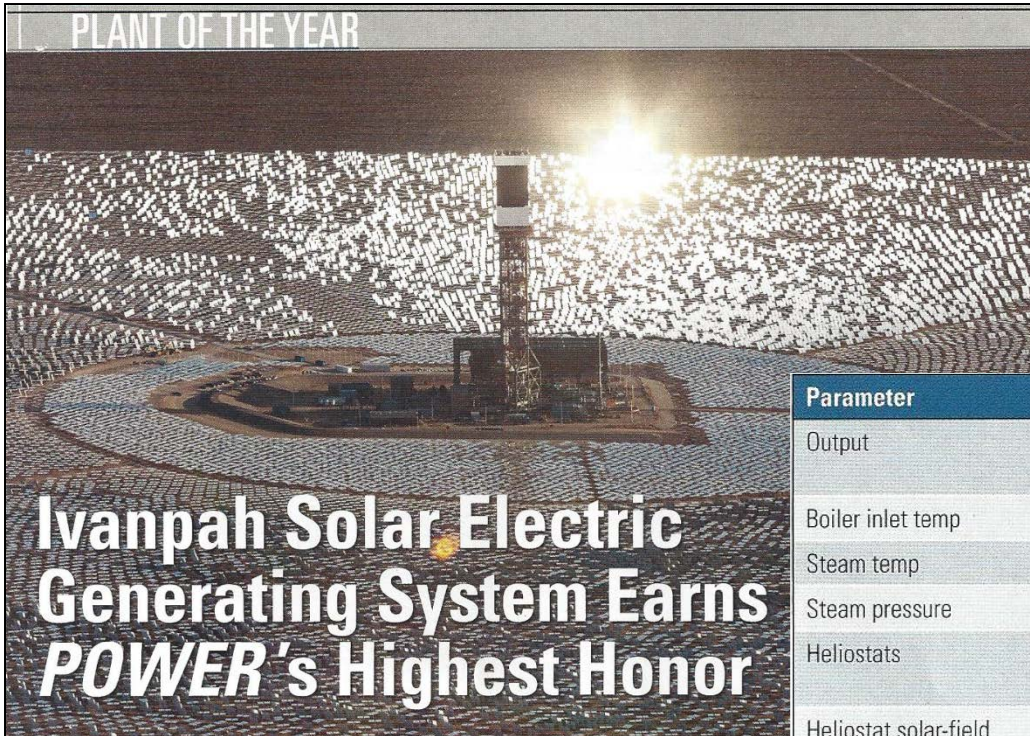




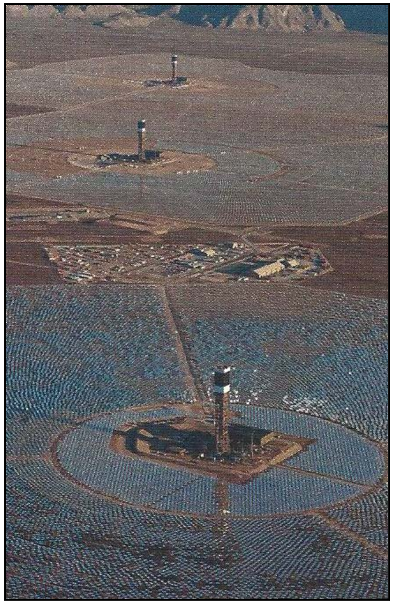
Molten Salt

base e

Concentrating "Big Solar"



Parameter	Ivanpah
Output	392 MW (gross), 377 MW (net)
Boiler inlet temp	368F
Steam temp	1,013F
Steam pressure	2,479 psi
Heliostats	173,500 (each holds two mirrors)
Heliostat solar-field aperture area	2,600,000 m^3
Tower height	459 ft
Net generation (first 100 days)	116,000 MWh
Gross efficiency	28.72%



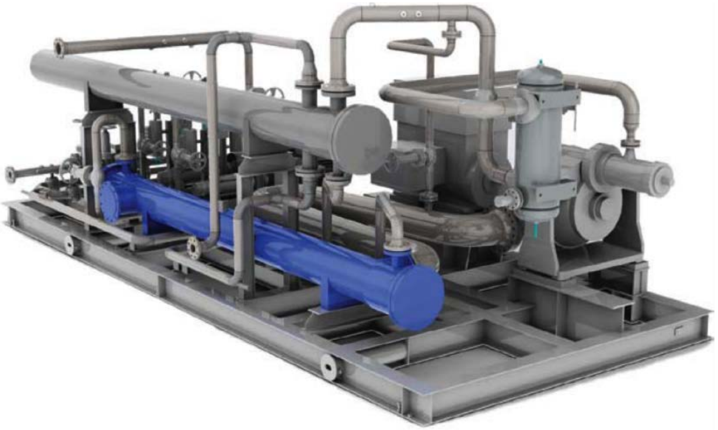
- Project Partners
- Bright Source Energy
- NRG Energy (NRG Renew)
- Google
- Bechtel

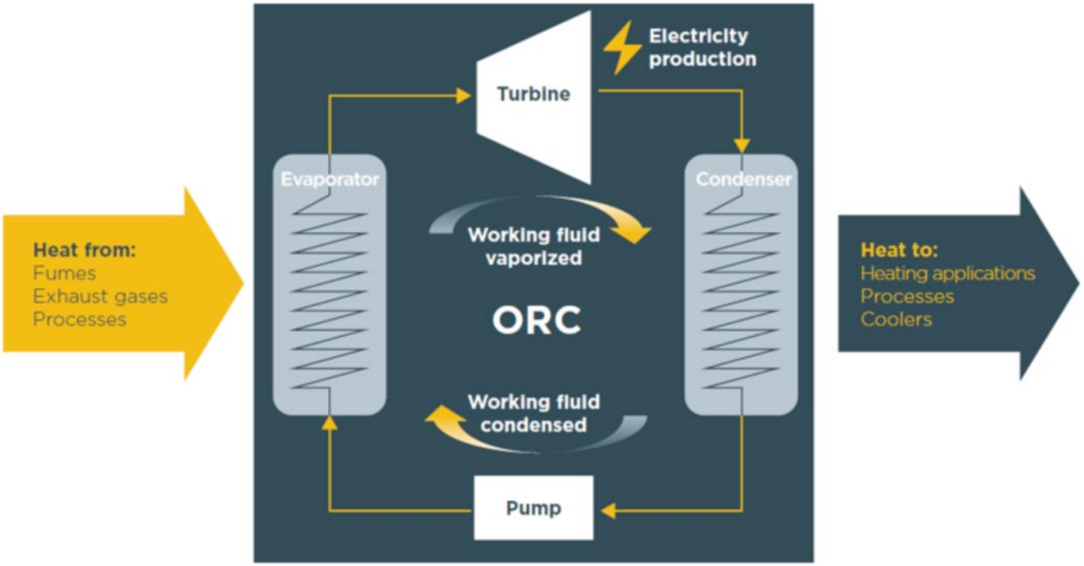
- Three self-contained units
- 3500 acres
- 5 miles end-to-end
- 4 types of heliostats depending on distance
- Air-cooled condensers

Source: Power Magazine August 2104

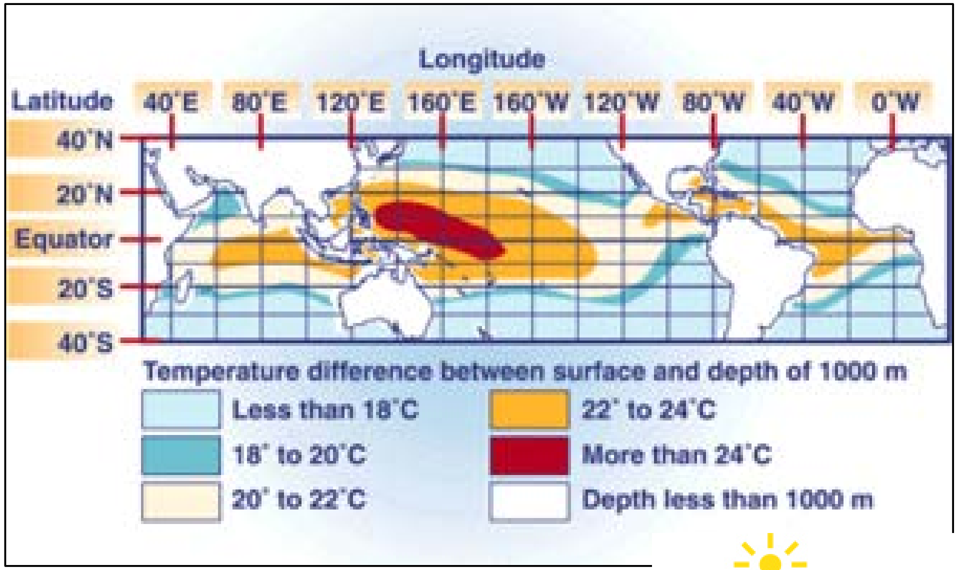
Organic Rankine Cycle

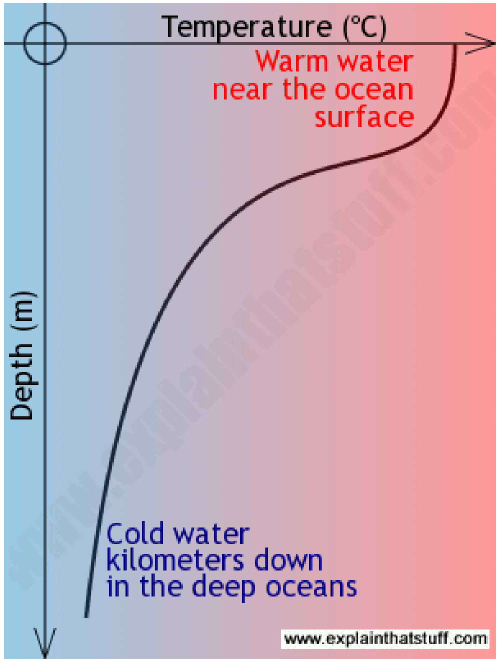
- **Low Grade Heat Recovery**
- **Matches working fluid to available temperatures**
  - Geothermal 90% Isobutane/10% Isopentane
  - Concentrated Solar Power (CSP)
  - Gas Turbine exhaust
  - Landfill

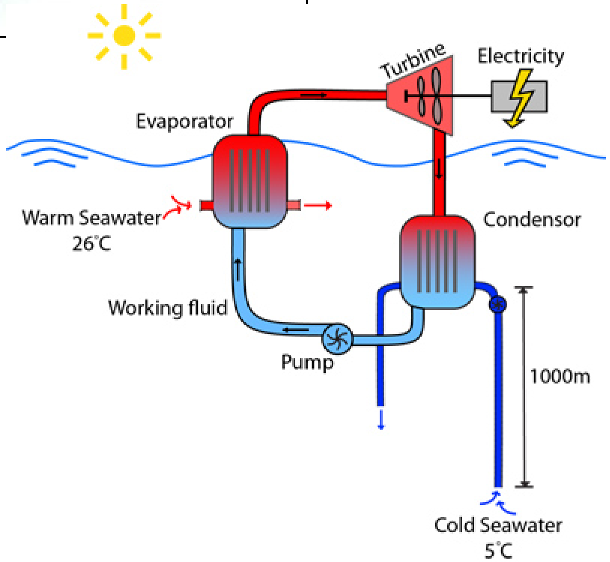




Ocean Thermal Gradients



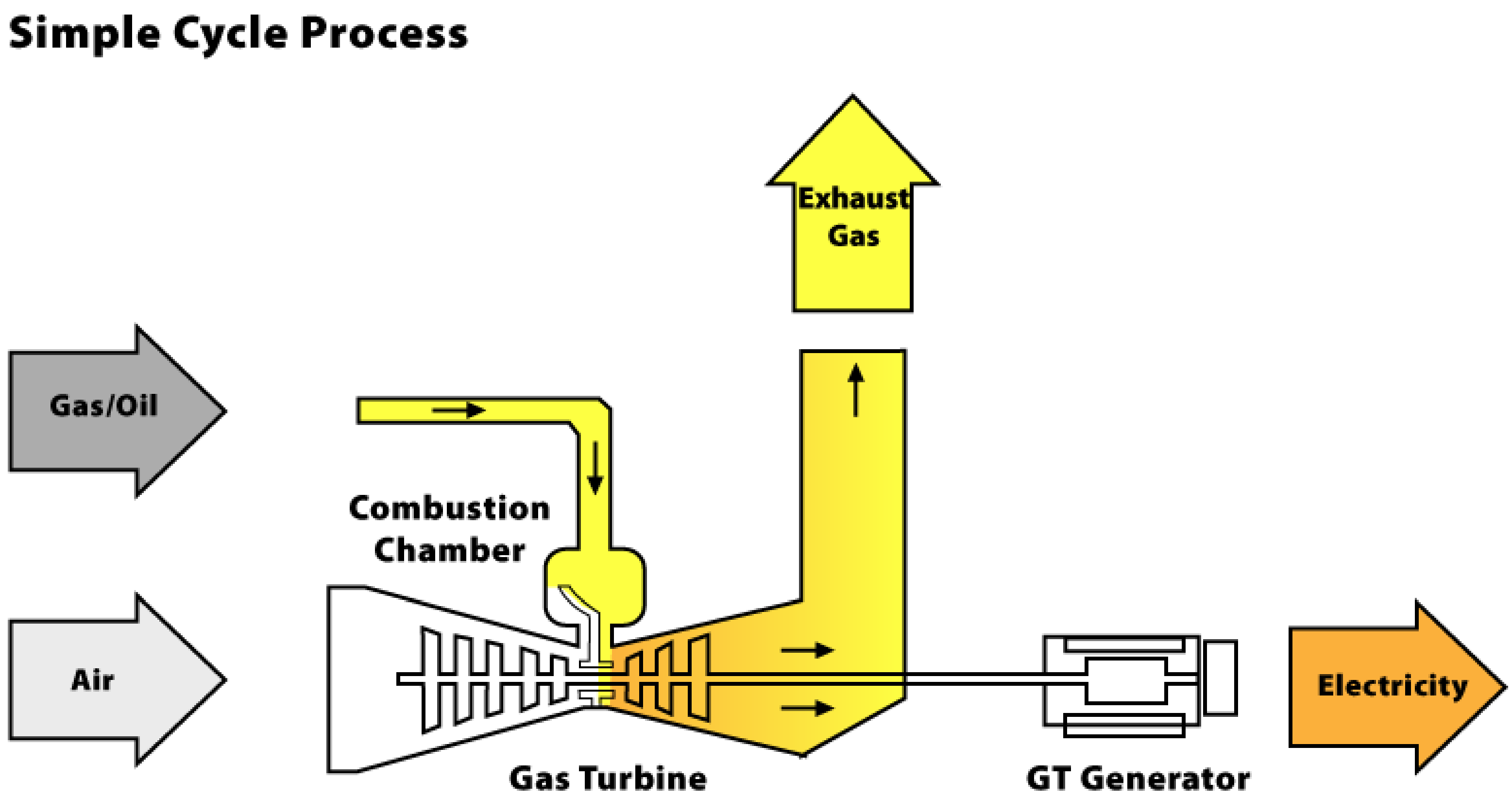




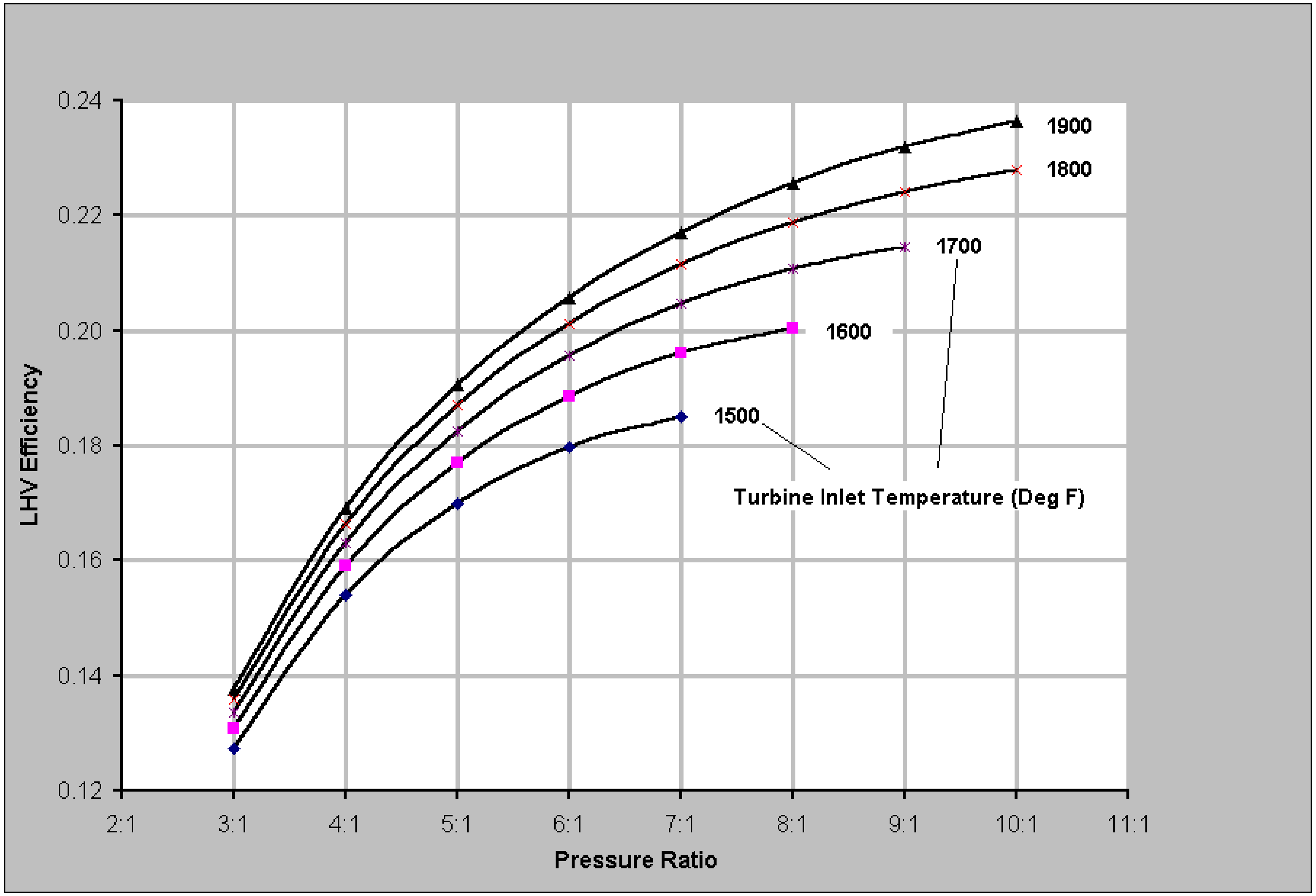
base*e*

"Practical Strategies for Emerging Energy Technologies"

Open Brayton Cycle

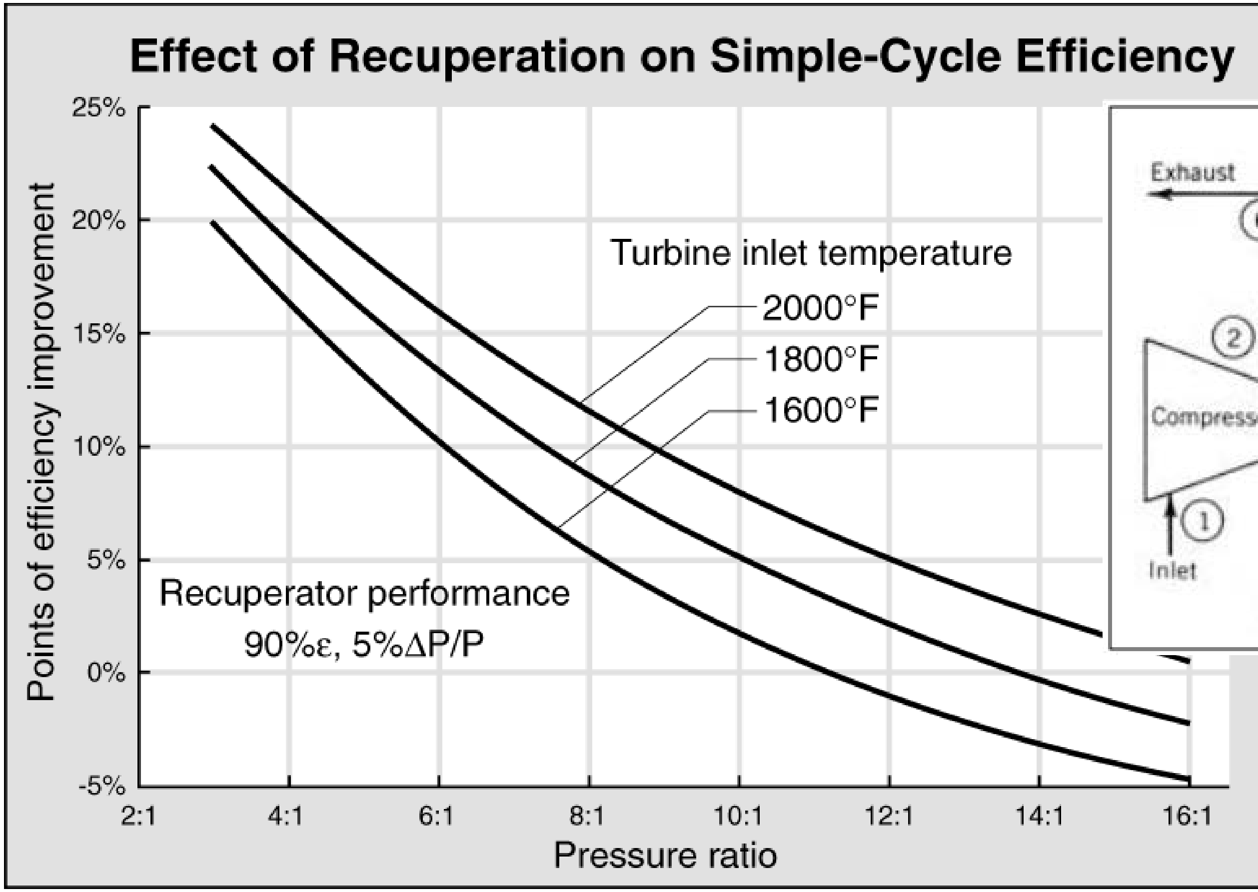


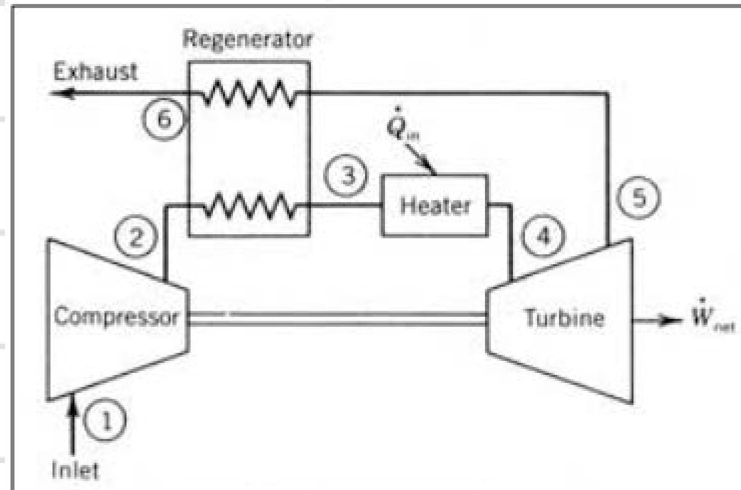
Impact of Design Conditions on Efficiency



Source: NREC

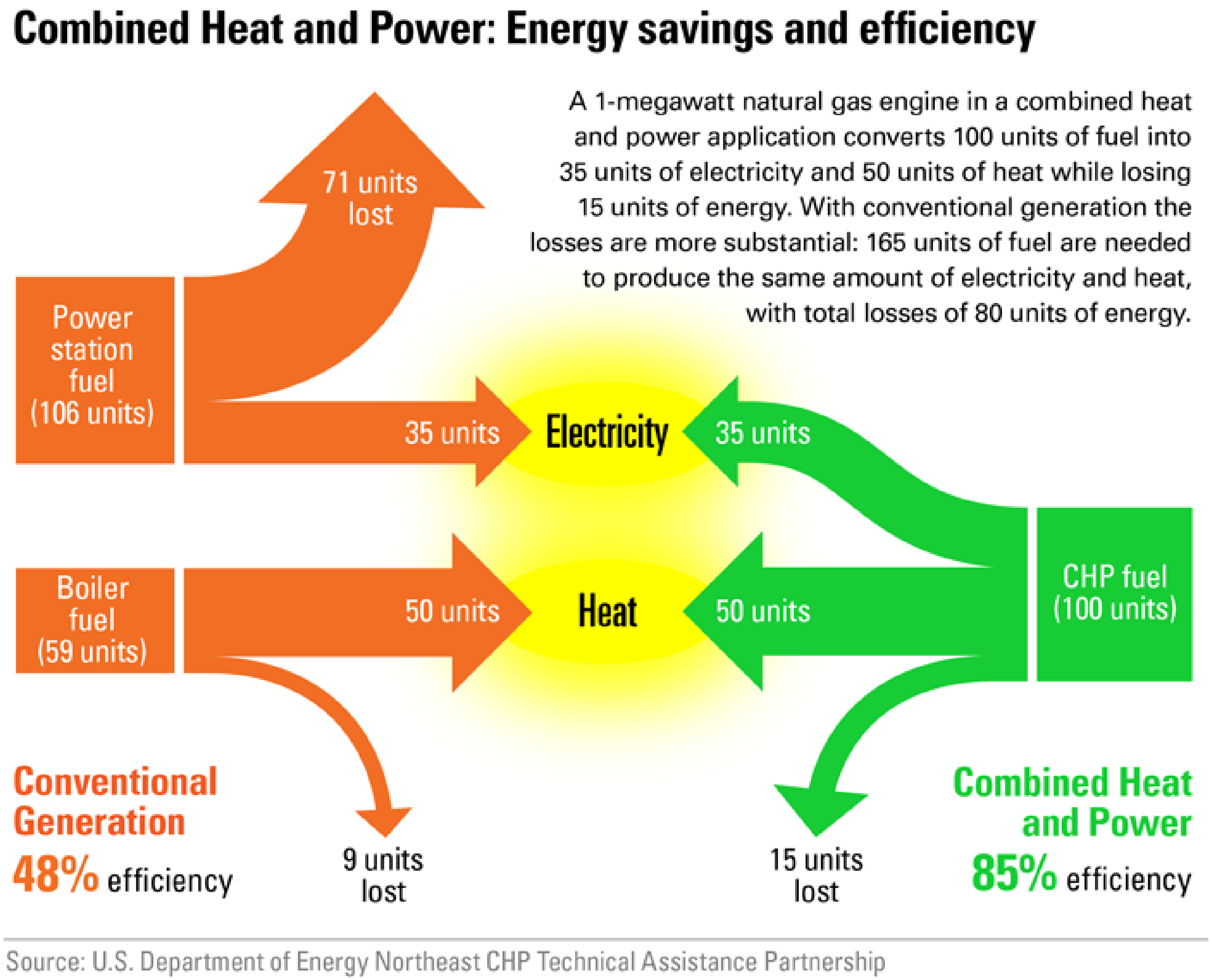
Recuperated Brayton Cycle



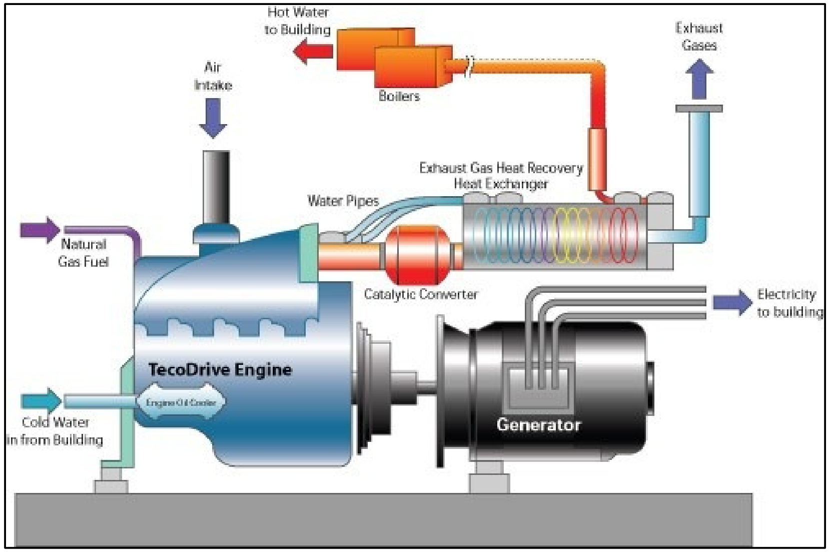


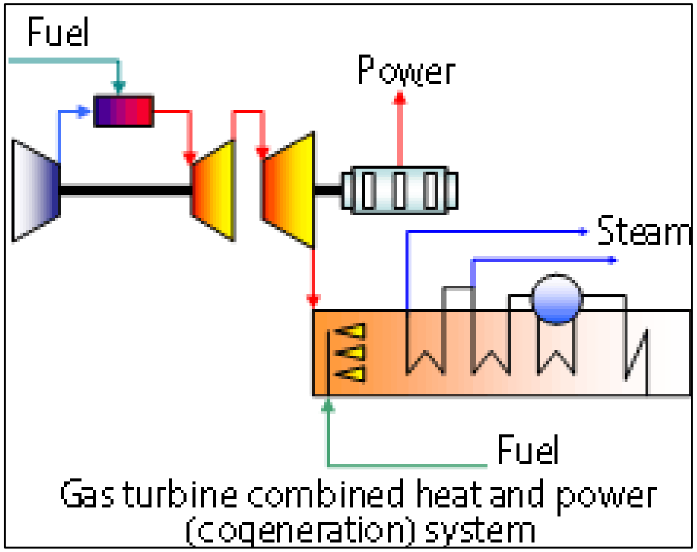
Open regenerative Brayton cycle

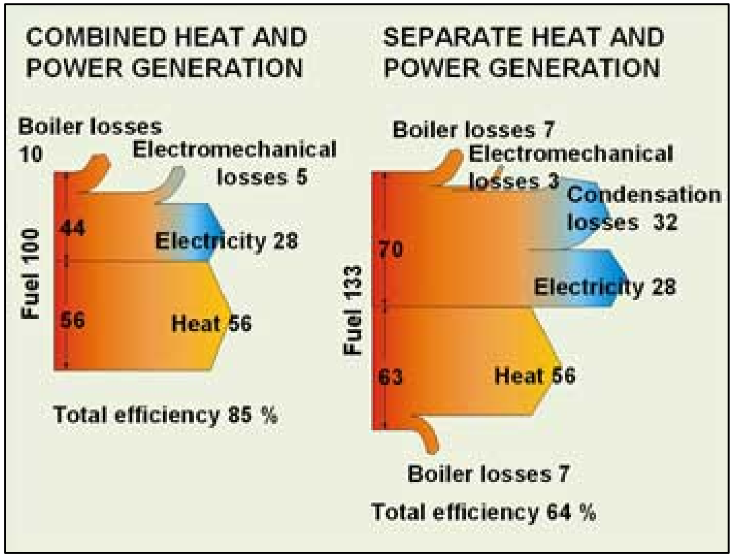
Combined Heat & Power (CHP)



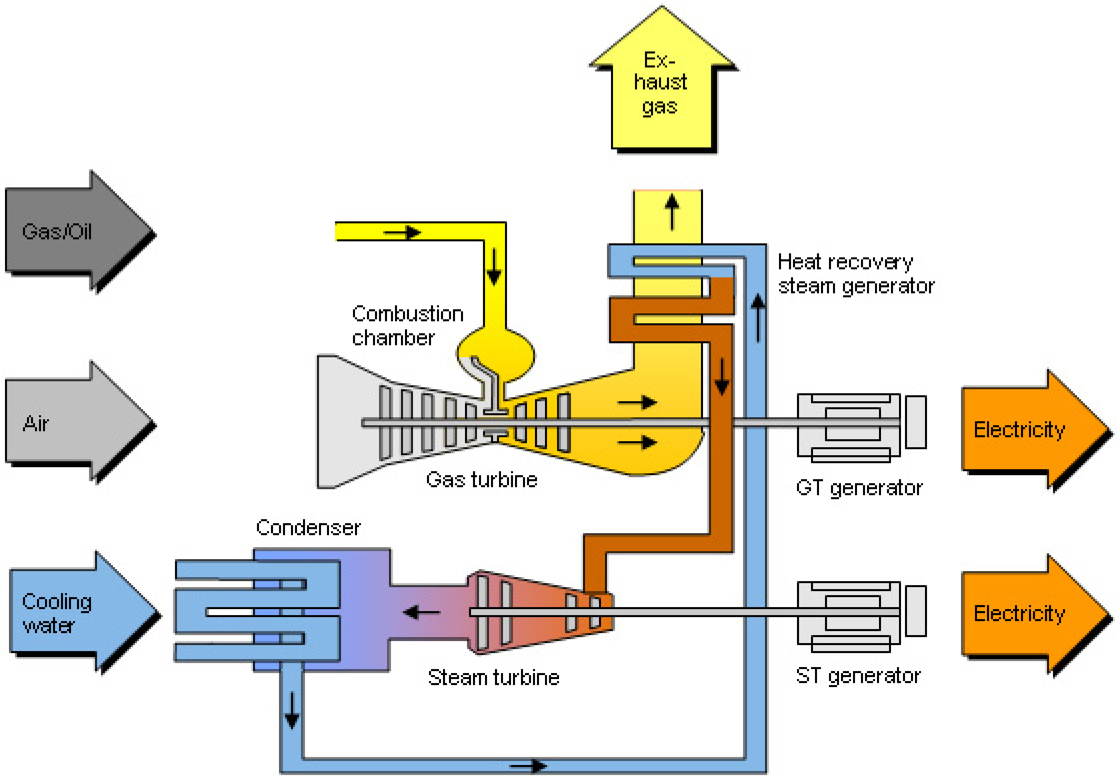
Engine or Gas Turbine Cogeneration (CHP)



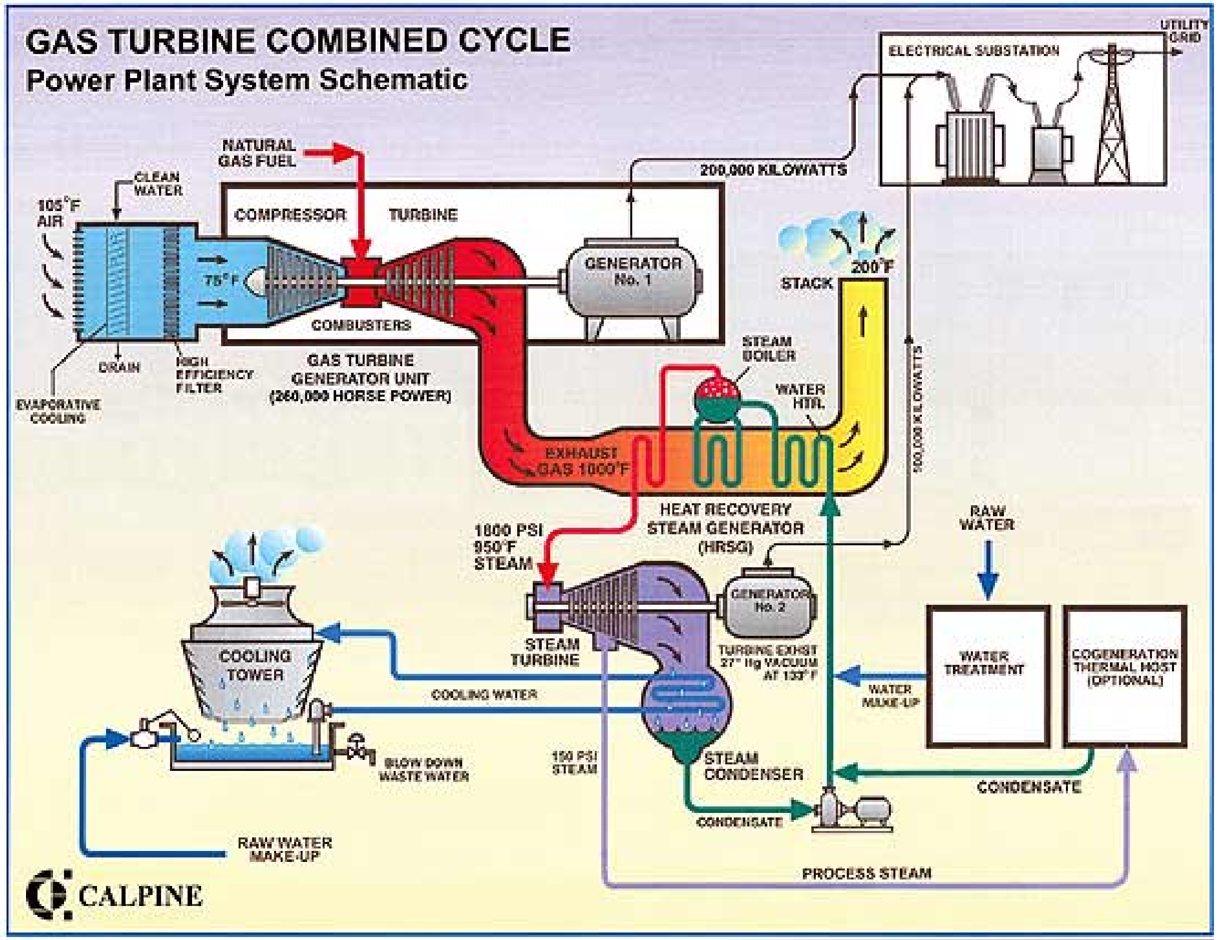




Natural Gas Combined Cycle - NGCC



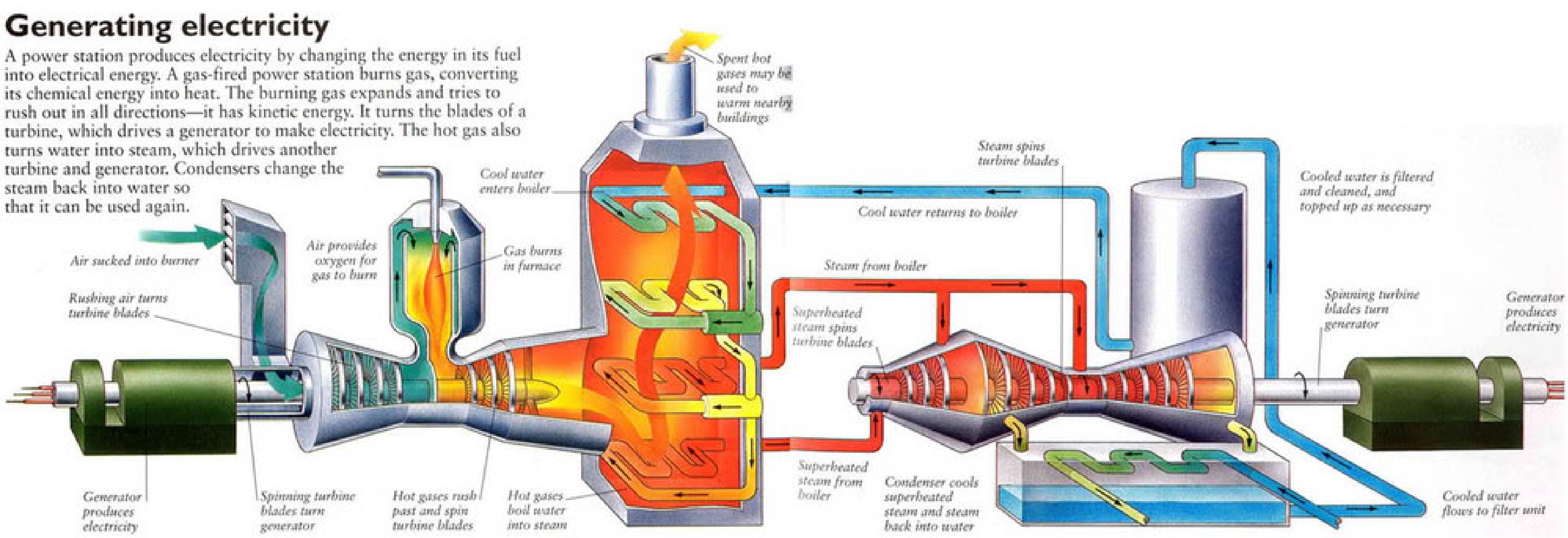
Combined Brayton/Rankine Cycle (NGCC)



base e

"Practical Strategies for Emerging Energy Technologies"

Natural Gas Combined Cycle - NGCC



Simples Cycle Gas Turbine Section
40% LHV Efficiency
1100 lb-CO_2/MWh

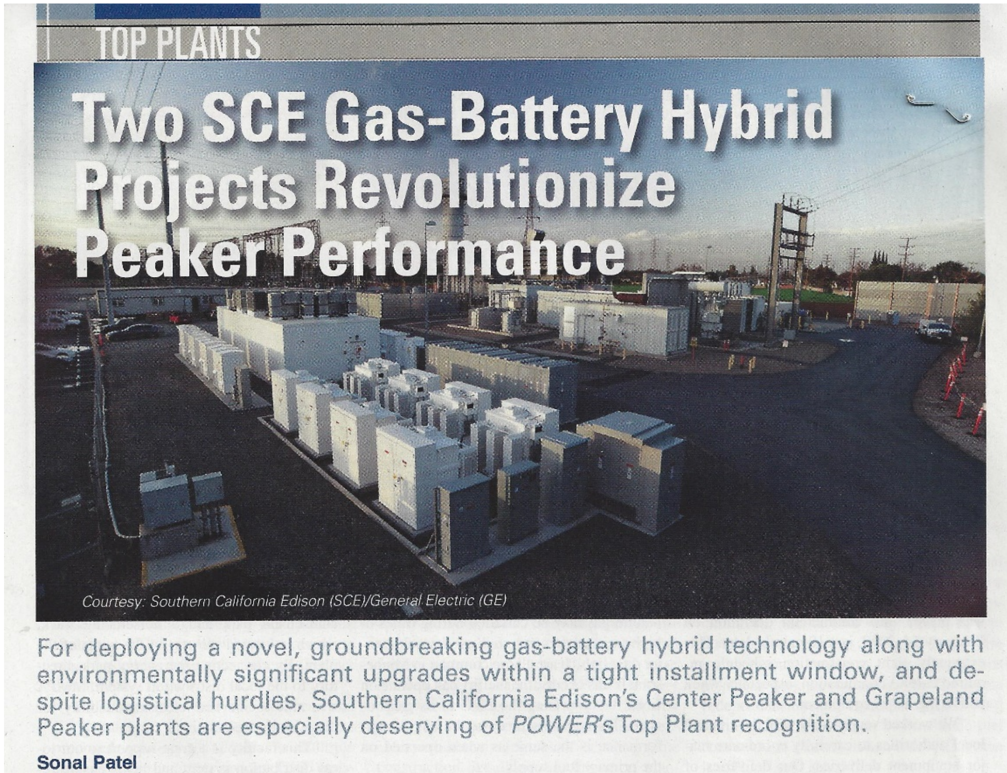
Combined Cycle “Adder”
60% LHV Efficiency
800 lb-CO2/MWh

“Practical Strategies for Emerging Energy Technologies”

Meeting New Challenges

- This issue concentrates on adapting HRSG to rapid start/load changes
- It neglects the impact on Downstream CCS systems……when employed

Gas-Battery Spinning Reserve



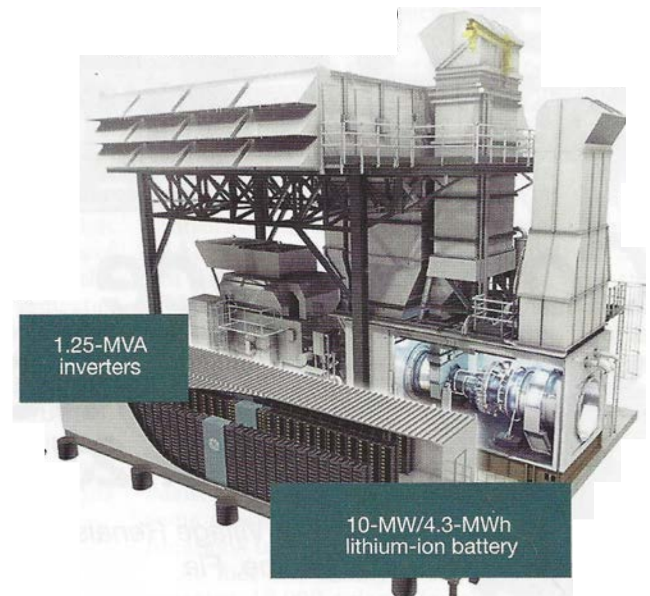
TOP PLANTS

Two SCE Gas-Battery Hybrid Projects Revolutionize Peaker Performance

Courtesy: Southern California Edison (SCE)/General Electric (GE)

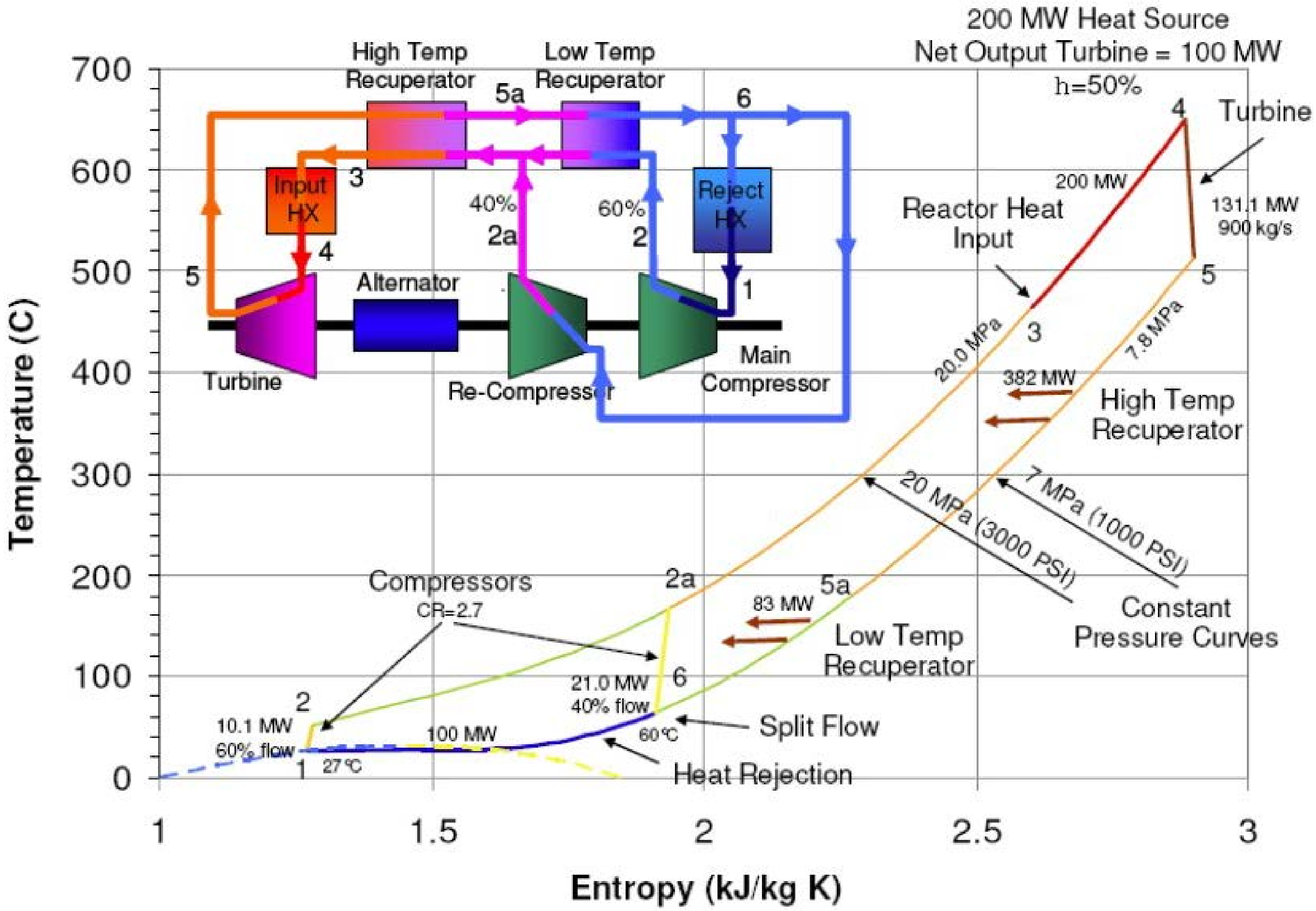
For deploying a novel, groundbreaking gas-battery hybrid technology along with environmentally significant upgrades within a tight installment window, and despite logistical hurdles, Southern California Edison's Center Peaker and Grapeland Peaker plants are especially deserving of *POWER*'s Top Plant recognition.

Sonal Patel



1. Hybrid EGT's most valuable function is, perhaps, its ability to respond instantaneously to grid needs

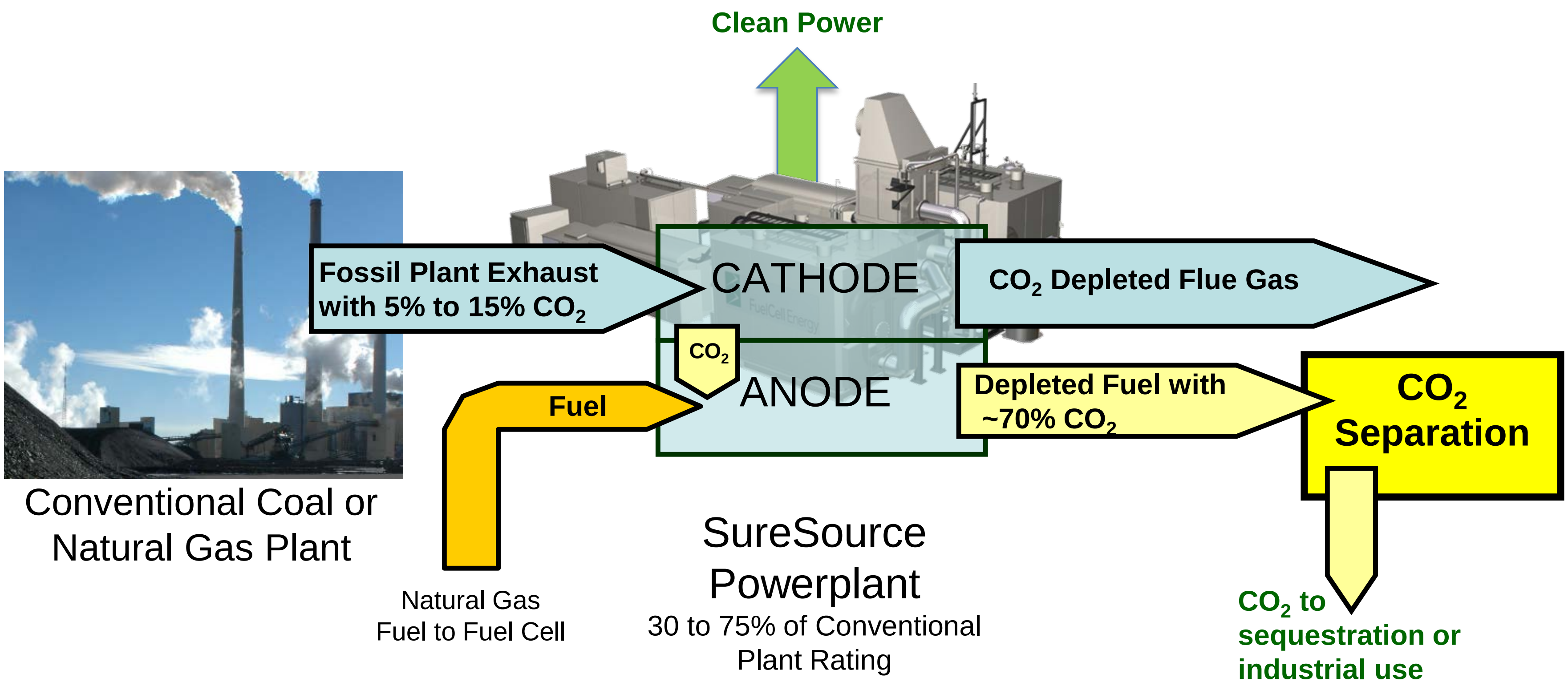
S-CO_2 Brayton Cycle



Supercritical CO_2 Brayton Cycle

Fuel Cell Carbon Capture

- Carbonate electrochemical process transfers CO_2 from Air Electrode (Cathode) to Fuel Electrode (Anode)
- CO_2 is easily separated from Anode exhaust gas because it is no longer diluted with air



CO_2 is concentrated by fuel cell process as a side reaction of power generation. Co-production of power during carbon capture enhances capture economics

Renewables

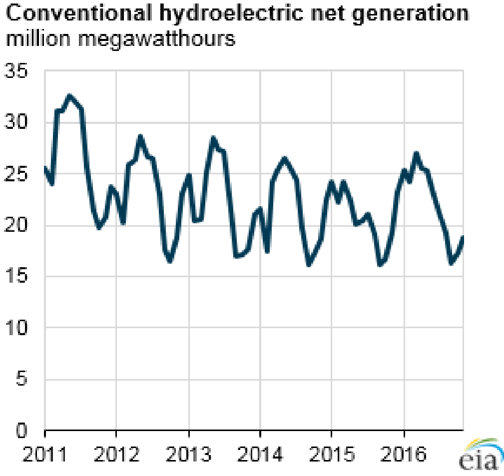
Electric Utility Power Mix Forecast

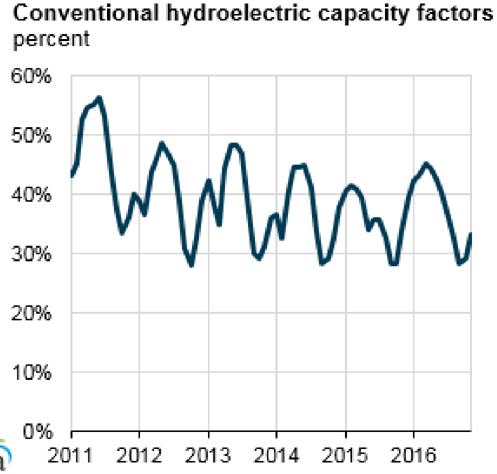
How do you think your utility's power mix will change over the next 10 years?

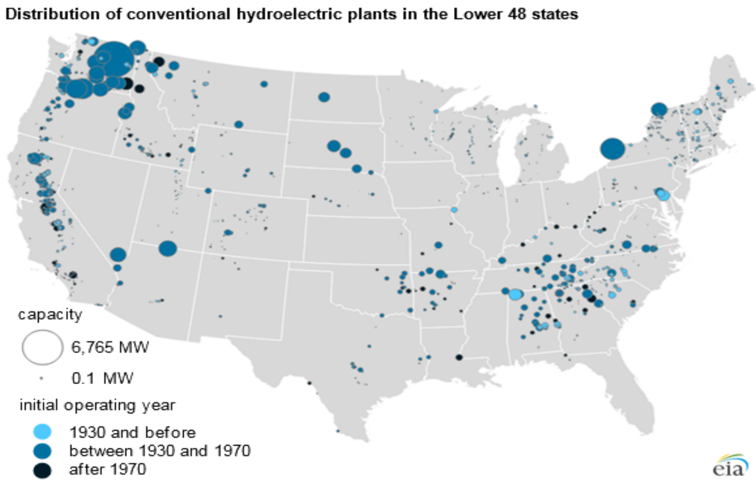
	Decrease significantly	Decrease moderately	Stay about the same	Increase moderately	Increase significantly
Utility Scale Solar	2%	1%	16%	**43%**	39%
Distributed generation	2%	2%	14%	**50%**	33%
Distributed energy storage	2%	1%	18%	**52%**	27%
Grid-scale energy storage	2%	2%	18%	**49%**	29%
Wind	2%	3%	24%	**48%**	23%
Natural Gas	2%	9%	25%	**42%**	22%
Hydro	2%	4%	**73%**	17%	4%
Biofuels	8%	6%	**61%**	23%	3%
Nuclear	20%	18%	**54%**	4%	4%
Oil	35%	19%	**42%**	3%	1%
Coal	**52%**	27%	18%	2%	2%

THE STATE OF ELECTRIC UTILITY 2017

U.S. Hydro Capacity is Very Old



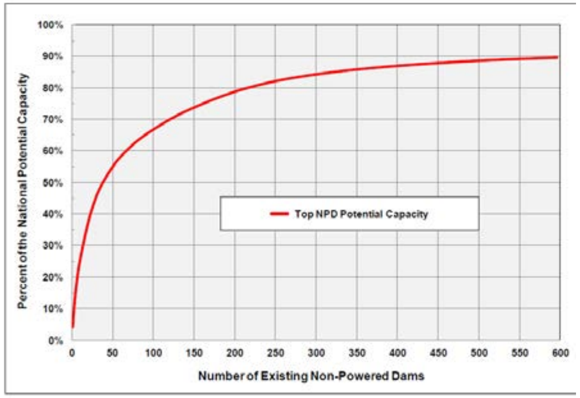


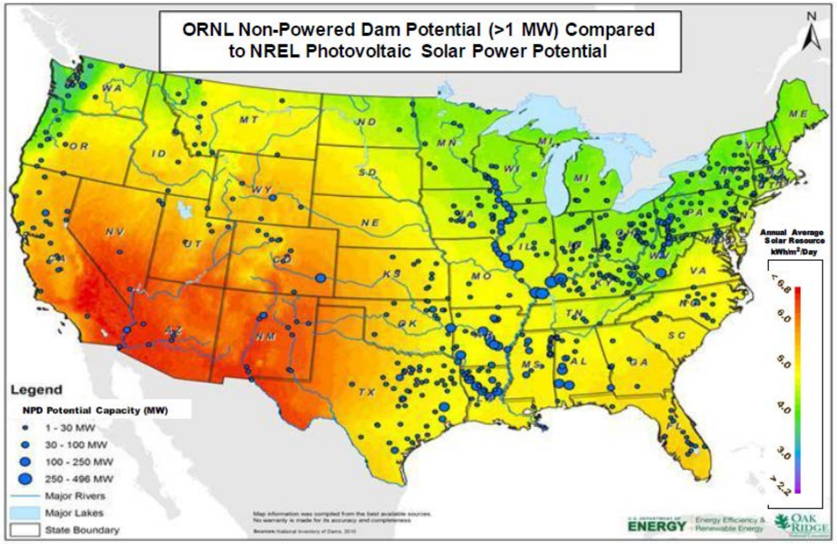


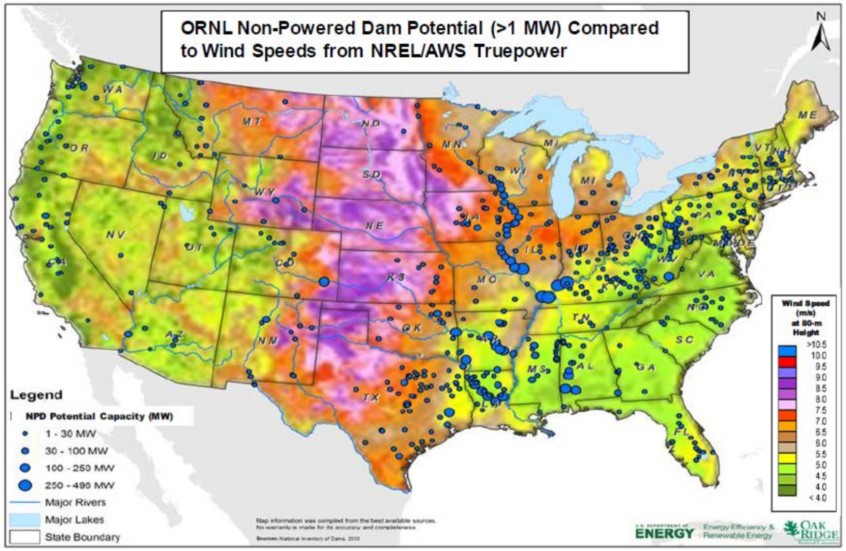
- Conventional hydroelectric generators account for 7% of the operating electricity generating capacity in the United States and about 6% to 7% of U.S. electricity generation each year.
- Hydropower plants account for 99% of all currently operating capacity built before 1930
- The 50 oldest electric generating plants in the United States are all hydroelectric generators; each has been in service since 1908.
- Many reservoirs must balance power output with competing water demand for irrigation, municipal, industrial, and other needs, as well as concerns with fish migration.
- As a result, hydroelectric facilities often do not run at full output. U.S. hydroelectric capacity factors, which measure actual output as a percent of total capacity, average between 30% and 40%.

12GW Complimentary Non-Power Dams (NPD)

Hydrologic Regions (HUC02)	Potential Capacity (MW)	Potential Generation (TWh/yr)	Hydrologic Regions (HUC02)	Potential Capacity (MW)	Potential Generation (MWh/yr)
1 New England	243	1.110	10 Missouri	258	0.865
2 Mid-Atlantic	479	1.997	11 Arkansas-White-Red	1898	5.960
3 South Atlantic-Gulf	1618	3.778	12 Texas-Gulf	608	1.308
4 Great Lakes	156	0.903	13 Rio Grande	98	0.241
5 Ohio	3236	13.603	14 Upper Colorado	53	0.145
6 Tennessee	53	0.197	15 Lower Colorado	124	0.370
7 Upper Mississippi	2027	9.943	16 Great Basin	29	0.080
8 Lower Mississippi	743	2.802	17 Pacific Northwest	225	0.871
9 Souris-Red-Rainy	58	0.239	18 California	156	0.586



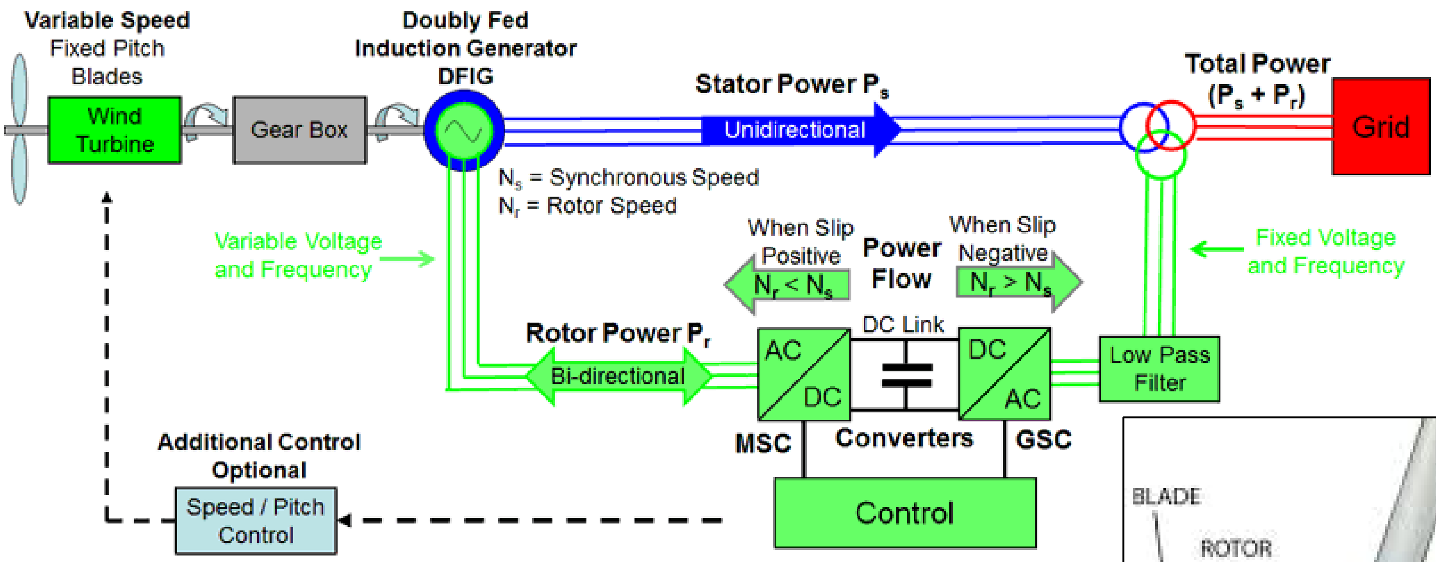


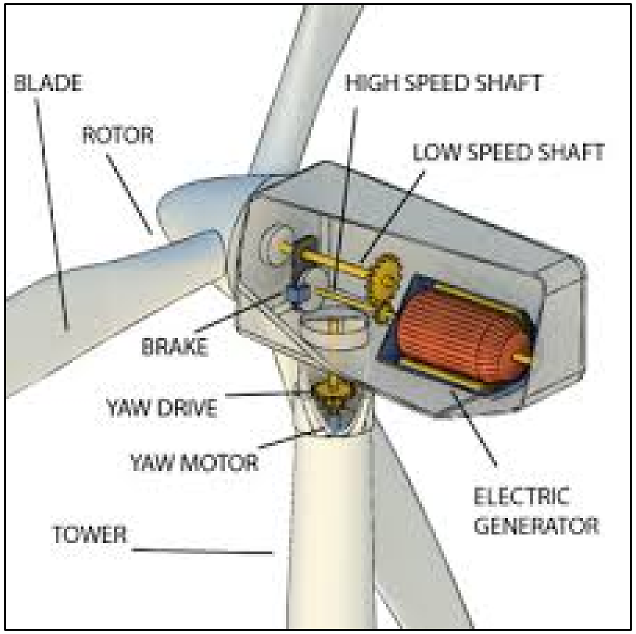


base e

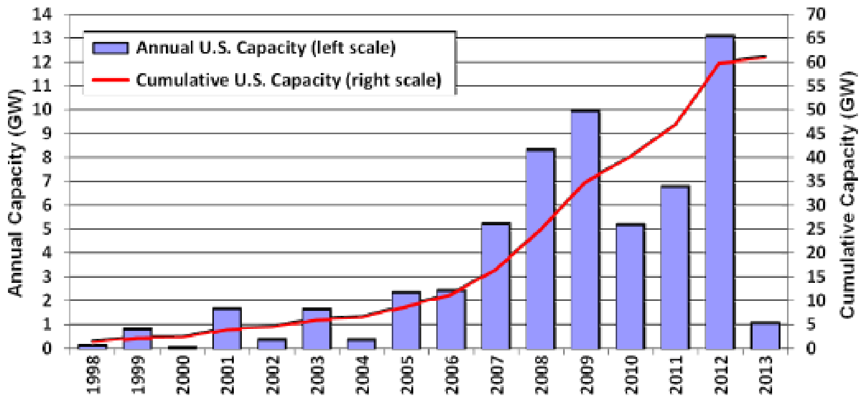
Wind Turbine

Asynchronous DFIG Wind Power Generator (Grid Scale)



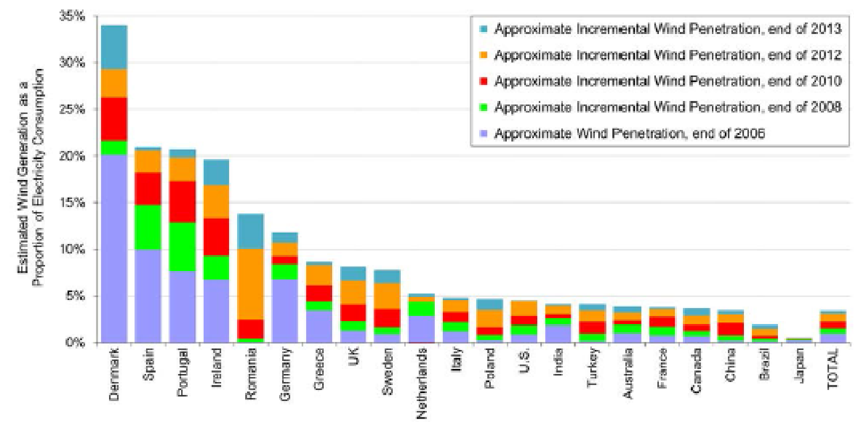


Wind Data



Source: AWEA project database

Figure 1. Annual and cumulative growth in U.S. wind power capacity



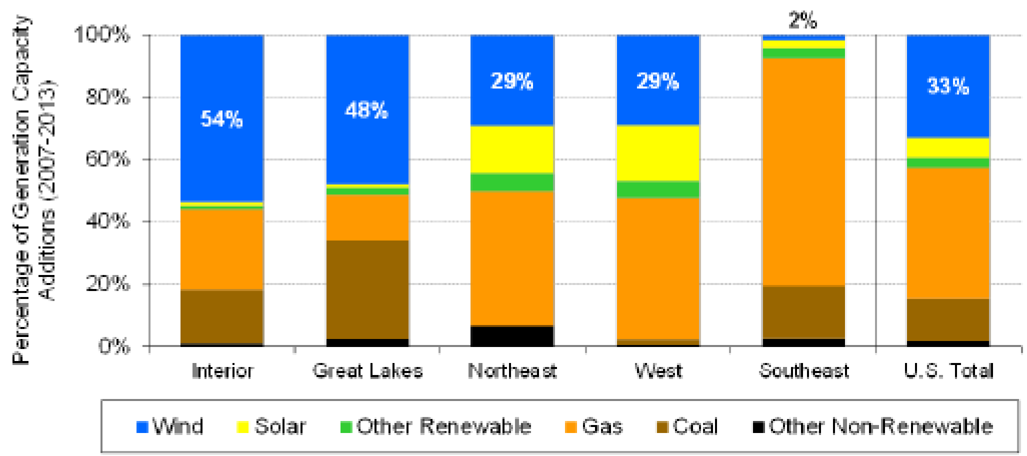
Source: Berkeley Lab estimates based on data from Navigant, EIA, and elsewhere

Figure 4. Approximate wind energy penetration in the countries with the greatest installed wind power capacity

Table 1. International rankings of wind power capacity

Annual Capacity (2013, MW)		Cumulative Capacity (end of 2013, MW)	
China	16,088	China	91,460
Germany	3,237	United States	61,110
India	1,987	Germany	34,468
United Kingdom	1,833	Spain	22,637
Canada	1,599	India	20,589
United States	1,087	United Kingdom	10,946
Brazil	948	Italy	8,448
Poland	894	France	8,128
Sweden	724	Canada	7,813
Romania	695	Denmark	4,747
Rest of World	7,045	*Rest of World*	51,031
TOTAL	36,137	TOTAL	321,377

Source: Navigant; AWEA project database for U.S. capacity



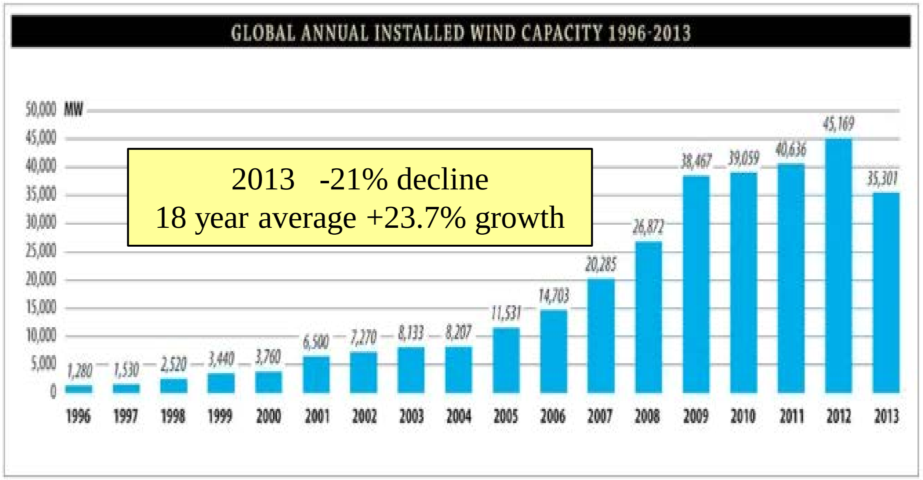
Source: EIA, Ventyx, AWEA, Interstate Renewable Energy Council, SEIA/GTM Research, Berkeley Lab

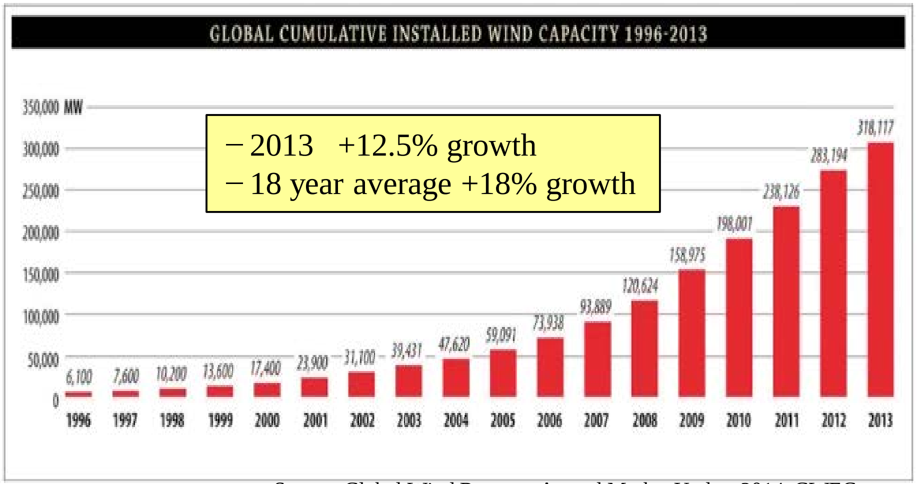
Figure 3. Generation capacity additions by region (2007–2013)

base e

“Practical Strategies for Emerging Energy Technologies”

Wind Installed Capacity & Load Factors (2012)





Source: Global Wind Report – Annual Market Update 2014, GWEC

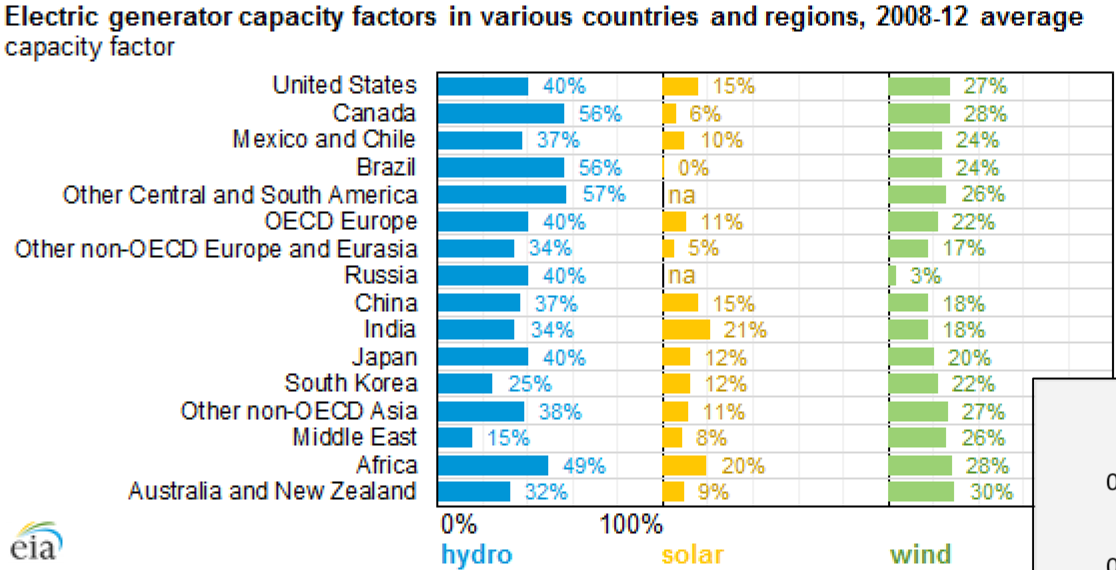
Average Load Factor is 21.5%

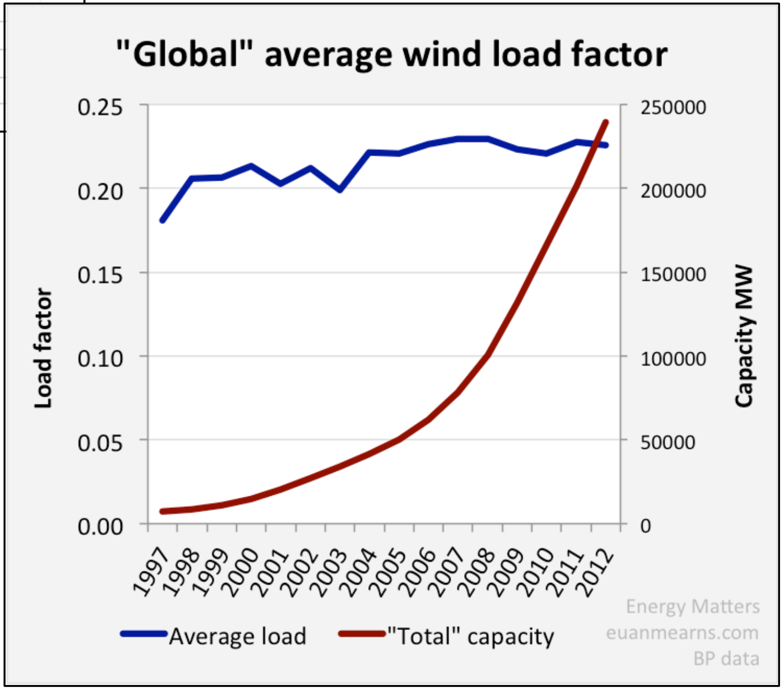
- High 28.3% - Denmark
  - 26.8% - USA
  - 17.9% - China
- Low 16.8% - Germany

Top windpower electricity producing countries in 2012 (TWh)

Country	Windpower Production	% of World Total	Nameplate GW	Nameplate TWh	Load Factor
United States	140.9	26.40%	60.0	526	26.8%
China	118.1	22.10%	75.3	660	17.9%
Spain	49.1	9.20%	22.8	200	24.6%
Germany	46.0	8.60%	31.3	274	16.8%
India	30.0	5.60%	18.4	161	18.6%
United Kingdom	19.6	3.70%	8.4	74	26.6%
France	14.9	2.80%	7.6	67	22.4%
Italy	13.4	2.00%	8.1	71	18.9%
Canada	11.8	2.20%	6.2	54	21.7%
Denmark	10.3	1.90%	4.2	36	28.3%
Rest of World	80.2	15.00%	40.9	358	22.4%
World Total	534.3	100.00%	283.1	2480	21.5%

Renewables Load Factor

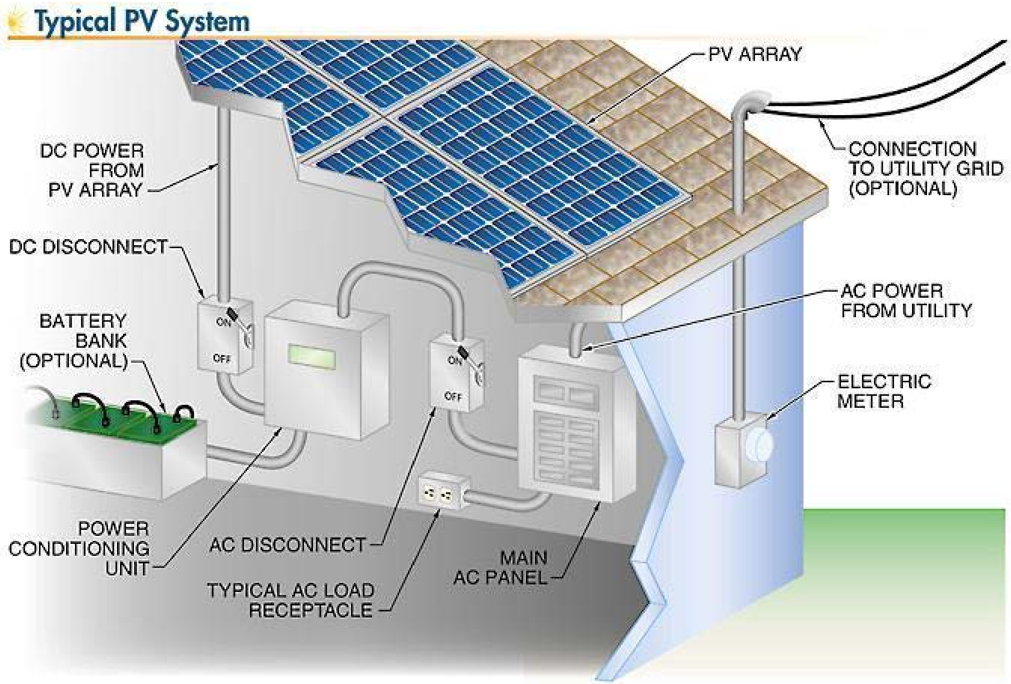




base e

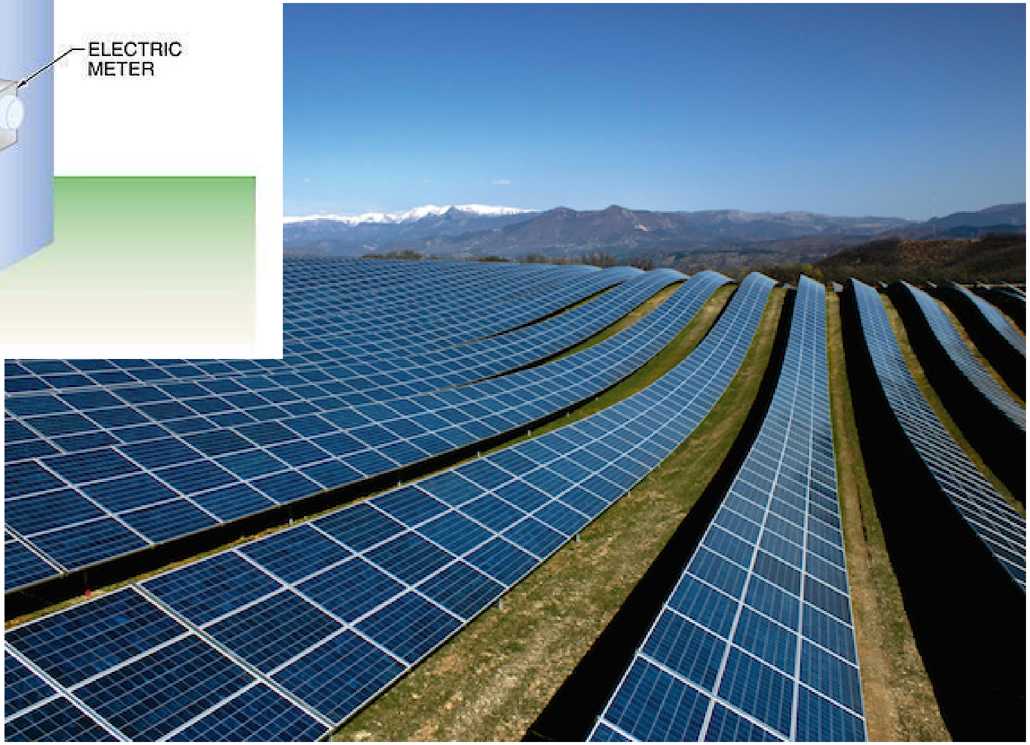
“Practical Strategies for Emerging Energy Technologies”

Photovoltaic (PV)

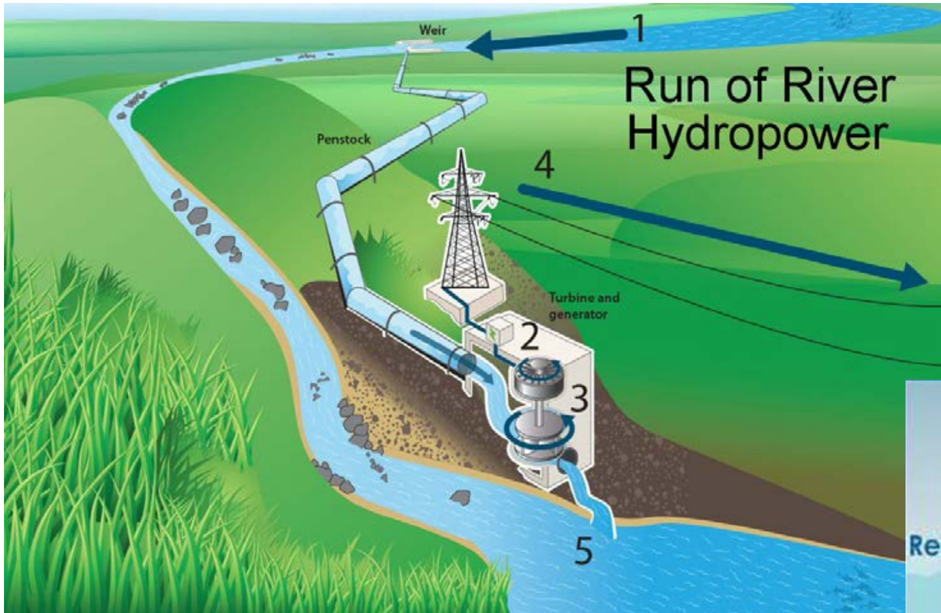


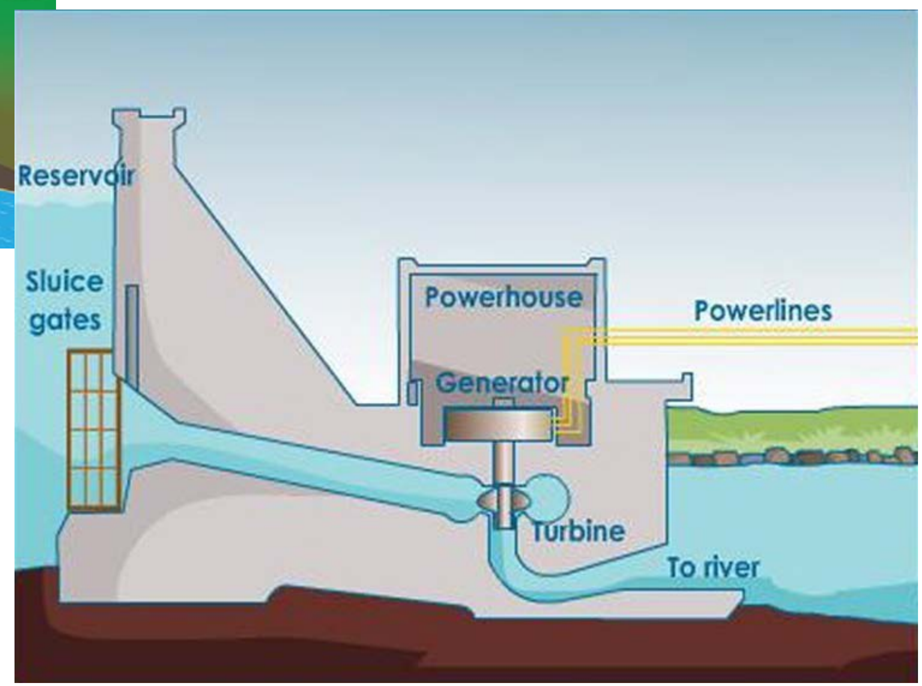
Residential

Utility Scale



Hydro Power

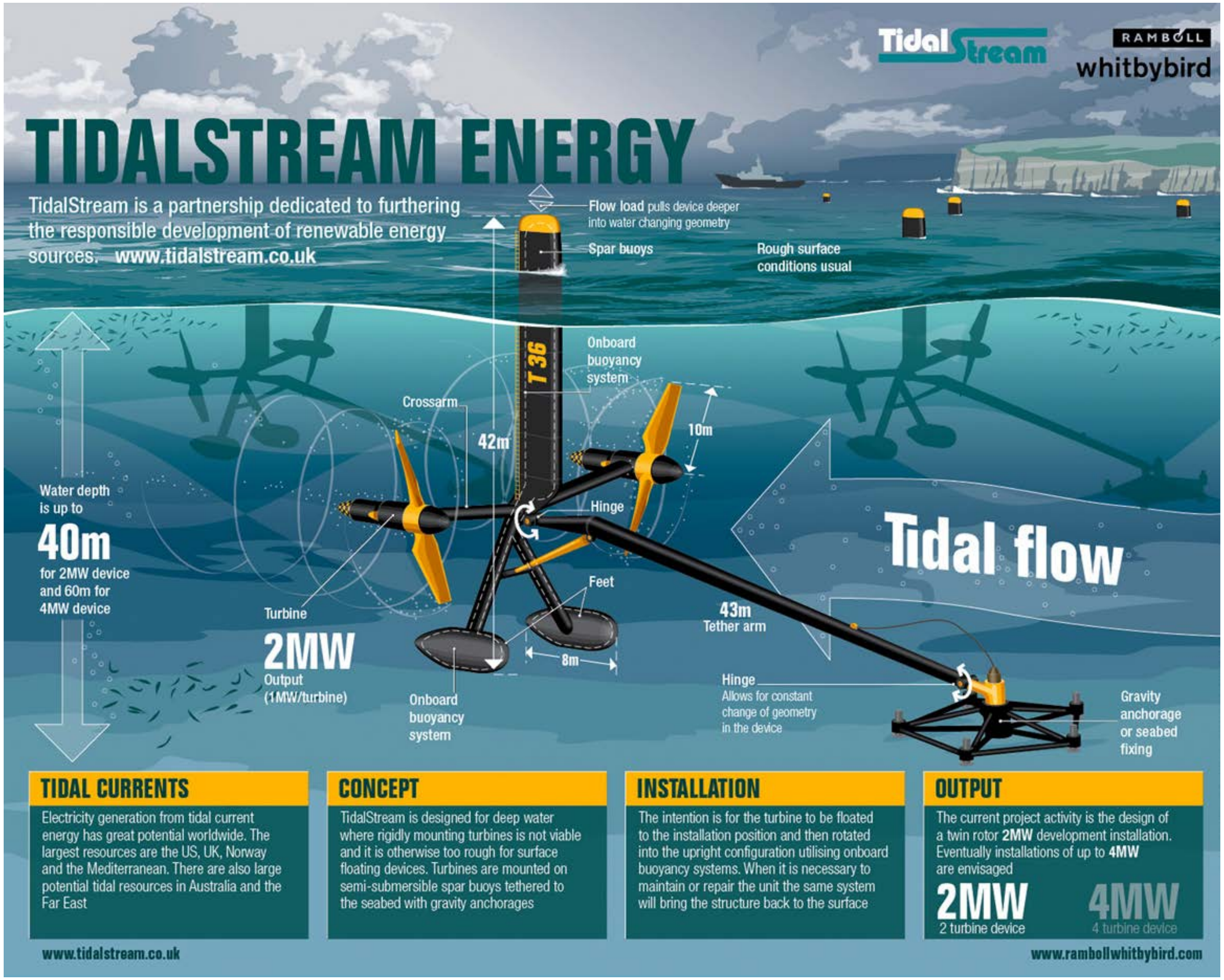




base$_e$

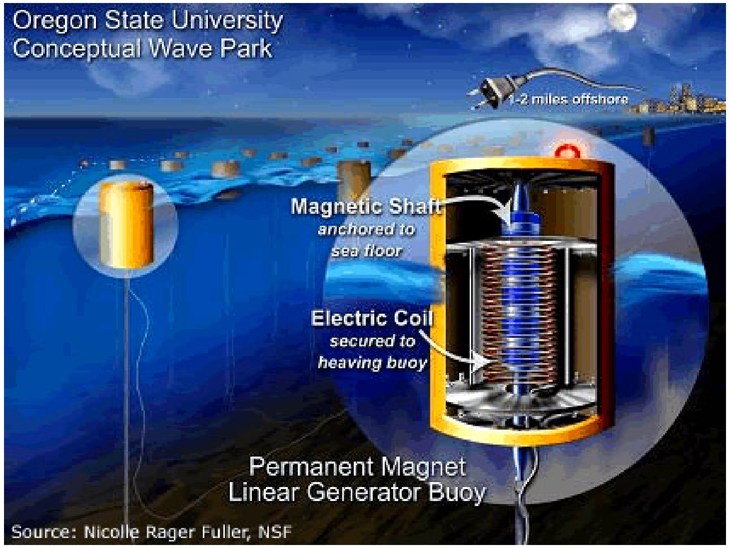
"Practical Strategies for Emerging Energy Technologies"

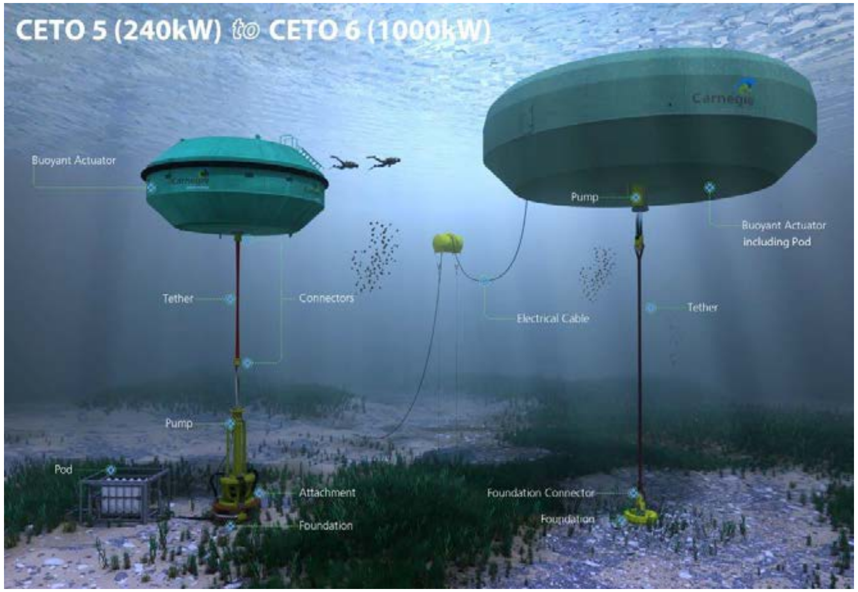
Tidal Power



TidalStream
RAMBOLL
whitbybird
TIDALSTREAM ENERGY
TidalStream is a partnership dedicated to furthering the responsible development of renewable energy sources. www.tidalstream.co.uk
Flow load pulls device deeper into water changing geometry
Spar buoys
Rough surface conditions usual
Onboard buoyancy system
T 36
Crossarm
42m
10m
Hinge
Water depth is up to
40m
for 2MW device and 60m for 4MW device
Feet
Tidal flow
Turbine
2MW
Output (1MW/turbine)
8m
43m
Tether arm
Onboard buoyancy system
Hinge
Allows for constant change of geometry in the device
Gravity anchorage or seabed fixing
TIDAL CURRENTS
Electricity generation from tidal current energy has great potential worldwide. The largest resources are the US, UK, Norway and the Mediterranean. There are also large potential tidal resources in Australia and the Far East
CONCEPT
TidalStream is designed for deep water where rigidly mounting turbines is not viable and it is otherwise too rough for surface floating devices. Turbines are mounted on semi-submersible spar buoys tethered to the seabed with gravity anchorages
INSTALLATION
The intention is for the turbine to be floated to the installation position and then rotated into the upright configuration utilising onboard buoyancy systems. When it is necessary to maintain or repair the unit the same system will bring the structure back to the surface
OUTPUT
The current project activity is the design of a twin rotor 2MW development installation. Eventually installations of up to 4MW are envisaged
2MW
2 turbine device
4MW
4 turbine device
www.tidalstream.co.uk
www.rambollwhitbybird.com

Wave Power

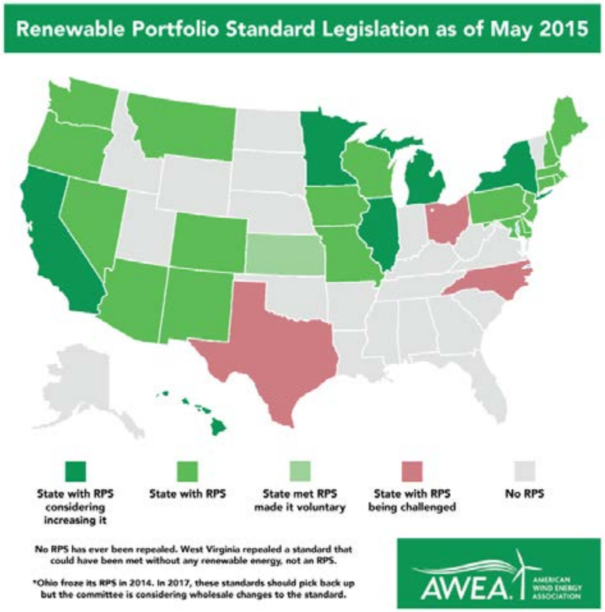




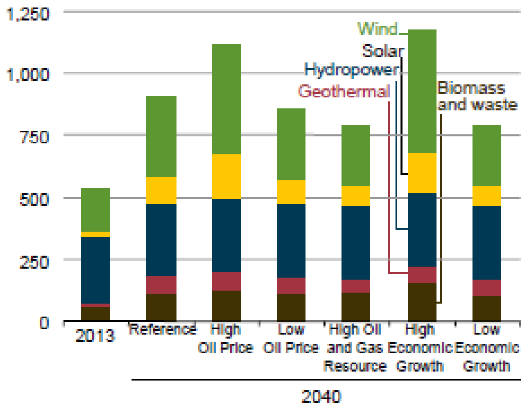
base e

"Practical Strategies for Emerging Energy Technologies"

Renewable Portfolio Standards



- Seven states—Hawaii, California, Nevada, Colorado, Minnesota, Connecticut, and Oregon—have effective RPS requirements of 25 percent or greater.
- Six states – CA, MI, NY, MN, IL and VT – are seriously debating an increase in their RPS this year.
- Ohio: With the signing of Senate Bill 310 in 2014, Ohio became the only state to “freeze” its RPS, effectively halting the state’s mandates for efficiency and renewables until 2017. In 2017, these standards should pick up where they left off when the freeze occurred, however an Energy Mandates Study Committee is reviewing wholesale changes to the standard. In this context of policy uncertainty, renewable energy employment and investment is moving away, to more welcoming states.
- Legislators in four states (CO, MT, CT, and NH) have voted down proposals to diminish or repeal RPS policies this year.



AEO 2015 Total U.S. renewable generation by fuel in 2013 & six 2040 cases (billion kWh)

Net total available to the grid

2013	= 3,888 billion kWh (~14%)
2040 Ref	= 4,672 billion kWh (~19%)

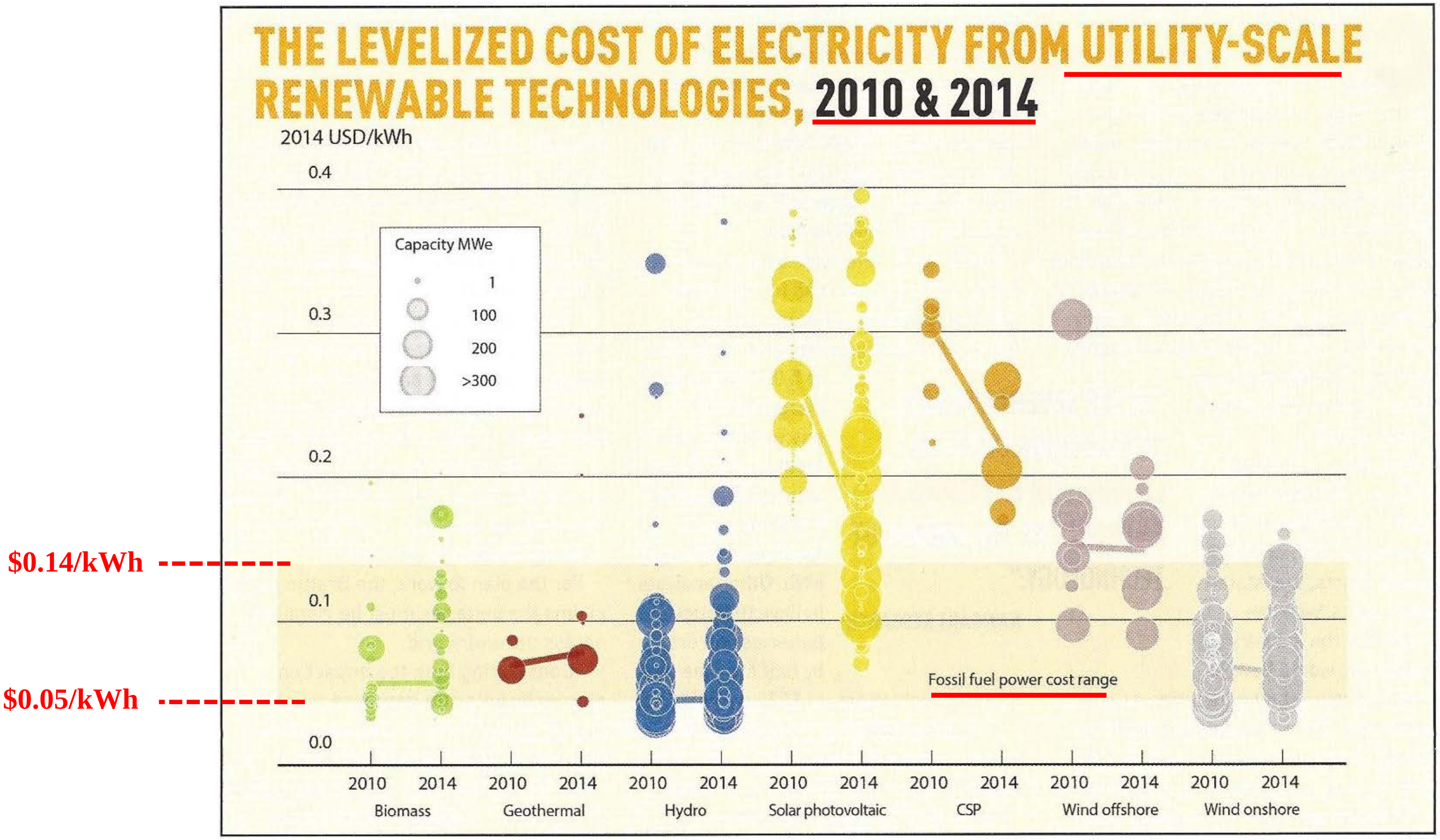
- Renewables get to dispatch first
- If they can make power, the grid has to take it
- Imposing their inherent variability on the entire grid

Source: American Wind Energy Association (AWEA)

Summary of PTC & ITC Extension Phase Down

- The final extension of the PTC and ITC occurred in the FY16 Omnibus Appropriations Bill, passed on December 18, 2015
  - Included a five-year extension and phase-down of the PTC
  - As well as the option to elect the investment tax credit for wind energy
- The tax credits, extended through 2019, have begun phasing down by 20 percent each year beginning in 2017
  - PTC wind projects that started construction
    - 2015 and 2016 receive a full value PTC of 2.4 cents per kilowatt hour.
    - 2017, the credit is at 80 percent of full value
    - 2018, 60 percent PTC
    - 2019, 40 percent PTC.
  - The ITC election for wind energy projects that started construction
    - 2015 and 2016 are eligible for a full 30 percent ITC
    - 2017, a 24 percent ITC
    - 2018, an 18 percent ITC
    - 2019, a 12 percent ITC.
- Rules will allow wind projects to qualify as long as they start construction before the end of the period.

Renewables Levelized Cost 2010 & 2014

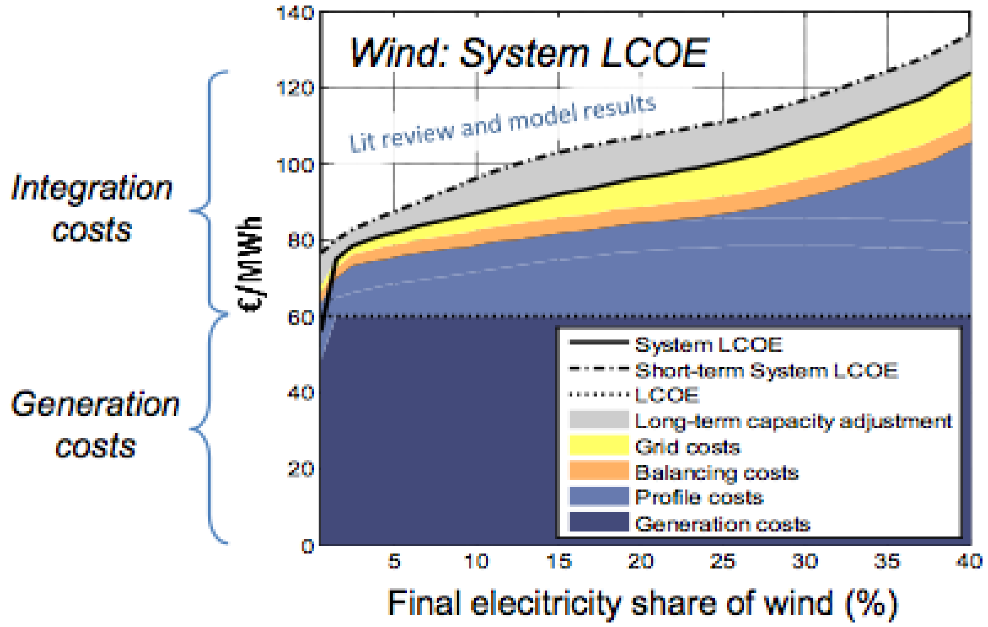


Source: IRENA Renewable Cost Database.
Note: Size of the diameter of the circle represents the size of the project. The centre of each circle is the value for the cost of each project on the Y axis. Real weighted average cost of capital is 7.5% in OECD countries and China; 10% in the rest of the world.

Wind Integration Costs

- Integration includes:
  - Fluctuating output profile costs
  - Output uncertainties balancing costs
  - Grid costs

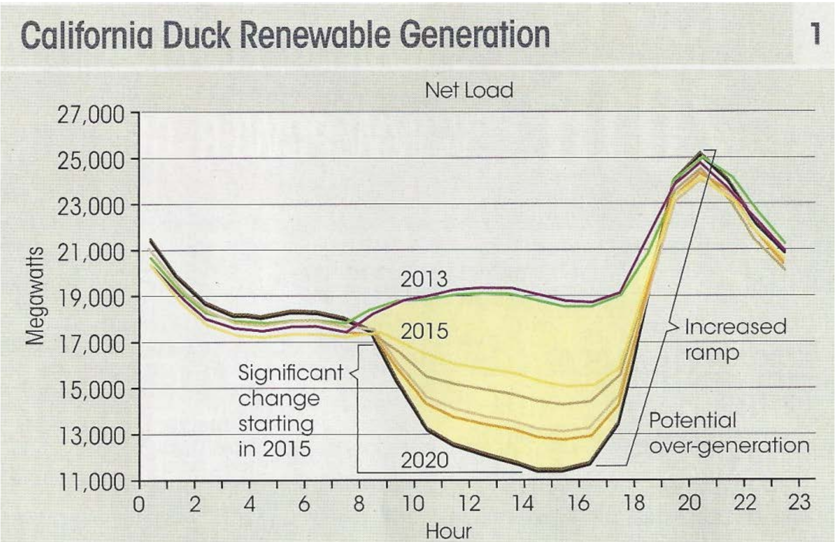
At higher penetration, integration costs for wind exceed generation costs.



Source: System LCOE: What are the costs of variable renewables?
Falko Ueckerdt, Lion Hirth, Gunnar Luderer, Ottmar Edenhofer
Paris, June 20, 2013 32th International Energy Workshop

As presented by John Thompson Clean Air Task Force CCS – Pittsburgh 2104

Dealing with an even "Bigger" Duck



The California Duck is a graphic published by the California Independent System Operator that projects the expected need for non-renewable generation over a 24-hour day. Each line in the duck is a different year from 2013 to 2020. As time marches on and more solar generation is placed on line, the non-renewable demand drops during midday. The change in hourly demand drives the 2013 line, the duck's back. The solar generation that will be online by 2020 results in a dip in non-renewable demand during midday – the duck's belly.

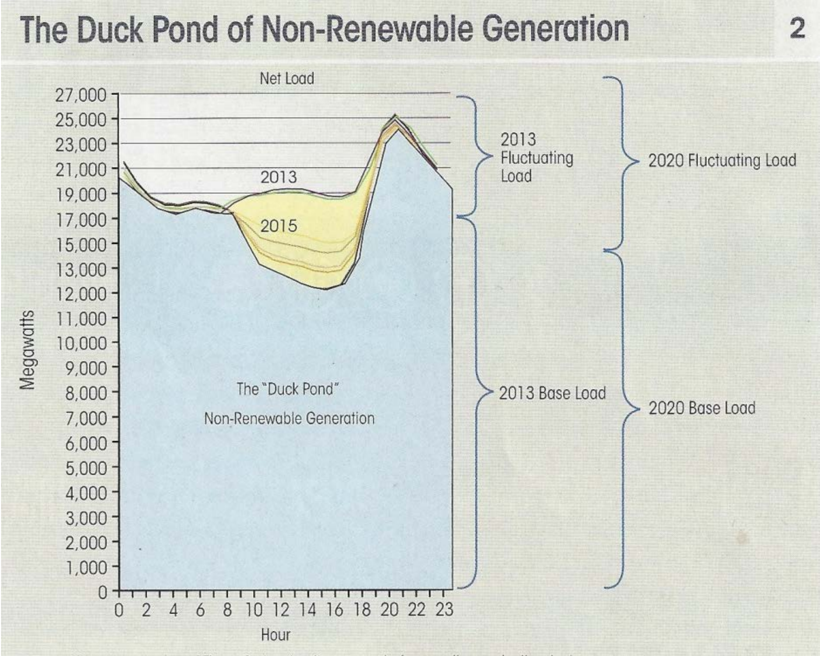
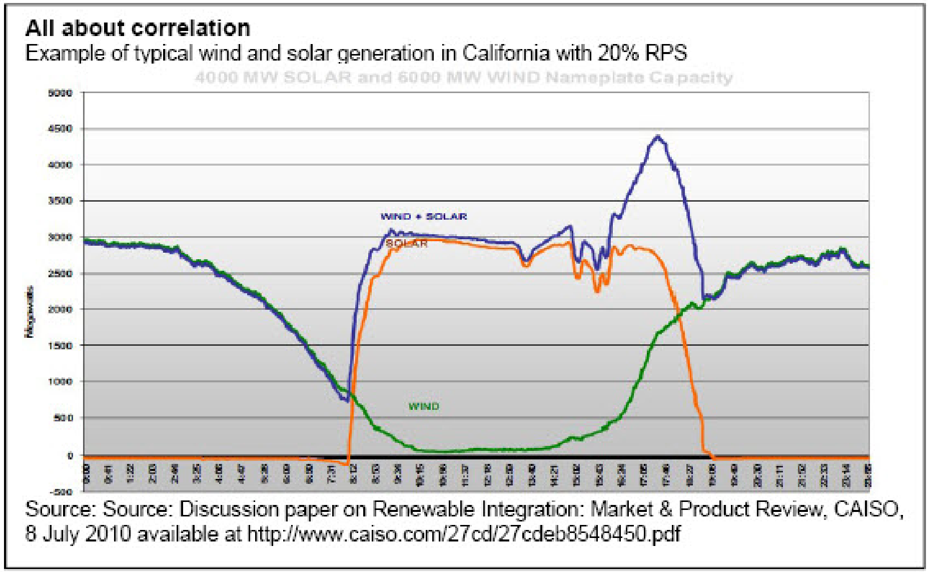
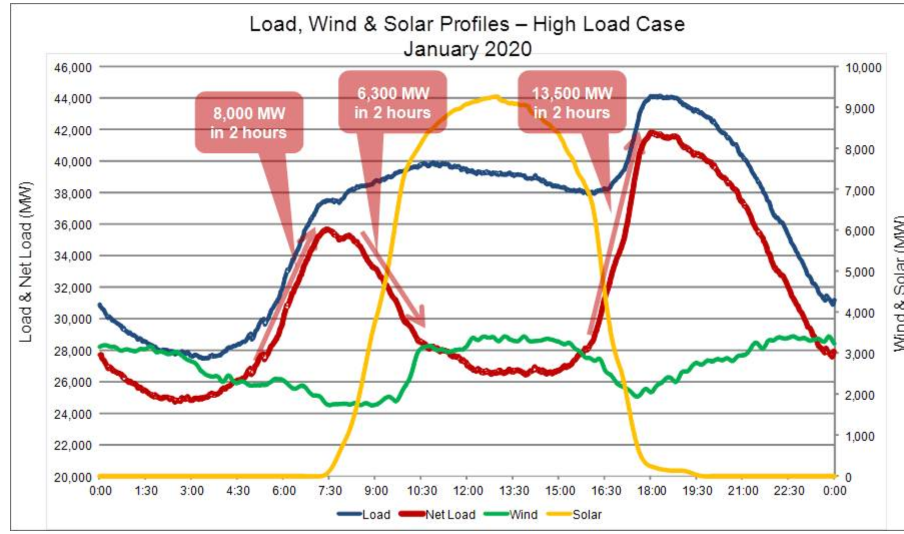


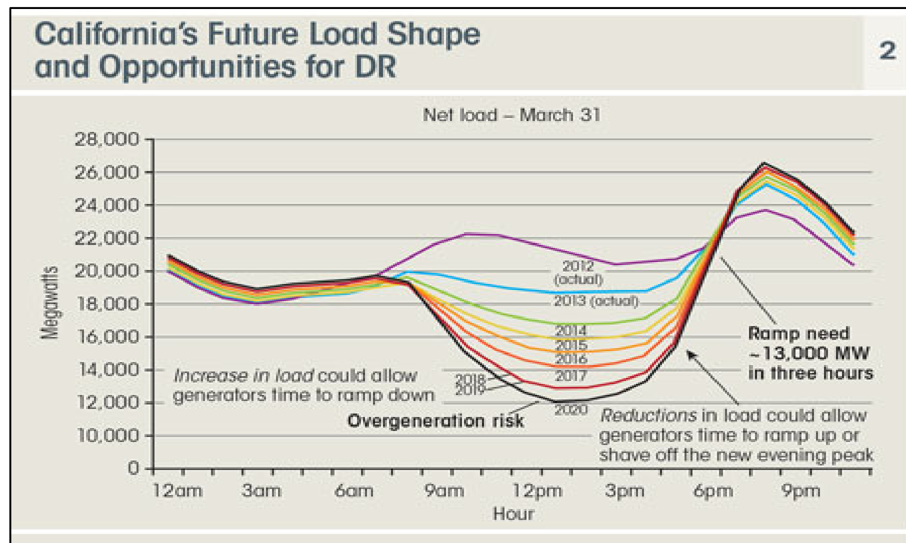
Figure 2 is an expansion of Figure 1, showing the amount of generation under the duck.

Source: Bonnie Marini – Siemens Energy
Through Power Engineering

Integrating Renewables "Dealing with The Duck"

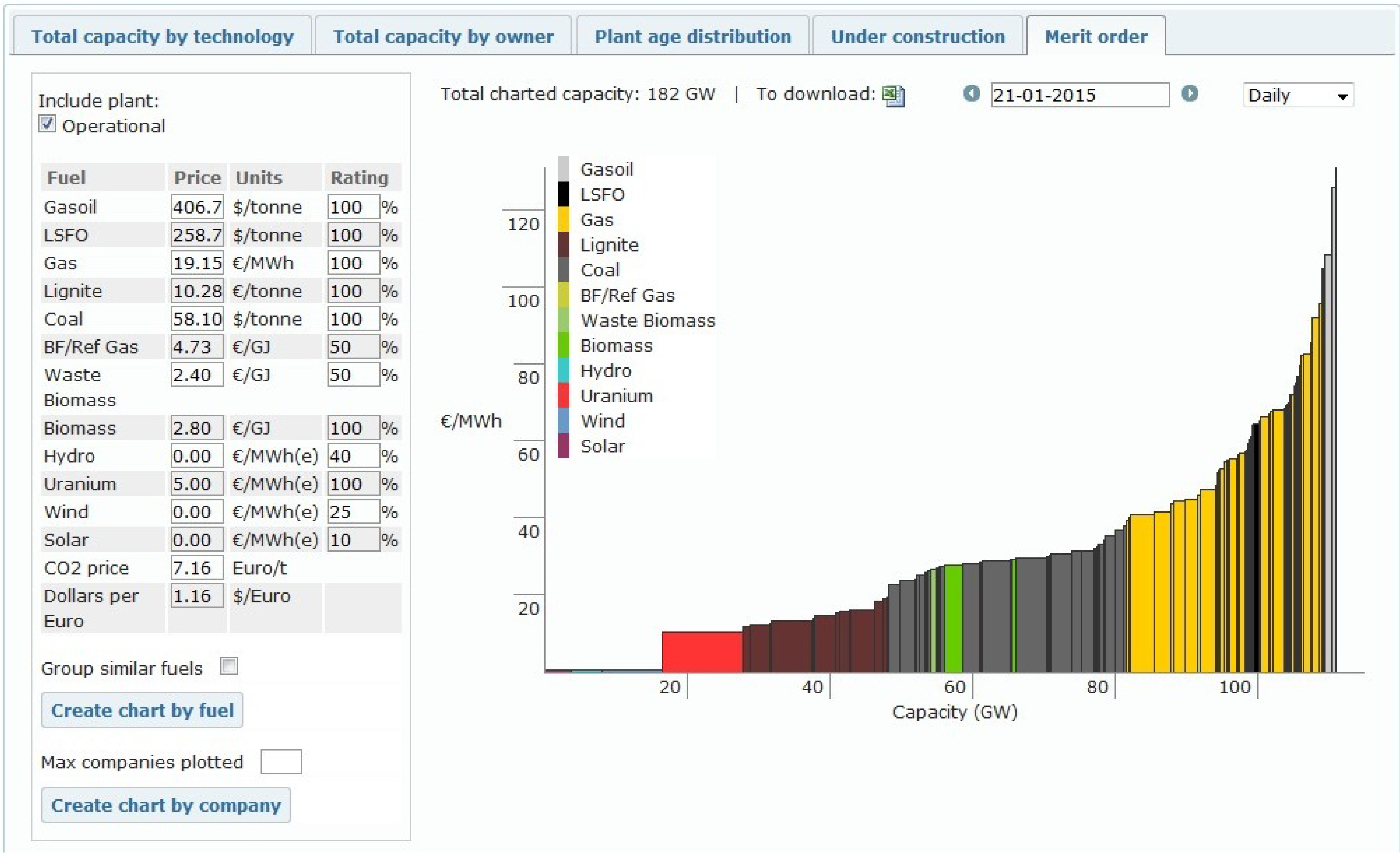






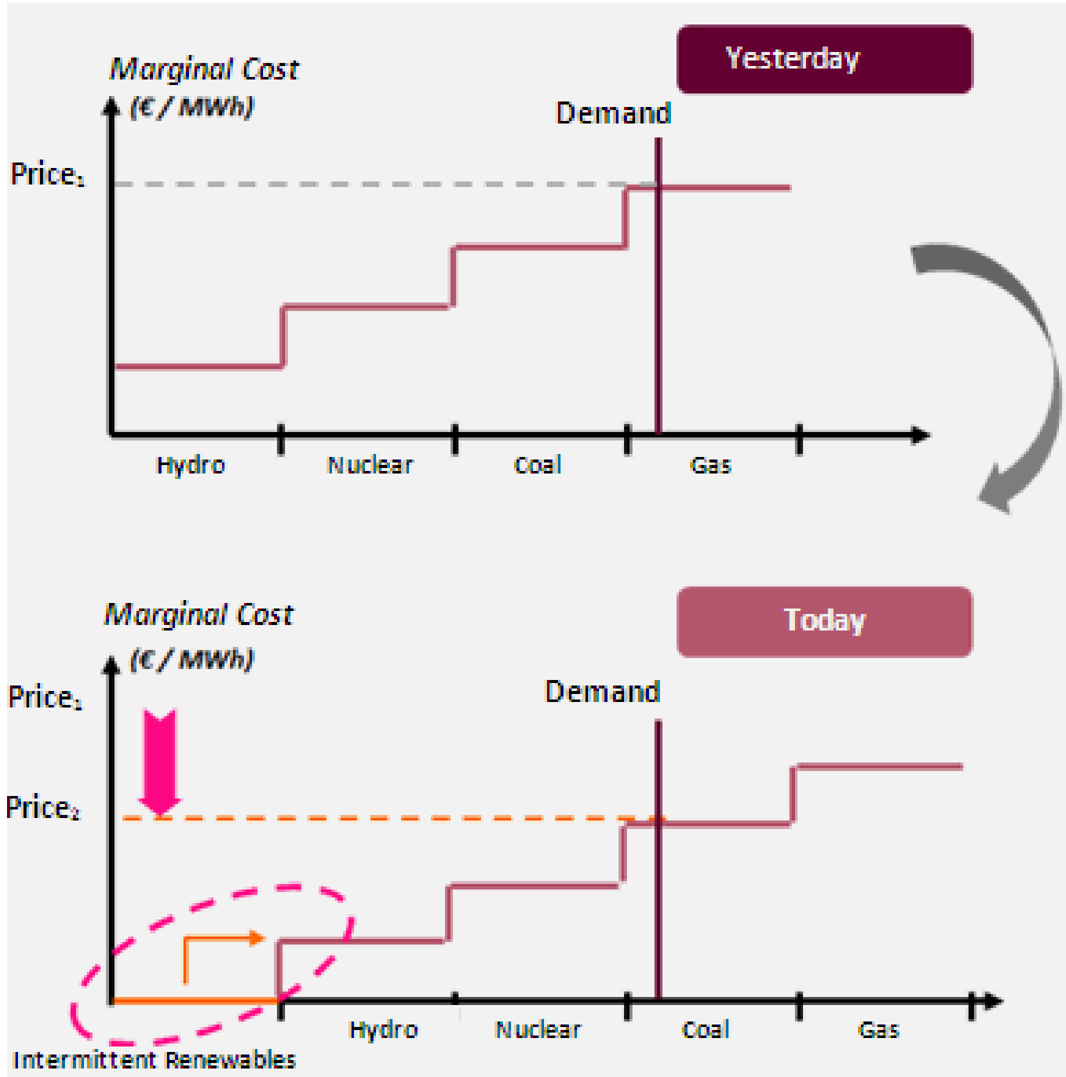
"Practical Strategies for Emerging Energy Technologies"

Economic Merit Order Dispatch



“Practical Strategies for Emerging Energy Technologies”

Impact of Intermittent Renewables on Merit Order



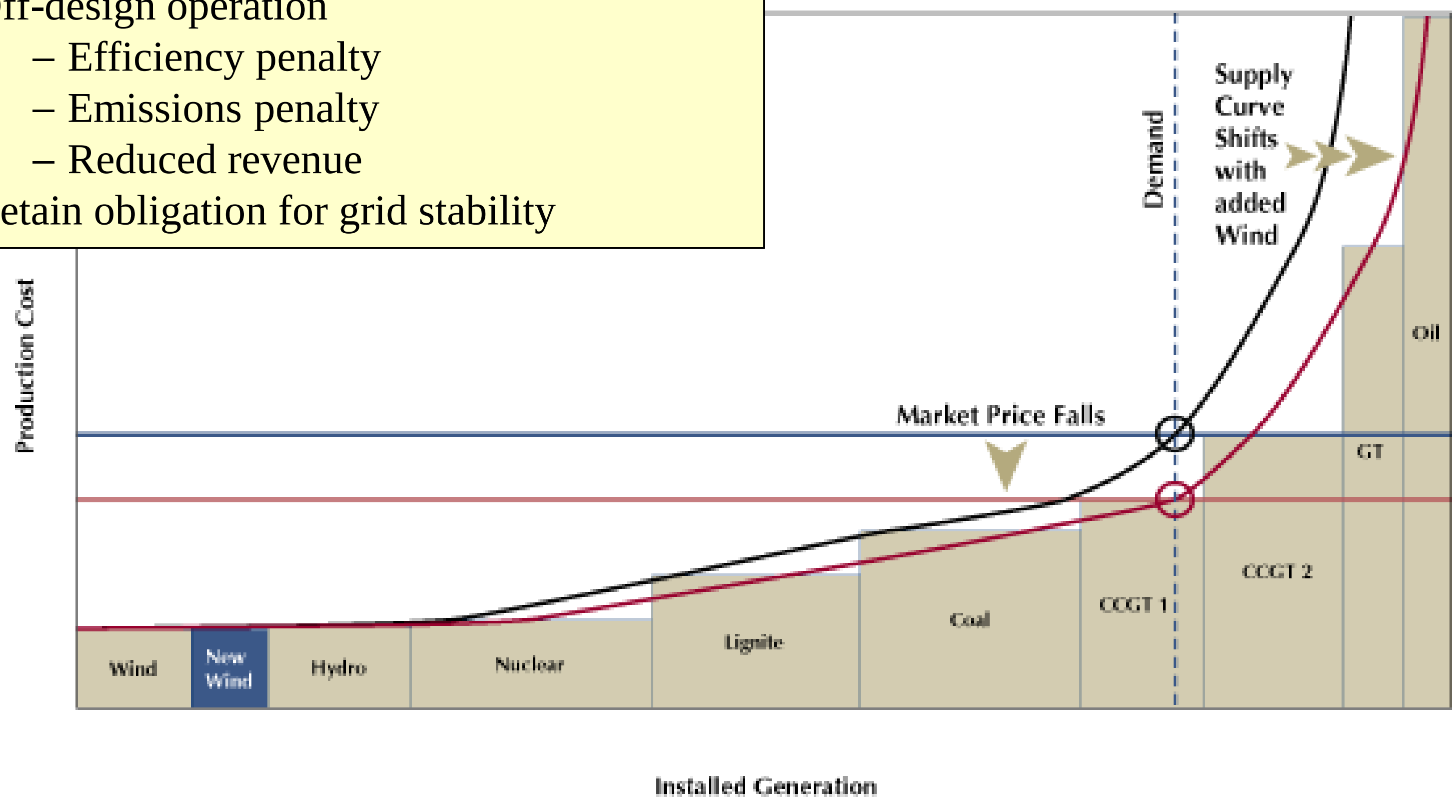
base e

"Practical Strategies for Emerging Energy Technologies"

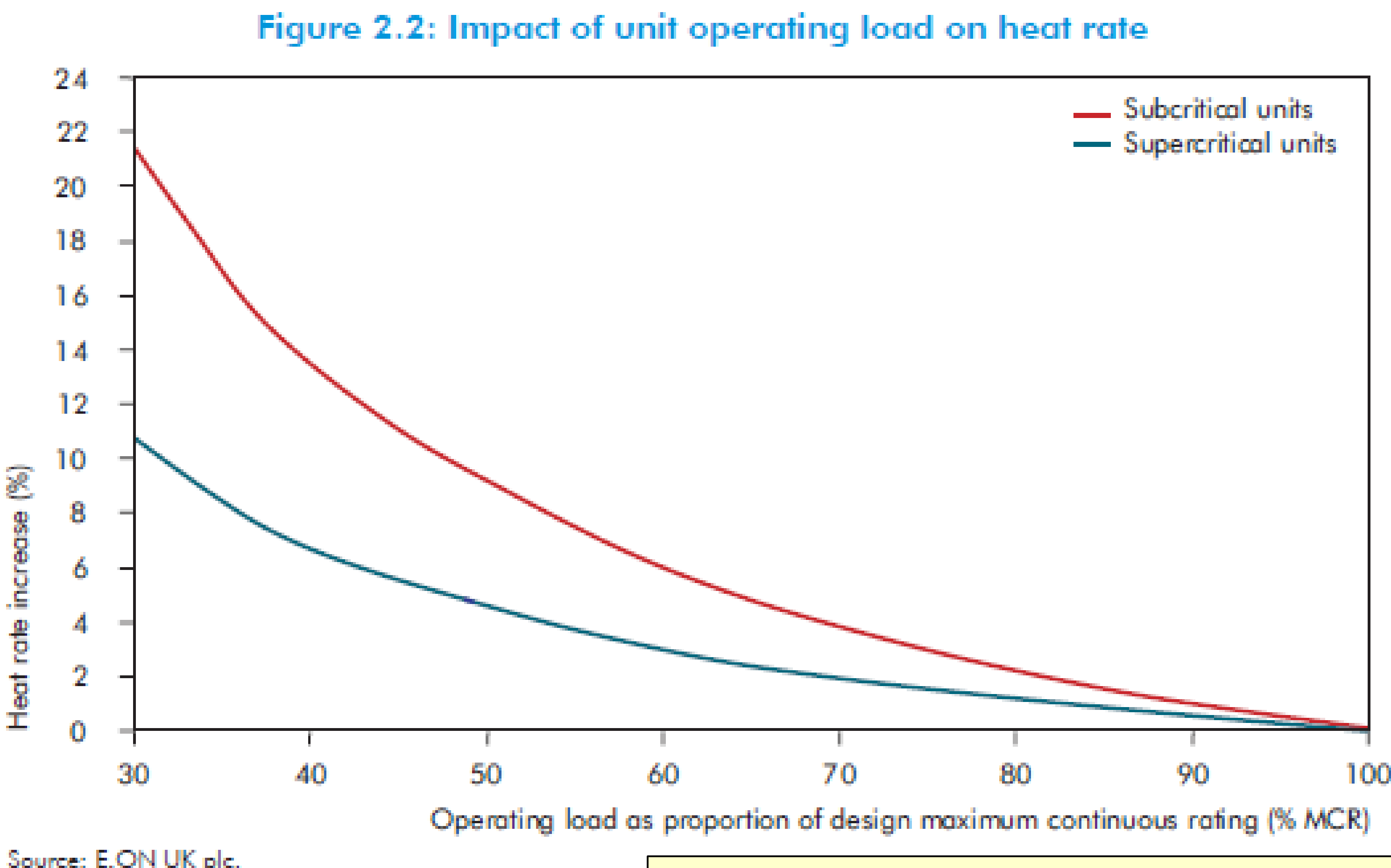
Shift in Supply Cost Curve with Renewables

Fossil Assets Pushed Back In Merit Order

– Reduced load factor 85% to 65%
– Rapid ramp rates and start/stop operation
– Off-design operation
  – Efficiency penalty
  – Emissions penalty
  – Reduced revenue
– Retain obligation for grid stability



Heat Rate Changes with Load Factor

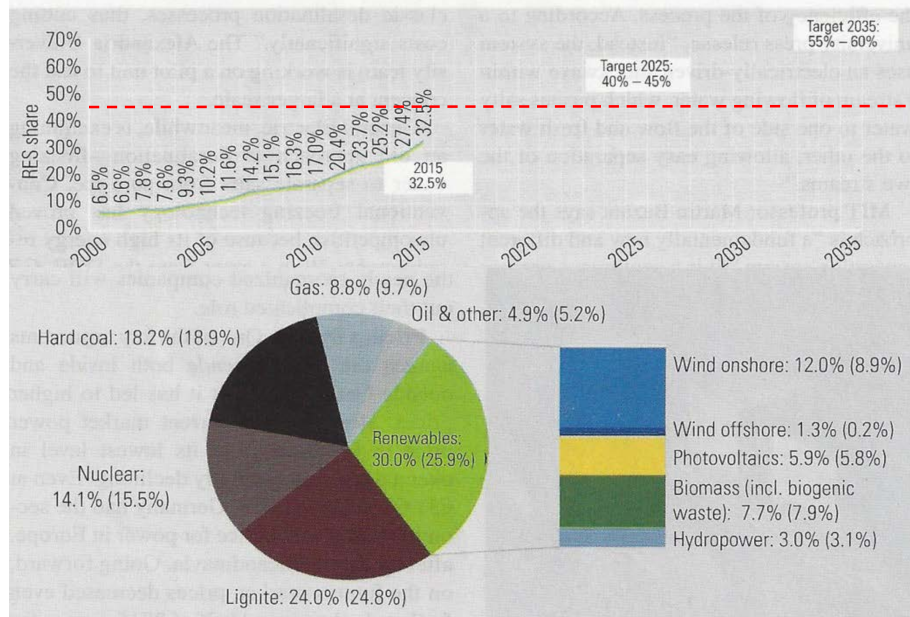


And, load factors decline!

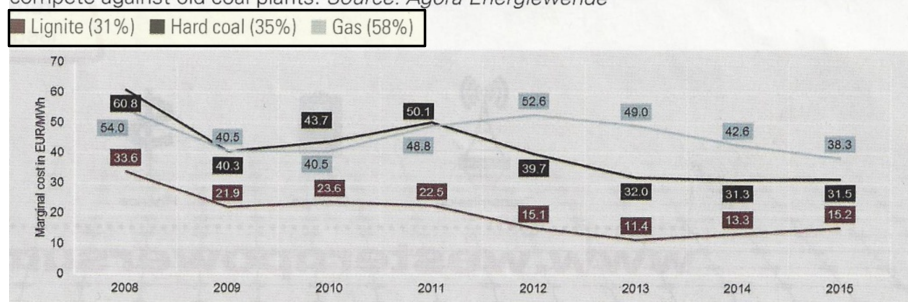
Germany Energiewende

- **Energiewende at a new turning point**
- **No more than** 45% renewable energy by 2025
- Goal for completing underground transmission lines for wind in the north to industry in the south by 2022
- Rapidly decreasing load factors are killing financial returns of old-line power producers
- Conventional utilities restructuring into:
  - Legacy assets
  - Renewables
- RWE mothballed a brand new billion-euro Westfalen-D coal-fired plant
  - Damaged at start-up
  - Decision not to correct error, but to de-construct plant
- E.ON applied to shutter two new gas-fired unit in 2015 as unprofitable
- Merit Order Dispatch Consequences
  - First determined based on fuel input cost
  - However, all renewable energy must be absorbed first
  - Dispatch order is solar, wind, hydro, biomass, nuclear, lignite, hard coal, and then natural gas.
  - Germany burns imported hard coal, generating excess capacity, export that capacity elsewhere in Europe
  - New gas plants cannot compete

1. The path to more renewables in Germany. Renewable energy sources (RES) already supply about a third of the country's electricity. *Source: Agora Energiewende; data from AG Energiebilanzen 2015*



3. Marginal costs for new gas and old coal power plants 2008–2015. Despite lower prices for natural gas and slightly higher CO_2 prices, new gas plants cannot compete against old coal plants. *Source: Agora Energiewende*



base e

La Paloma Plant Going Bankrupt

A natural gas-fired power plant in California that earlier this year warned it might need to shut down filed for bankruptcy protection on Tuesday, blaming "inhospitable" regulations and a shift toward renewable energy for power generation.

La Paloma Generating Co LLC [CMENGL.UL], a 1,200 megawatt combined cycle plant about 110 miles northwest of Los Angeles, filed for U.S. Chapter 11 bankruptcy in Delaware on Tuesday, citing $524 million of debt.

In its filing, La Paloma said market factors including slower-than-expected growth in electricity demand and a rise in renewable generation resources in California were "exacerbated by an inhospitable regulatory environment."

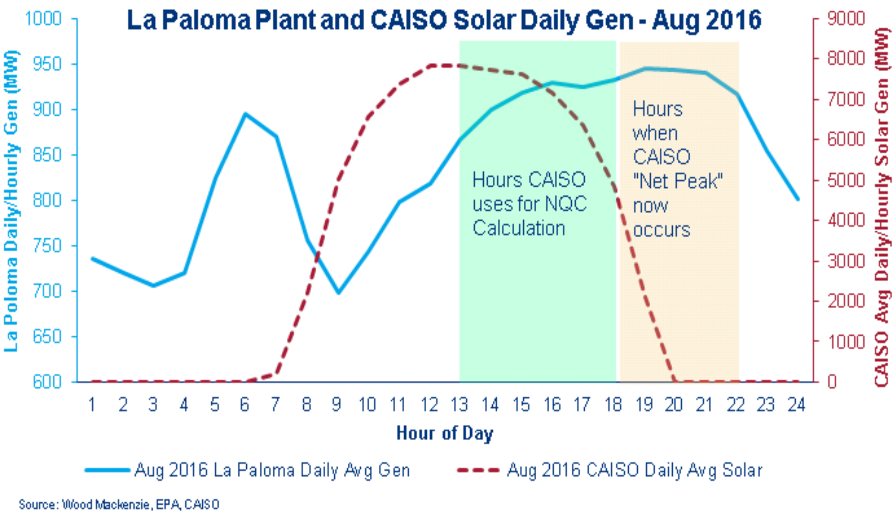
La Paloma is owned by Rockland Capital LLC, one of several California plant owners that has asked the state for help in offsetting losses, arguing that it is in the state's interest to support the natural gas plants because they provide stability and reliability to the power grid.

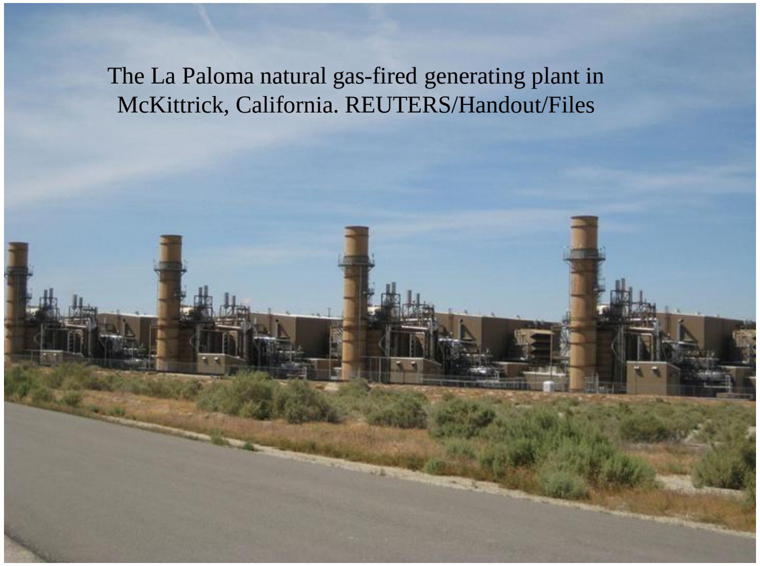
An unexpected combination of oversupply of natural gas and a boom in solar and other renewable energy has depressed power prices and threatened the viability of natural gas plants that sell power into California's electricity market.

In its court filing, La Paloma said it had decided that Chapter 11 was in the best interests of the company and its creditors and stakeholders, following consultation with financial and legal advisers.

The company listed Bank of America Corp (BAC.N) and SunTrust Bank [STIHCB.UL] as its lenders. It has trade debt with a number of organizations including Alstom Power Inc, the West Kern Water District and Pacific Gas & Electric Co (PCG_pa.A).

(Reporting by Tracy Rucinski; Eiting by Steve Orlofsky)




The La Paloma natural gas-fired generating plant in McKittrick, California. REUTERS/Handout/Files

http://www.reuters.com/article/us-la-paloma-bankruptcy-idUSKBN13V2PY

Exelon's Texas merchant subsidiary files bankruptcy

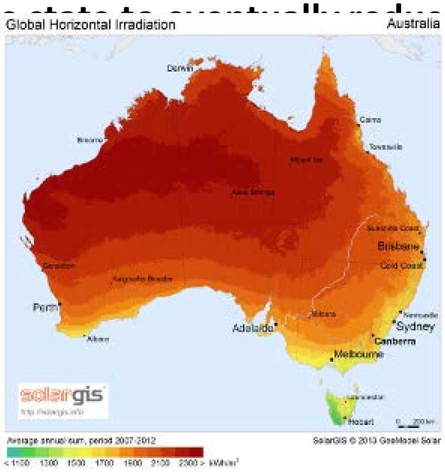
- ExGen Texas Power owned five generating facilities in the Lone Star state, but the bankruptcy agreement will change that.
- Exelon blamed the financial woes on "historically low power prices within Texas" that created "challenging market conditions for all power generators, including the five natural gas-fired EGTP plants."
- The Exelon development comes as Vistra Energy announced plans to close three coal-fired power plants in Texas — part of the 5,625 MW of fossil fuel capacity that is slated to be retired or mothballed in the state in the coming year.
- EGTP owns two combined-cycle gas plants, two gas-fired steam boilers and a small simple-cycle plant.
- Cheap gas has been pushing coal off the grid in some markets, and Texas' wind power is now having some of the same effect on gas. The Handley plant is a 3-unit, 1,265 MW facility located in Fort Worth, providing electricity to customers in the Electric Reliability Council of Texas.

Australia’s rooftop solar brings grid demand to historic lows

02/11/2017
By Tildy Bayar
Features Editor

Demand for grid power in the state of Western Australia has fallen to an eight-year low thanks in part to rooftop solar installations, Australian renewables news site ReNew Economy found.

Grid power demand fell to a record low of 1265 MW last Sunday during a midday interval when rooftop PV systems generated 420 MW.
And WA’s grid operator expects the growing amount of rooftop solar in th e grid power demand to zero on some days. It is anticipated that PV systems cou nt of businesses and two-thirds of homes within a decade.
Rooftop PV installations in WA are up 49 per cent this year on 2016 levels, city standing at 785 MW.
And the trend is seen in other states too. Figures from the Australian PV in rooftop systems installed in New South Wales, while a Climate Council re Queensland where 50 per cent of residential buildings have rooftop solar.
South Australia's grid demand hit a record low in September, with just 588 afternoon when rooftop PV generated over 700 MW.
Image credit: GHI Solar Map © 2017 Solargis



“Practical Strategies for Emerging Energy Technologies”

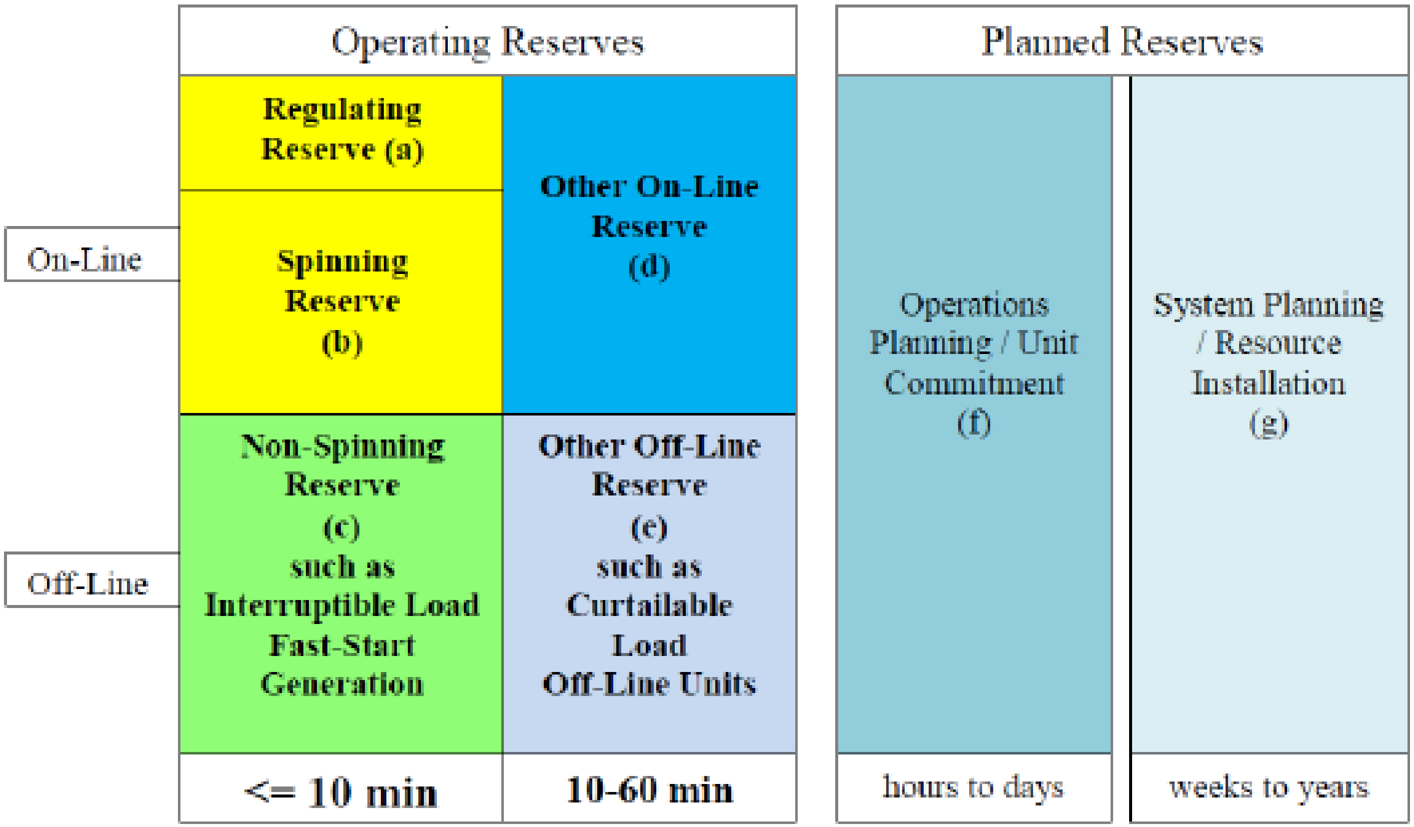
Definitions - NOPR

Notice of Proposed Rulemaking (NOPR)

- **Baseload Power Supply** is a term used to describe generation that falls at the bottom of the economic dispatch stack, meaning those power plants are the most economical to run
  - Coal and nuclear resources are designed for low cost O&M and continuous operation
  - These conventional steam-driven generation resources have low forced and maintenance outage hours and have low exposure to fuel supply chain issues
- **Variable Renewable Energy (VRE)** is a source that is non-dispatchable due to its fluctuating nature, like wind and solar
- **Controllable Renewable Energy (CRE?)** source such as hydroelectric, or biomass, or a relatively constant source such as geothermal power or run-of-the-river hydro

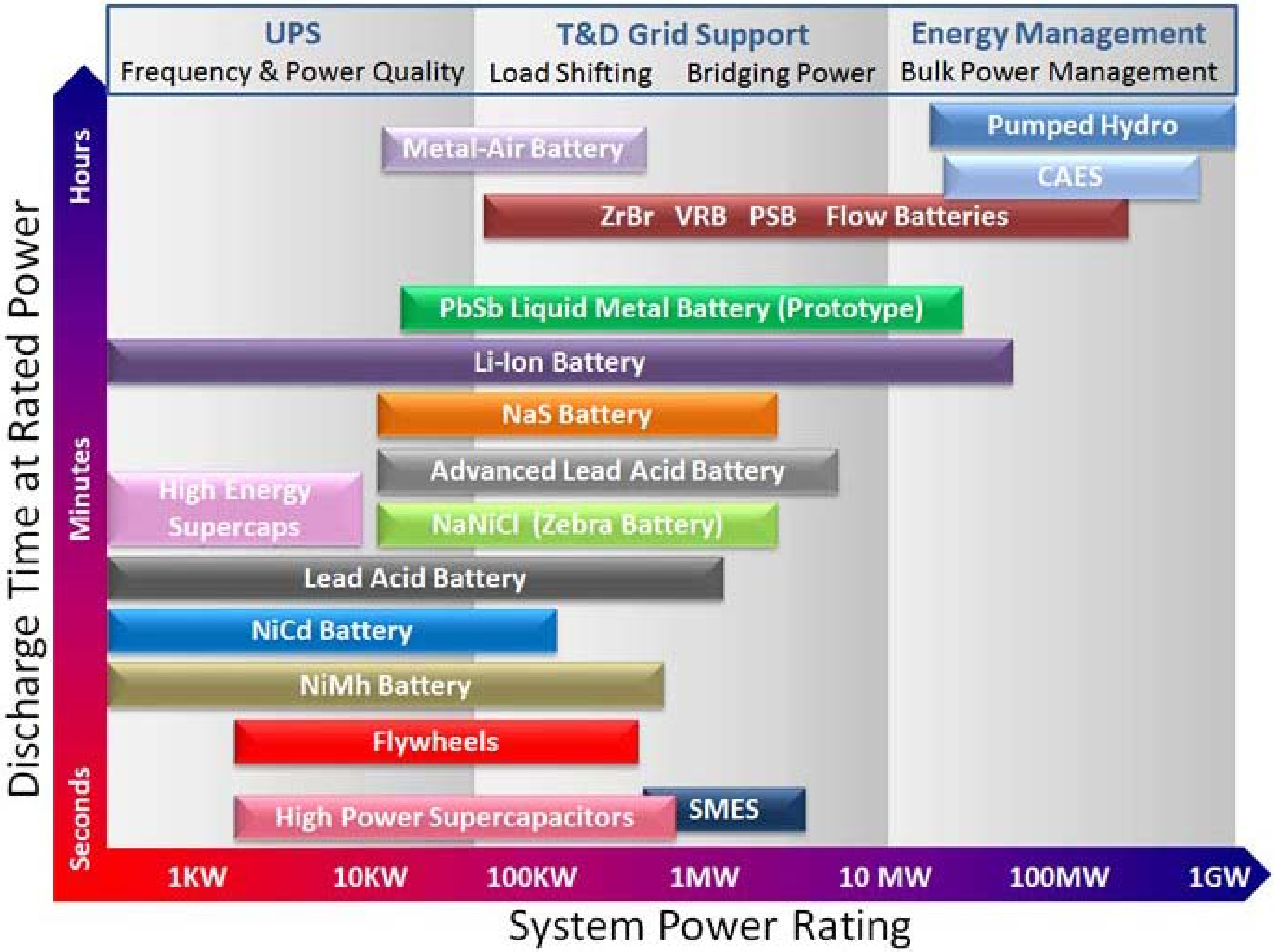
"Baseload" generation is not a requirement; however, having a portion of a resource fleet with high reliability characteristics, such as low forced and maintenance outage rates and low exposure to fuel supply chain issues, is one of the most fundamental necessities of a reliable Baseload Power Supply (BPS)

Reserves Definition



Storage

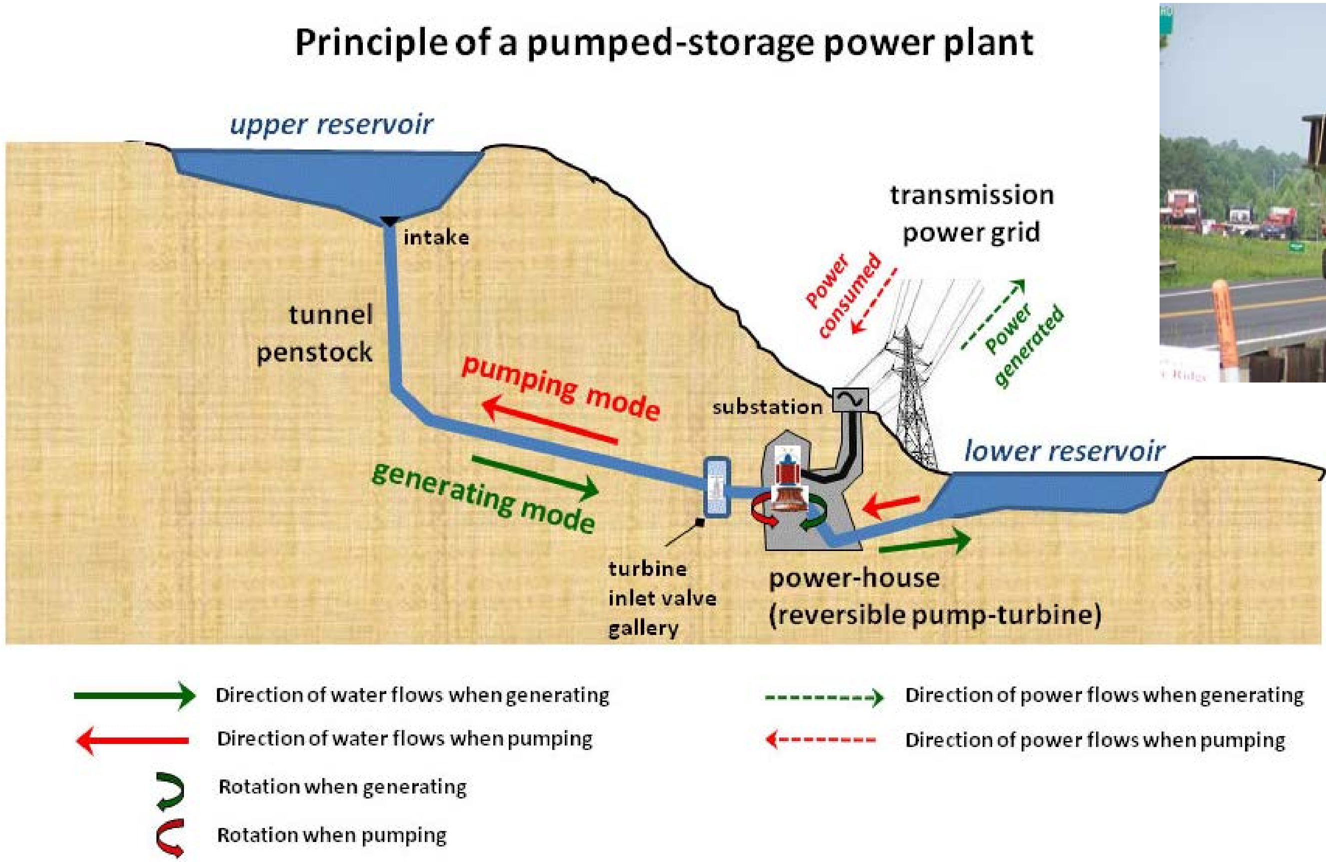
Energy Storage Technologies

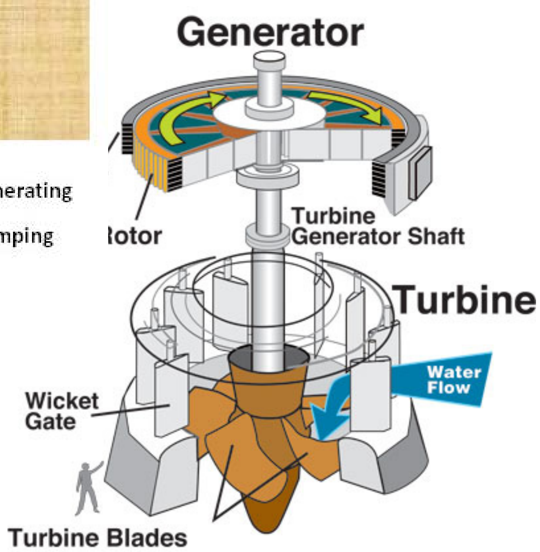


base$_e$ ®

"Practical Strategies for Emerging Energy Technologies"

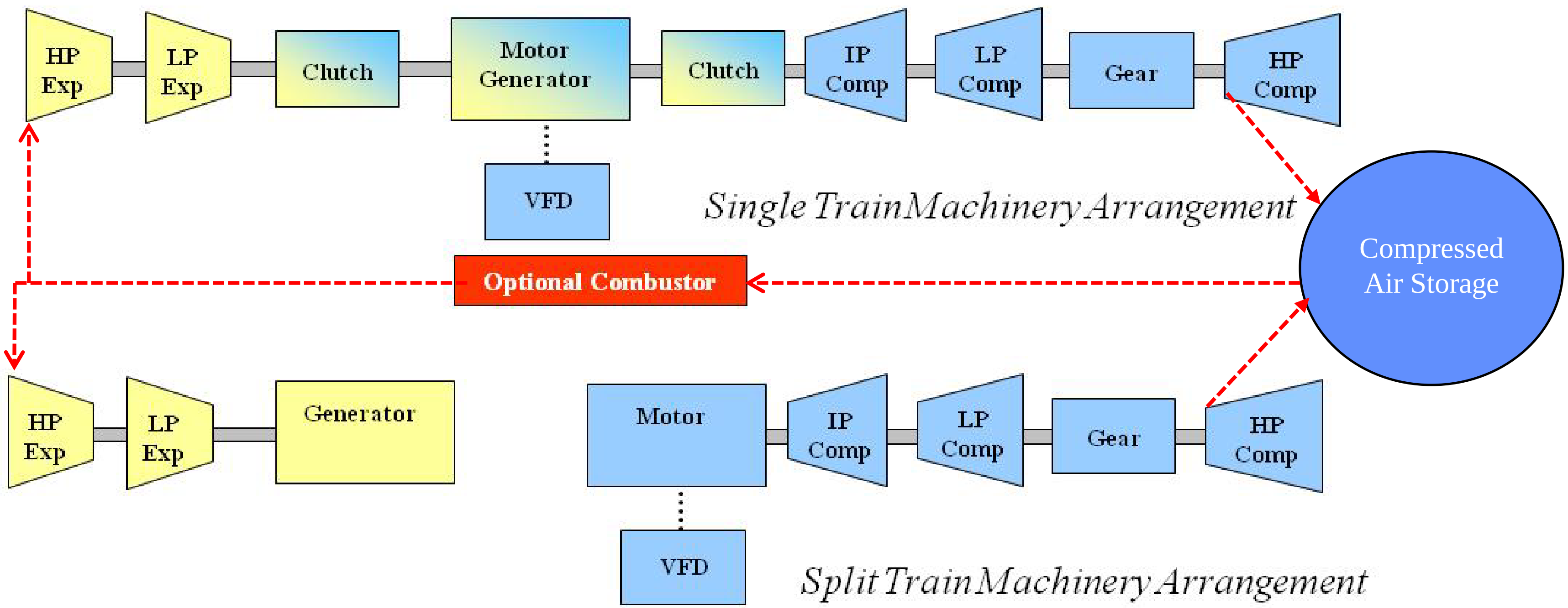
Pumped Hydro Storage





base e

Compressed Air Energy Storage (CAES)



Split the two components of a gas turbine

1. **Compressor**
2. **Turbine (Expander)**

So they can operate at different time(s) of day
Turbine may be "fired" or "un-fired"

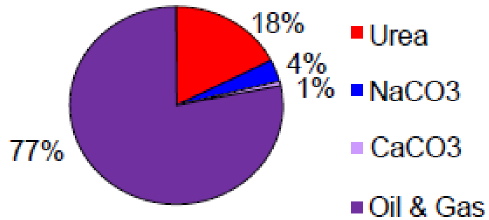
Source: Dresser-Rand

Carbon Capture Utilization & Storage (CCUS)

Annual U.S. CO_2 Utilization vs. Emissions

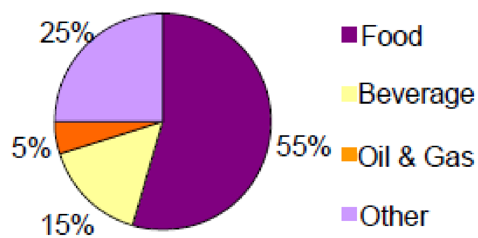
Gaseous Consumption

Mainly enhanced oil recovery



Liquid/Solid Consumption

Mainly Food



Total Utilization ~ 100 Mt

Sources: SRI Consulting, MIT, UT Austin

5 Largest CO_2 Emitters in 2009

	Plant	Location	CO_2, Mt/yr	GWe
1	Scherer	Juliette, GA	25.0	3.56
2	Bowen	Cartersville, GA	20.8	3.50
3	Miller	Quinton, AL	23.3	2.82
4	Martin Lake	Tatum, TX	26.0	2.38
5	Gibson	Owensville, IN	22.2	3.34
		Total	**117.3**	**15.6**

U.S. Utilization = 100 Mt
= Emissions 5 large plants
U.S. Emissions = 2400 Mt from utility
= 6000 Mt total

Sources: EPA, IEA

DOE estimates ~25% of coal power CO_2 emissions could be used for EOR, if ~$30/t

EPRI ELECTRIC POWER RESEARCH INSTITUTE

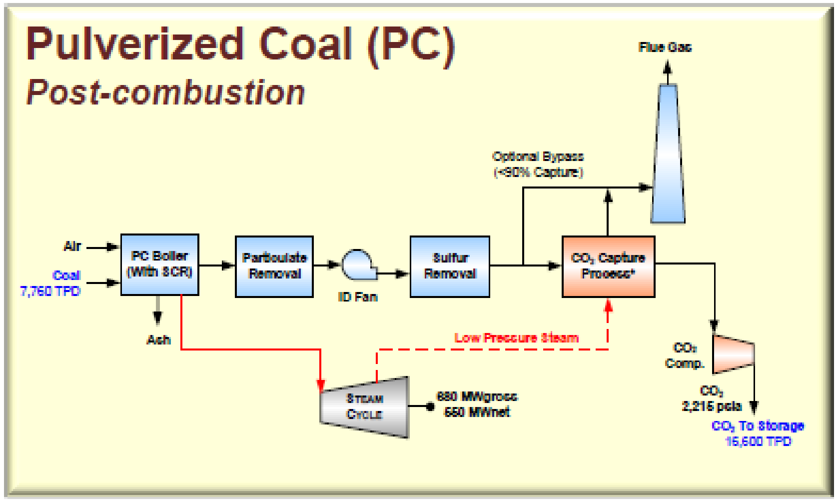
We do not grasp the scale of the problem

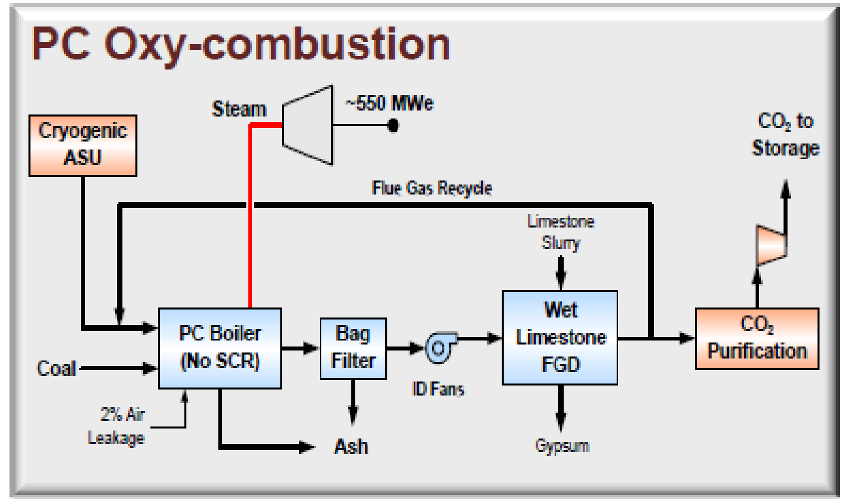
base e

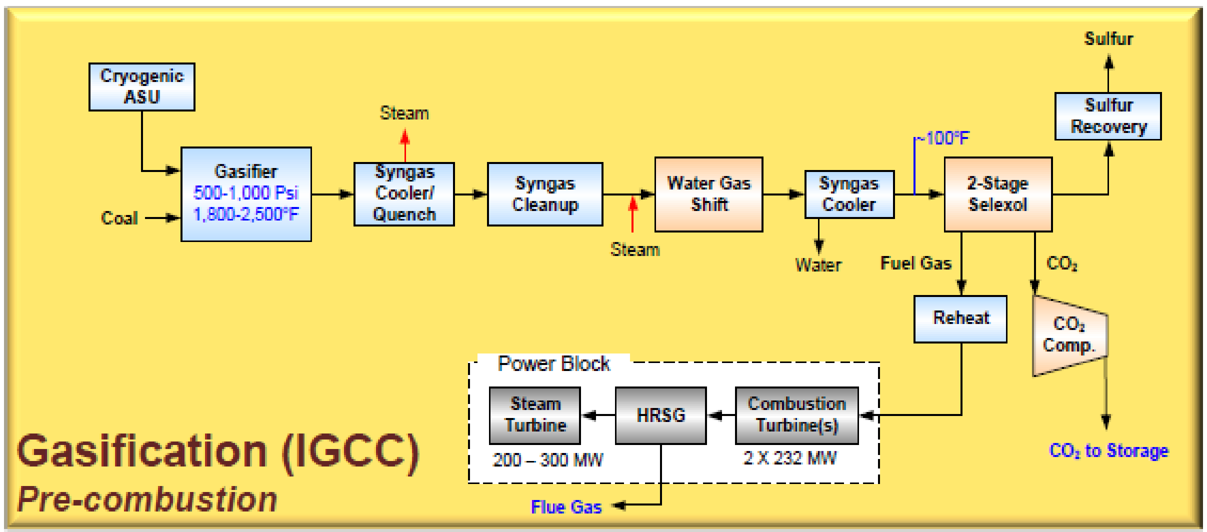
EPRI CO2 Utilization

- CO_2 chemical conversion to fuels
  - Requires ~6-15 times more energy produced
  - Uses CO_2 as energy storage – other options much better
- CO_2 conversion to other chemicals
  - Requires more energy and/or reactants than produced
  - Scale mismatch - CO_2 production dwarfs other chemicals
- Mineralization
  - Emits >50% of carbon captured at low capture efficiency
  - Scale of reactants, energy needed, low conversion
- Biological conversion
  - Land use requirement: size of Ohio for US coal fleet
  - Significant energy cost: EROI <2

CO_2 Power Plant/Capture Options

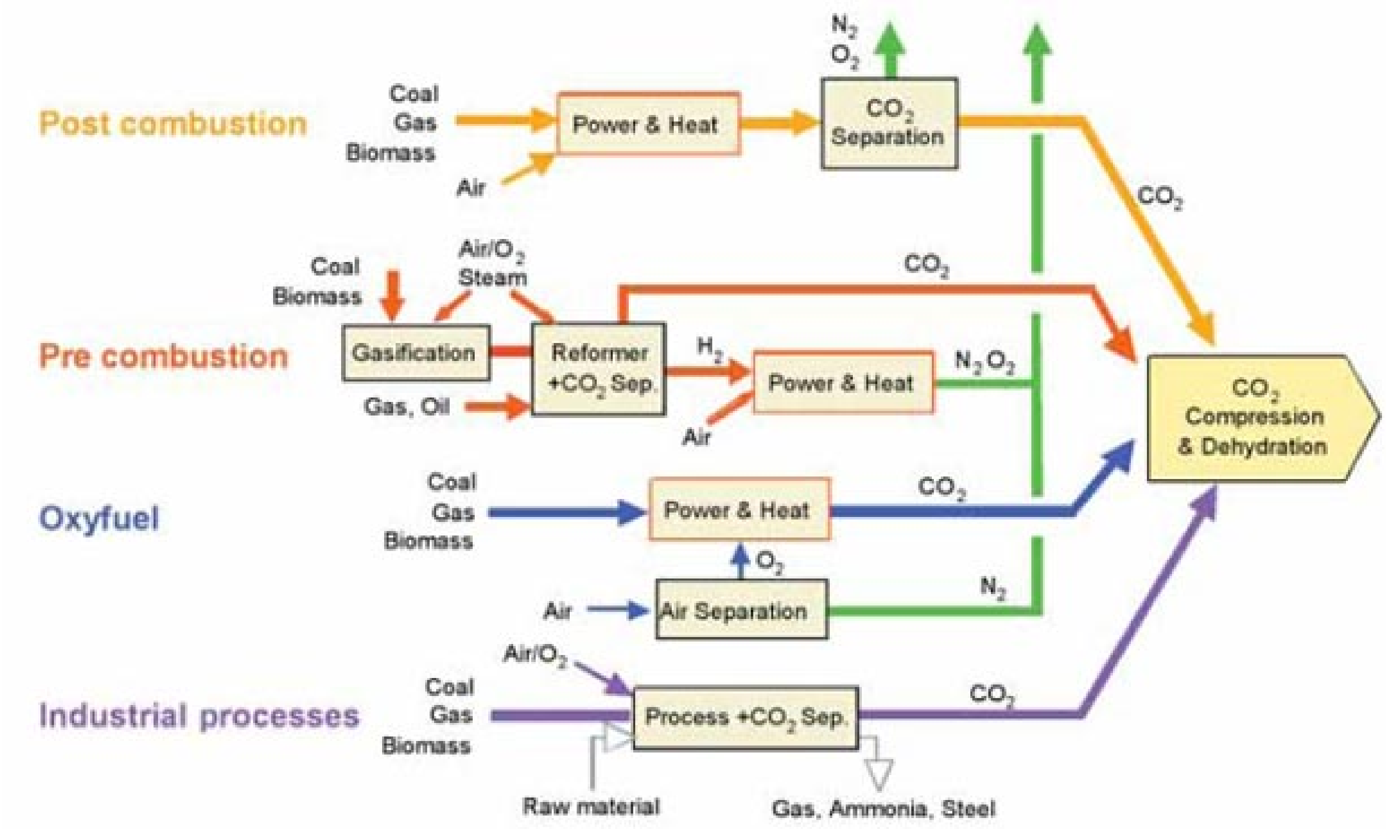






Source: Cost and Performance Baseline for Fossil Energy Power Plants study, Volume 1: Bituminous Coal and Natural Gas to Electricity; NETL, May 2007.

Carbon Capture Processes



$$CH_4 + 2O_2 \Rightarrow CO_2 + 2H_2O$$

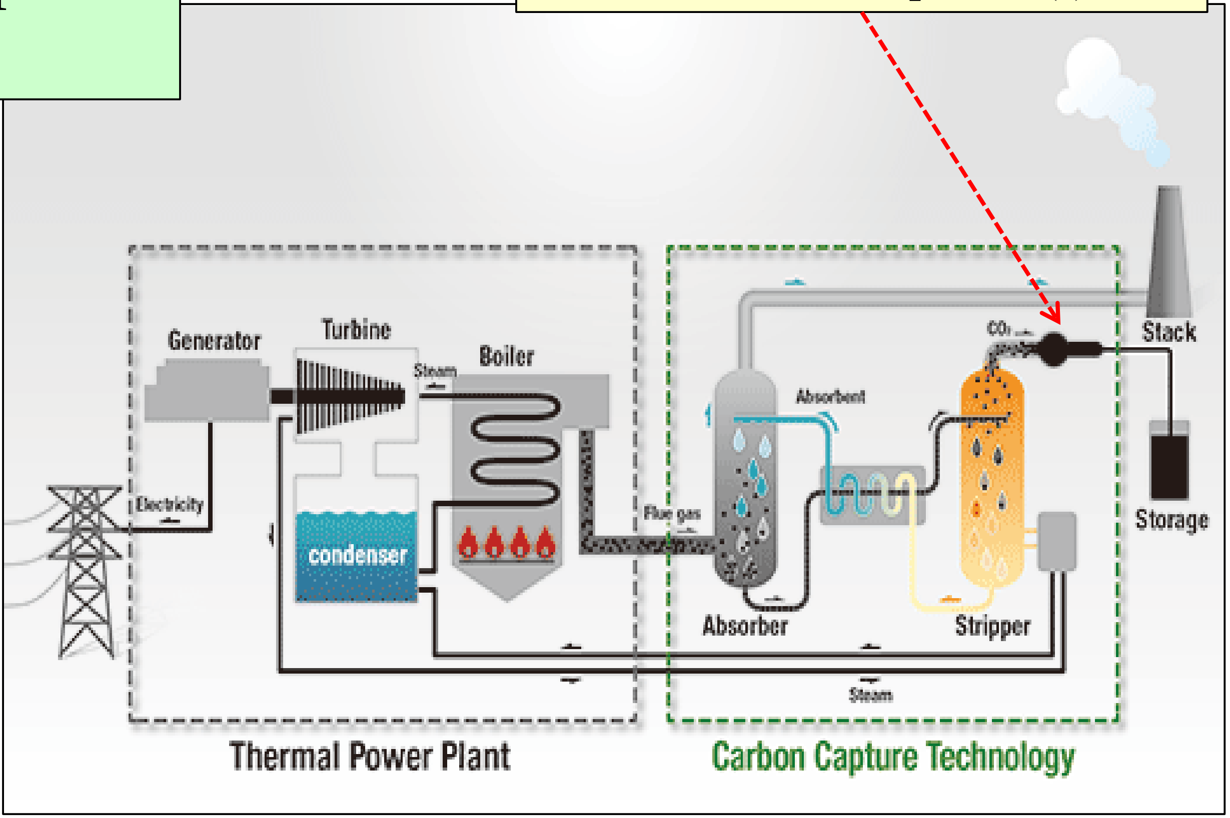
base e

"Practical Strategies for Emerging Energy Technologies"

Fossil Fuel Power Plant – CC&S

All fossil fuel power plants produce CO2

This is the compressor(s)



CO2 Compressor Power

- **Advanced pulverize coal – 8-12%**
  - **600MW ⇨70MW ⇨93,000 hp**
- **IGCC - 5%**
  - **600MW ⇨30MW ⇨40,000 hp**
- **NGCC – 8%**
  - **400MW ⇨32MW ⇨43,000 hp**

Compression Costs are 36% of Total Cost/Mt of CO2

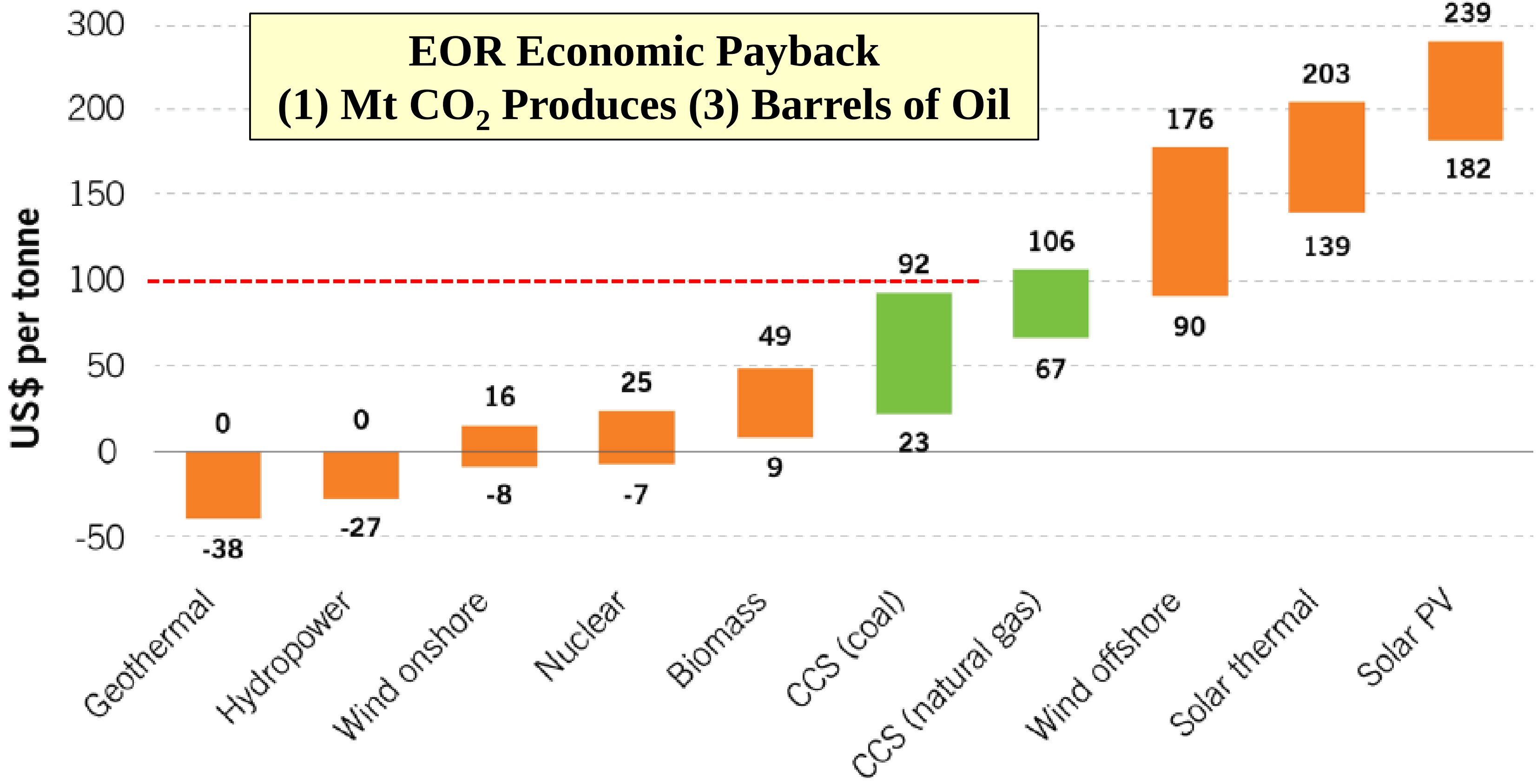
This is what 6000 hp Compressor Really Looks Like

Pr 200:1
1.70 Pr per stage
10-stage
6000 hp
$8.0 million
$1350/hp

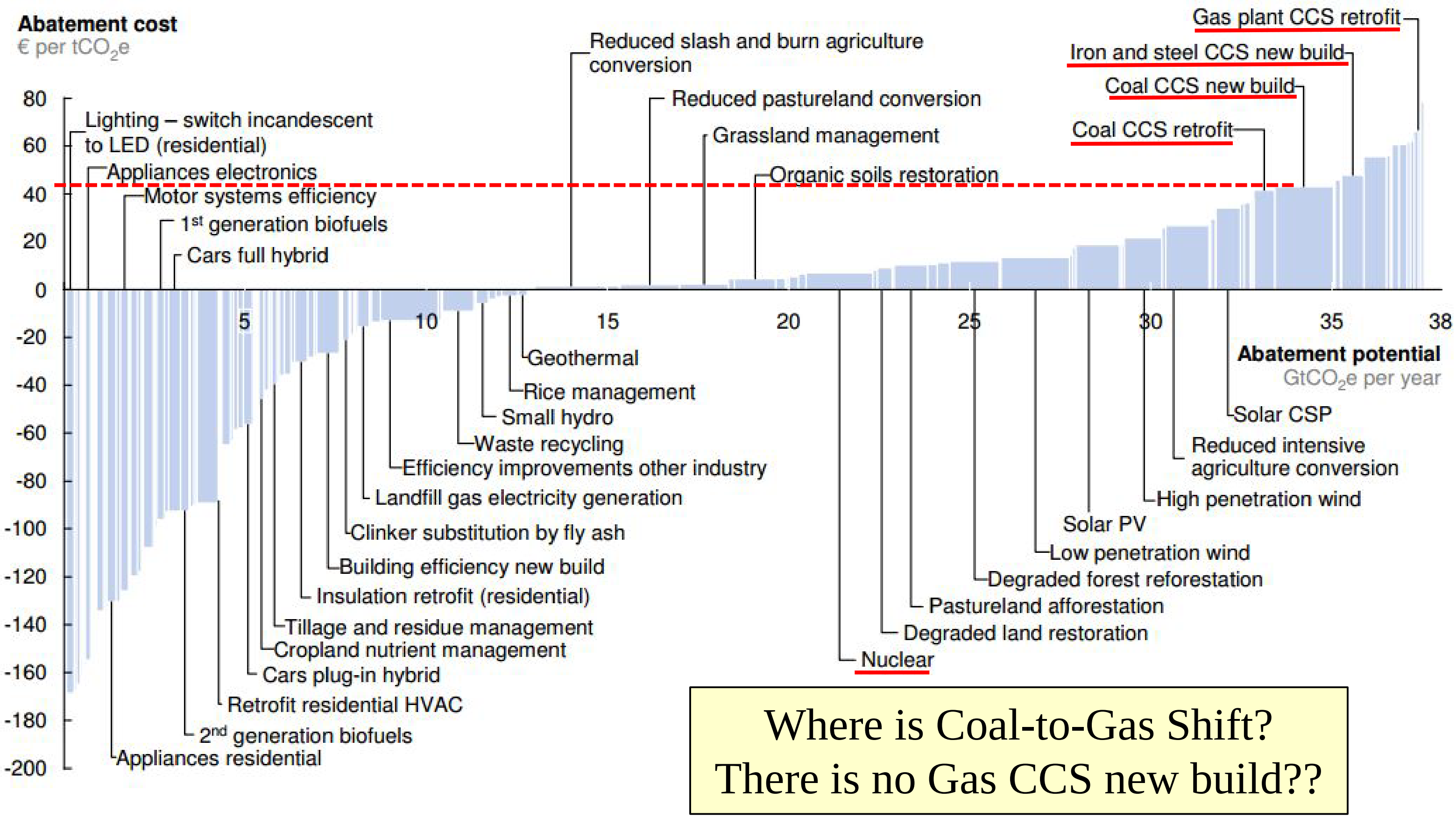
Costs of CO_2 Avoided

Source: Global CCS Institute Victor Der July 2013

Costs of CO_2 avoided



McKinsey Global GHG Cost Curve V2.1



Note: The curve presents an estimate of the maximum potential of all technical GHG abatement measures below €80 per tCO_2e if each lever was pursued aggressively. It is not a forecast of what role different abatement measures and technologies will play.

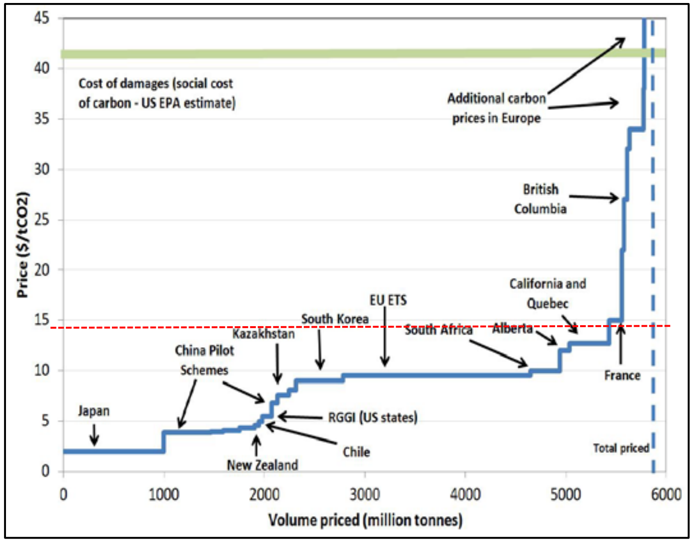
Source: Global GHG Abatement Cost Curve v2.1

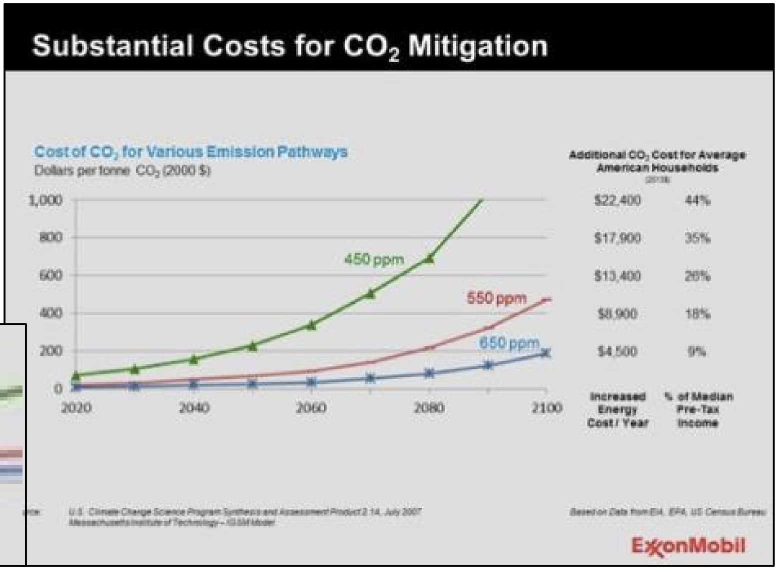
CO_2 Pricing

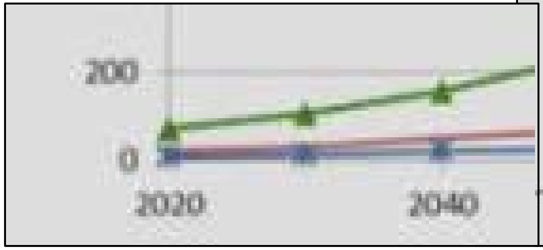
Source: On Climate Change Policy

Carbon pricing is spreading

– Prices are far too low to price emissions efficiently
– The vast majority of priced emissions – about 90% of the total – are priced below $14/t$CO_2$
– Higher carbon prices are invariably for small volumes, and are found in Europe, British Columbia and Alberta
– The environmental damage caused by emissions – as estimated the US EPA
– Carbon prices are thus too low even compared with a likely underestimate of the cost of emissions
– Taxes are too low and caps are too loose to price carbon adequately
– Consequently efficient abatement is not happening.







NETL U.S. Carbon Storage Atlas V

Estimates of CO_2 Stationary Source Emissions and Estimates of CO_2 Storage Resources for Geologic Storage Sites

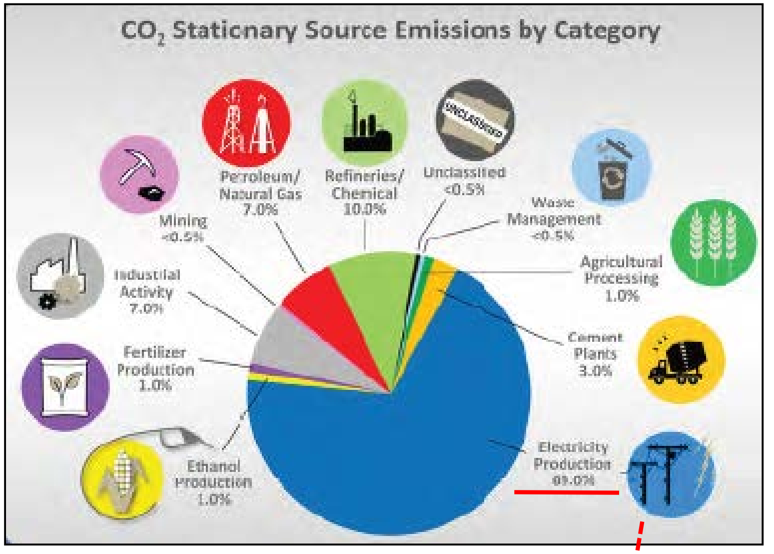
RCSP or Geographic Region	CO_2 Stationary Sources		CO_2 Storage Resource Estimates (billion metric tons of CO_2)								
	CO_2 Emissions (million metric tons per year)	Number of Sources	Saline Formations			Oil and Gas Reservoirs			Unmineable Coal Areas		
			Low	Med***	High	Low	Med***	High	Low	Med***	High
BSCSP	115	301	211	805	2,152	<1	<1	1	<1	<1	<1
MGSC	267	380	41	163	421	<1	<1	<1	2	3	3
MRCSP	604	1,308	108	122	143	9	14	26	<1	<1	<1
PCOR*	522	946	305	583	1,012	2	4	9	7	7	7
SECARB	1,022	1,857	1,376	5,257	14,089	27	34	41	33	51	75
SWP	326	779	256	1,000	2,693	144	147	148	<1	1	2
WESTCARB*	162	555	82	398	1,124	4	5	7	11	17	25
Non-RCSP**	53	232	--	--	--	--	--	--	--	--	--
Total	3,071	6,358	2,379	8,328	21,633	186	205	232	54	80	113

Source: U.S. Carbon Storage Atlas – Fifth Edition (Atlas V); data current as of November 2014

* Totals include Canadian sources identified by the RCSP

** As of November 2014, "U.S. Non-RCSP" includes Connecticut, Delaware, Maine, Massachusetts, New Hampshire, Rhode Island, Vermont, and Puerto Rico

*** Medium = p50



Sources >25,000 tonnes

Electricity Production 69%

2005 = 2416 Mt

2012 = 0.69 x 3,071 = 2,119 Mt

U.S. Totals

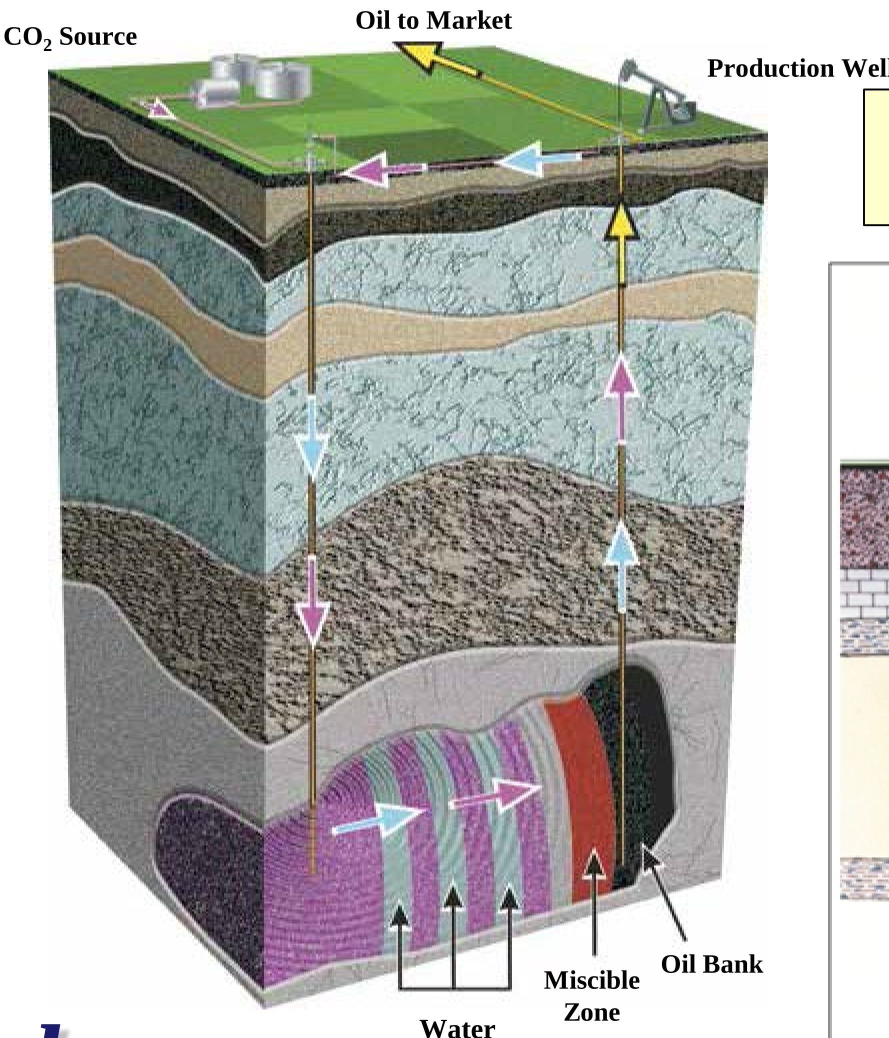
2011 = 5601 (37.6%)

2015 = 5680 (37.3%)

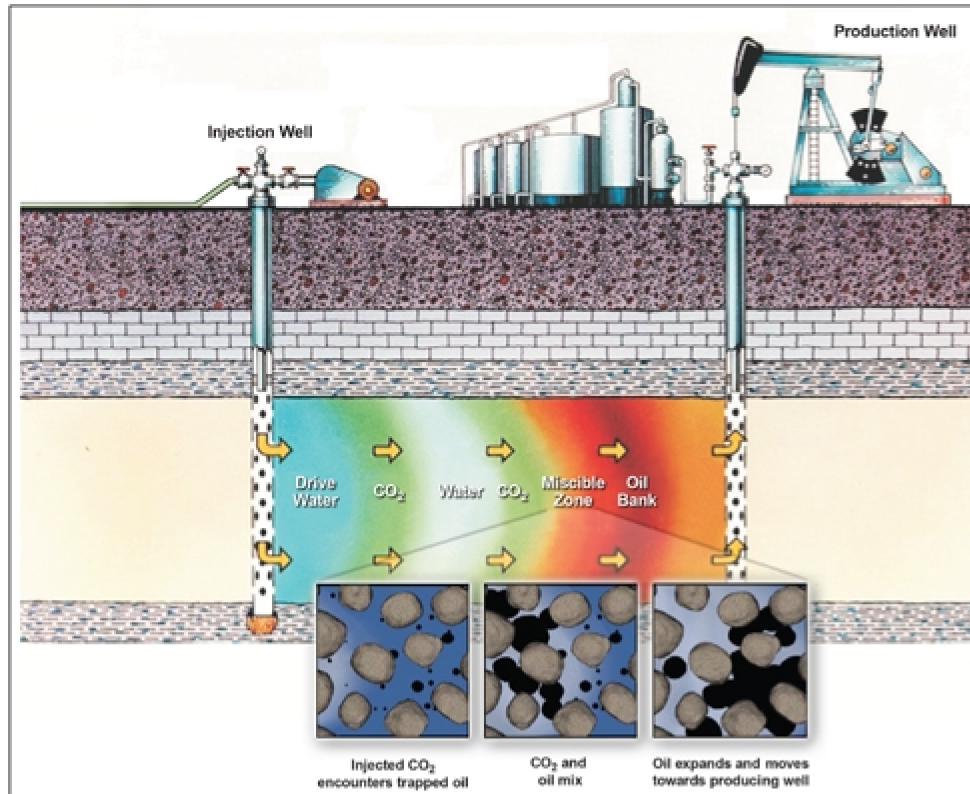
http://www.netl.doe.gov/research/coal/carbon-storage/natcarb-atlas

"Practical Strategies for Emerging Energy Technologies"

Enhanced Oil Recovery

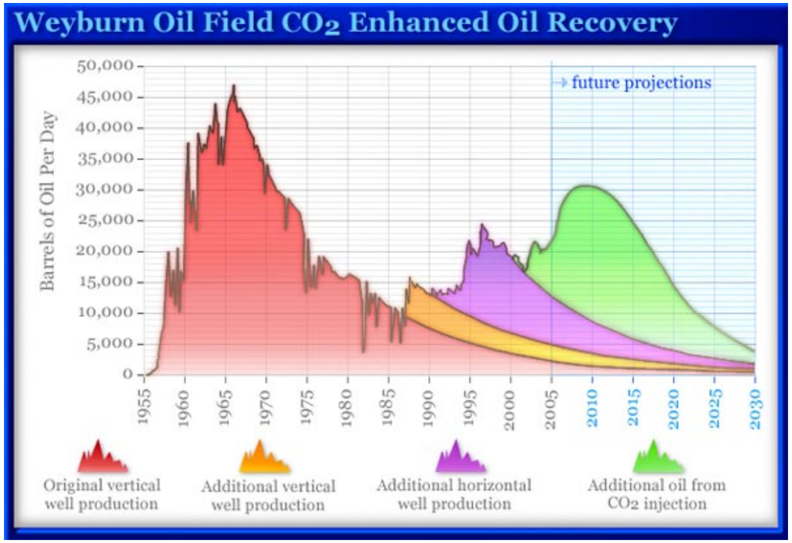


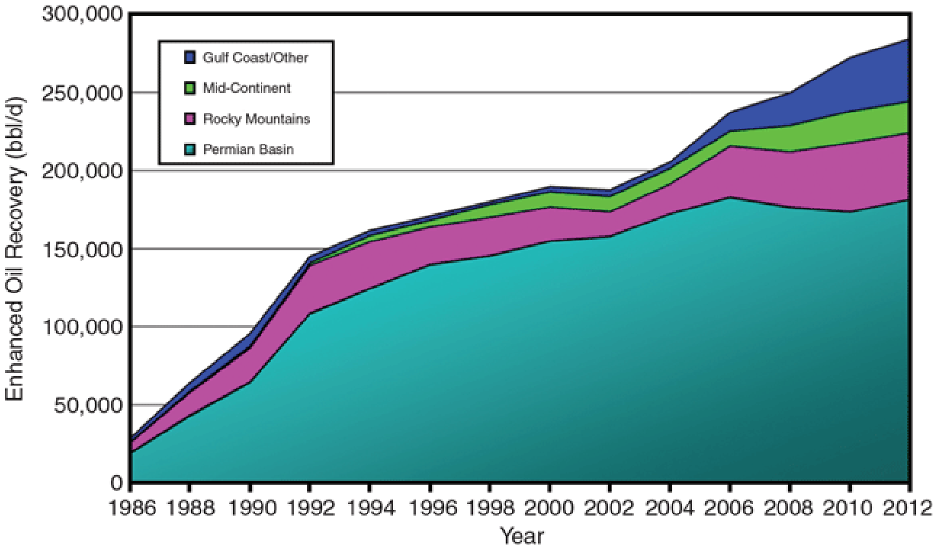
EOR Economic Payback
(1) Mt CO_2 Produces (3) Barrels of Oil



Enhanced Oil Recovery

- **Enhance Oil Recovery (EOR)**
  - Near term application
  - Recover up to 15% more oil from existing reservoirs
  - Extend useful life by 25 years
  - Substitute for natural gas re-injection
  - $800 million annual market potential
- **Enhanced Coal Bed Methane**
  - R&D efforts focused on similar use and effects
- **Oil Shale & Tar Sands**
  - 1 trillion bbl oil equivalent
  - In-situ methods under investigation
  - Potential CO_2 use
    - Stimulate production
    - Moderate in-situ combustion





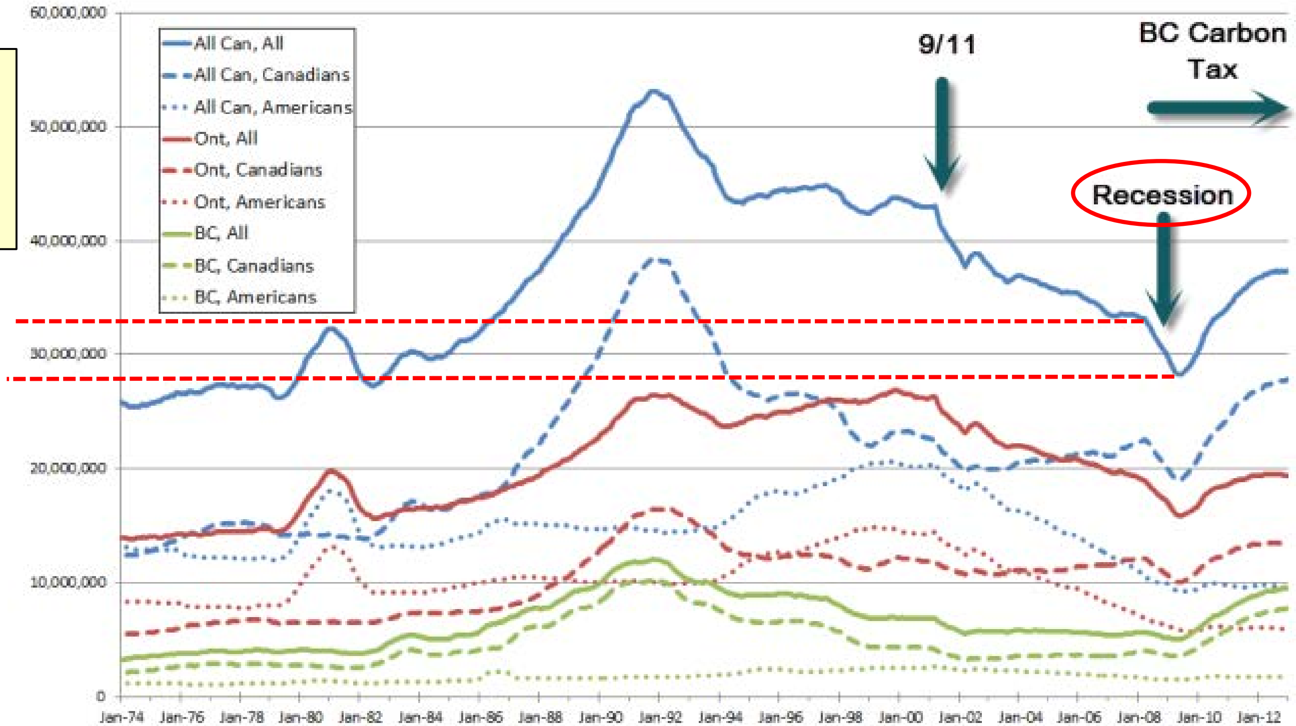
British Columbia Carbon Tax "Success"

- "Successful implementation"
  - 16% drop in consumption after introduction in 2008
- Initially \$C10/tonne, increasing to current \$C30/tonne
  - \$C30/tonne = 7 cents/liter = 26.5 cents/gallon
- Use of ½ Carbon Tax funds for Regional Transit expansion denied
- A 2nd Carbon Tax is being discussed to fund the Region's Transit expansion

"The goal of the carbon tax, reducing carbon, is just completely synchronous with public transit funding and getting people out of cars," he said. "Regardless of what the minister has said, we still believe it's the best source."

Richard Walton, mayor of the District of North Vancouver

15,000 miles
20 mpg
750 gal
\$200 @ \$26.5/gal



19.64 lb-CO_2/gal
750 gal
14,730 lb-CO_2
6.68 tonnes
\$200 @ \$30/tonne

base_e

Well-to-Wheels Comparison Electric vs. Gasoline

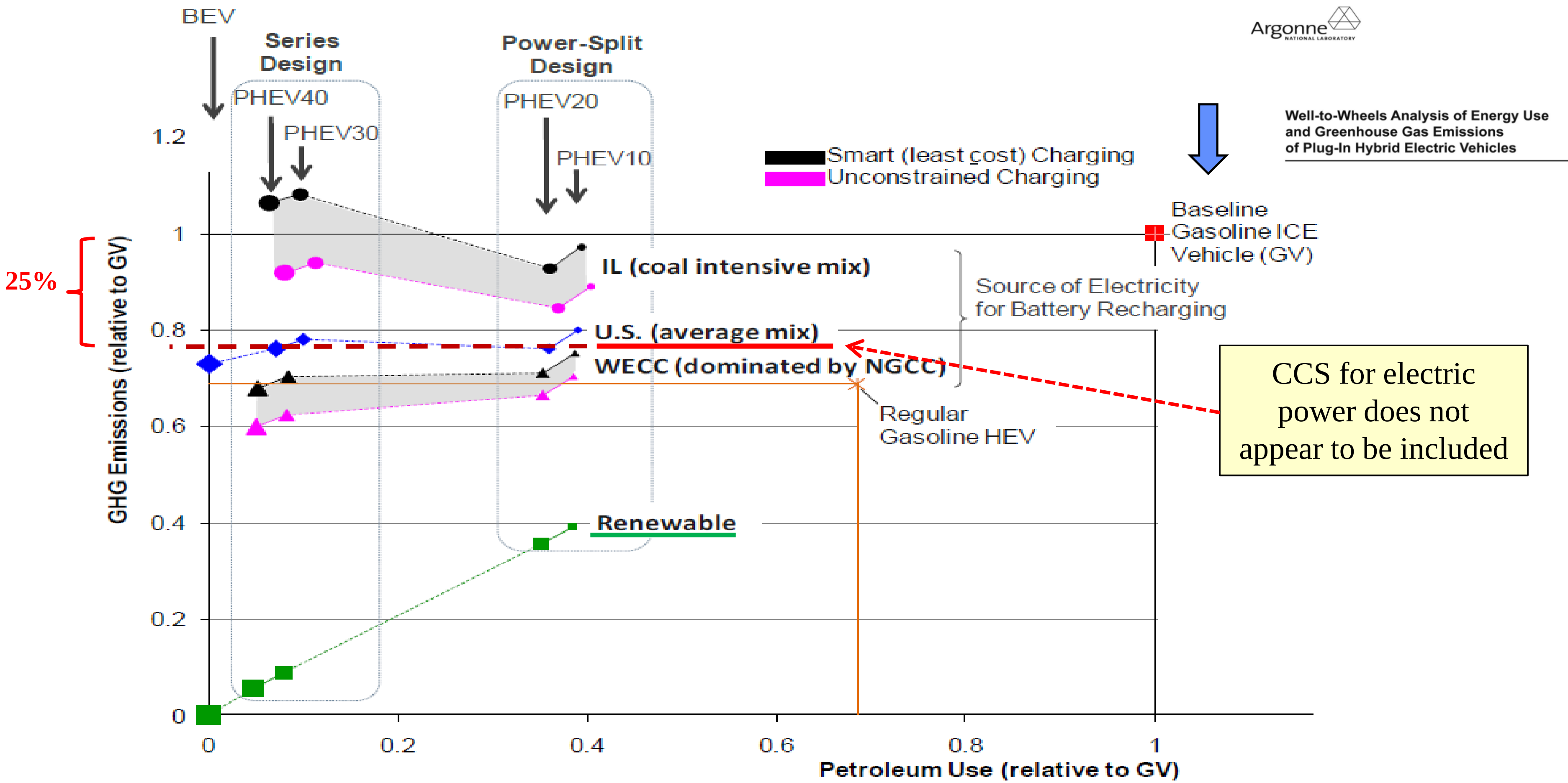
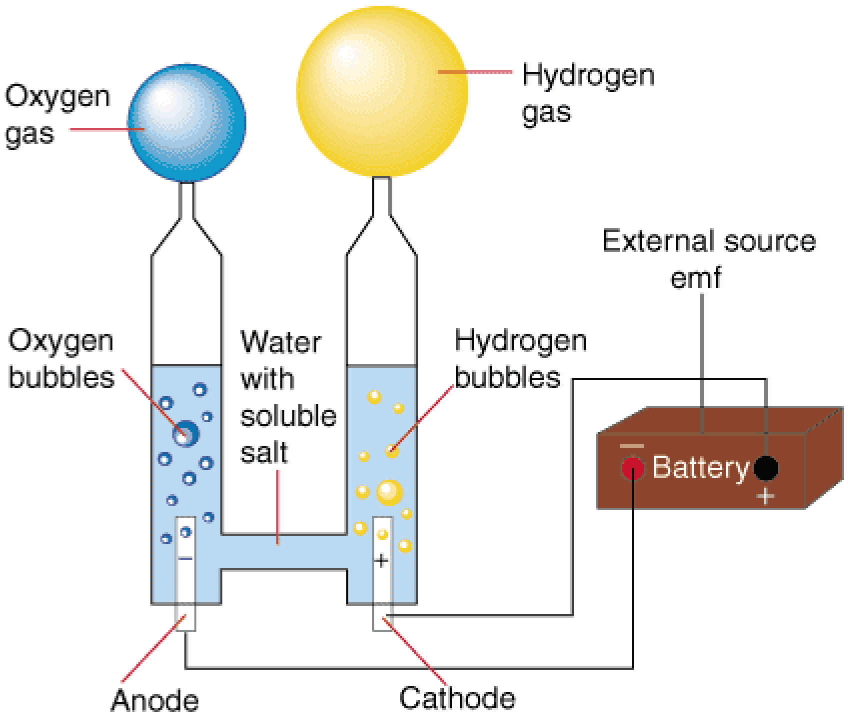
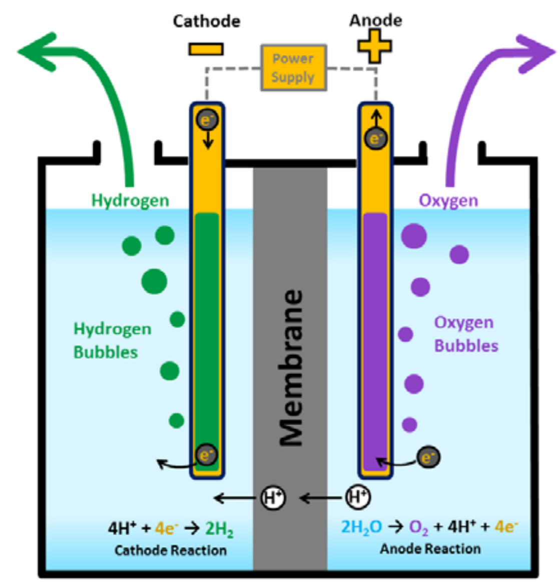


FIGURE ES.1 WTW Petroleum Use and GHG Emissions for CD Operation of Gasoline PHEVs and BEVs Compared with Baseline Gasoline ICEVs and Regular Gasoline HEVs

Hydrogen from Water

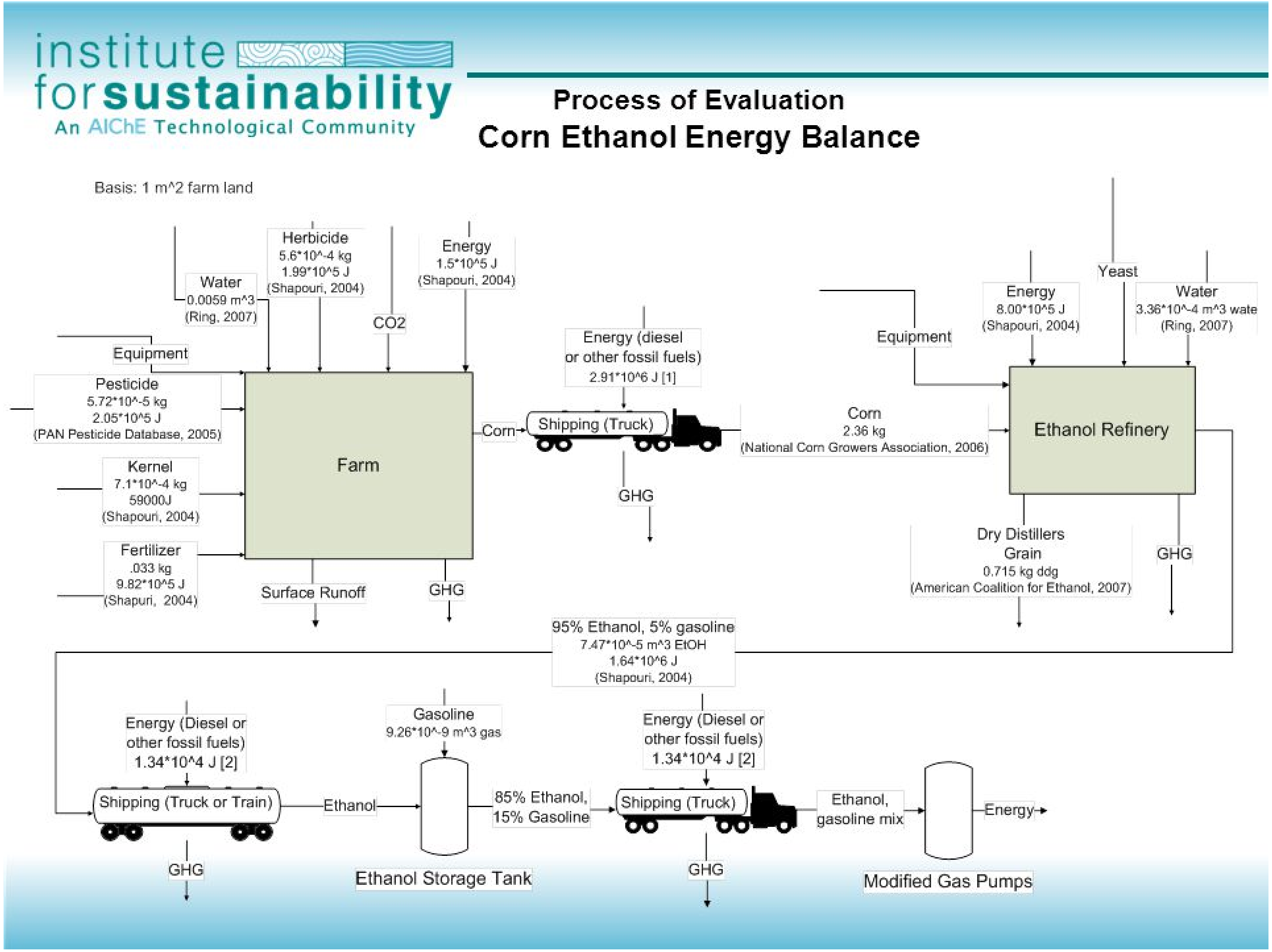




2H2O(l) = 2H2(g) + O2(g)

Solar PV + electrolyzer = Hydrogen

Corn Ethanol Energy Balance

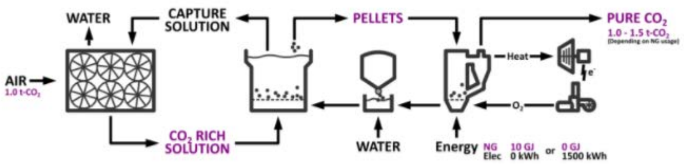


base e

"Practical Strategies for Emerging Energy Technologies"

Air Capture

As we move to commercialization, we envision industrial-scale air capture facilities, sited outside of cities and on non-agricultural land, that supply CO2 for fuel synthesis, and eventually for direct sequestration to compensate for emissions that are too challenging or costly to eliminate at source. At this large scale, our technology will be able to achieve costs of $100-150 USD per tonne of CO2 captured, purified, and compressed to 150 bar.



Other Issues & Countries to Watch

- LNG Supply Demand Balancing
- North American Shale
- Panama Canal
- Mexico
- East Mediterranean Resource
- Qatar
- China-Pakistan Economic Corridor
- Canadian Resources
- Arctic
- Turkmenistan–Afghanistan–Pakistan–India Pipeline (TAPI)
- Argentina
- Methane Hydrates
- Russia to be dominant fuel supplier to Asia
- International Maritime Organization (IMO) 3.5% to 0.5% marine fuel sulphur content in 2020
- Russian Plans to dominate fuel supply to Asia

Appendix 2

BP Conversion Factors

Approximate conversion factors

Crude oil*

From	To: tonnes (metric)	kilolitres	barrels	US gallons	tonnes per year
	Multiply by				
Tonnes (metric)	1	1.165	7.33	307.86	–
Kilolitres	0.8581	1	6.2898	264.17	–
Barrels	0.1364	0.159	1	42	–
US gallons	0.00325	0.0038	0.0238	1	–
Barrels per day	–	–	–	–	49.8

*Based on worldwide average gravity.

Products

	To convert: barrels to tonnes	tonnes to barrels	kilolitres to tonnes	tonnes to kilolitres
	Multiply by			
Liquefied petroleum gas (LPG)	0.086	11.60	0.542	1.844
Gasoline	0.120	8.35	0.753	1.328
Kerosene	0.127	7.88	0.798	1.253
Gas oil/diesel	0.134	7.46	0.843	1.186
Residual fuel oil	0.157	6.35	0.991	1.010
Product basket	0.125	7.98	0.788	1.269

Natural gas (NG) and liquefied natural gas (LNG)

From	To: billion cubic metres NG	billion cubic feet NG	million tonnes oil equivalent	million tonnes LNG	trillion British thermal units	million barrels oil equivalent
	Multiply by					
1 billion cubic metres NG	1	35.3	0.90	0.74	35.7	6.60
1 billion cubic feet NG	0.028	1	0.025	0.021	1.01	0.19
1 million tonnes oil equivalent	1.11	39.2	1	0.82	39.7	7.33
1 million tonnes LNG	1.36	48.0	1.22	1	48.6	8.97
1 trillion British thermal units	0.028	0.99	0.025	0.021	1	0.18
1 million barrels oil equivalent	0.15	5.35	0.14	0.11	5.41	1

Units

1 metric tonne	= 2204.62lb = 1.1023 short tons
1 kilolitre	= 6.2898 barrels = 1 cubic metre
1 kilocalorie (kcal)	= 4.187kJ = 3.968Btu
1 kilojoule (kJ)	= 0.239kcal = 0.948Btu
1 British thermal unit (Btu)	= 0.252kcal = 1.055kJ
1 kilowatt-hour (kWh)	= 860kcal = 3600kJ = 3412Btu

Calorific equivalents

One tonne of oil equivalent equals approximately:

Heat units	10 million kilocalories 42 gigajoules 40 million British thermal units
Solid fuels	1.5 tonnes of hard coal 3 tonnes of lignite
Gaseous fuels	See Natural gas and liquefied natural gas table
Electricity	12 megawatt-hours

One million tonnes of oil or oil equivalent produces about 4400 gigawatt-hours (= 4.4 terawatt-hours) of electricity in a modern power station.

1 barrel of ethanol = 0.57 barrel of oil
1 barrel of biodiesel = 0.88 barrel of oil