2021 NSPE-MI Annual Conference

“A Professional Engineer's Perspective of the U.S. Energy Industry over the Past 100 years”

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Note: Information to materials in this presentation is for education purpose only. Any reference to products is not an endorsement.

Speaker Profile

- A Product of the "Melting Post Greatest Generation"
- Entered U.S. Air Force 1973: Oil Embargo
- University of Dayton 1980's BSME - EADC
- Professional Engineering in 1990's
- Founding President of WMAEE
- Director of WPMC – Electric AES – 2003-2021
- Engineering Manager for a University (FSU)
- Adjunct Prof: "Energy Systems Engineering"

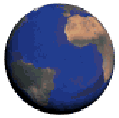
Speaker Profile – College Courses Taught

- 2012 “ Wind and Solar Energy Generation”
- 2013 “ Alternative Energy Generation”
- 2014 “ Energy – Cradle to Grave”
- 2020 “ Heat Transfer”

Presentation Topics

- The Basics : Understanding Energy

- The Past : Twentieth Century



- The Present : Twenty-First Century
- The Future : Twenty-First Century

The Basics : Understanding Energy

- What is meaning of “Energy” ?

- BTU Definition: Thermal Energy (Enthalpy)
  “Energy to Raise the Temperature of
  One Pound-mass of Water
  One Degree-Fahrenheit”

  - Thermodynamic Principles and Cycles
    - Rankin & Brayton Cycles

The Basics : Understanding Energy

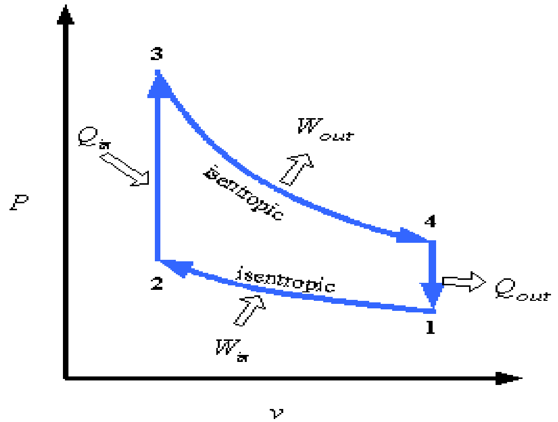
- kWh Definition: Work Energy (Entropy)
  "Force through a distance:
  kWh: kJ per second during an hour"

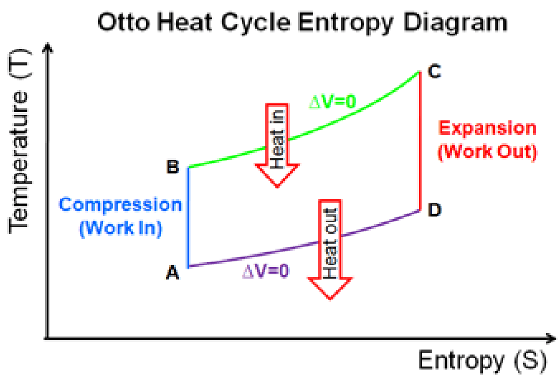
- The higher level of energy to a
  lower level of energy with the by-product of
  thermal energy.

- Work on the Fluid (Compressors & Pumps) or
- Work by the Fluid (Turbine)

The Basics : Understanding Energy

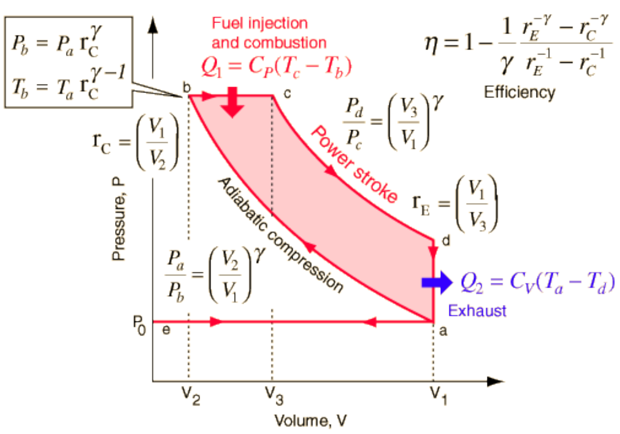
- **Energy Cycles : Automotive and Generator**
  - **Otto Cycle**
    - **(Working Fluid: Air)**

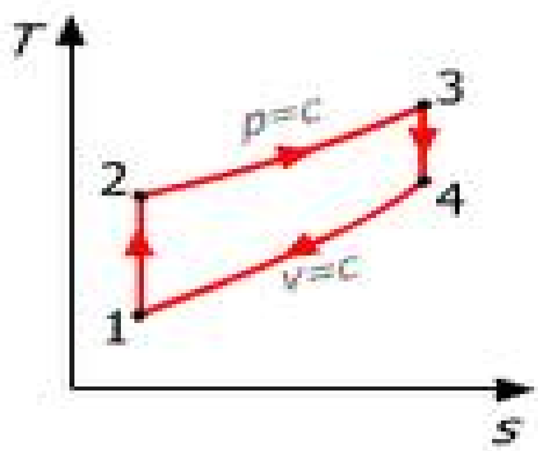




The Basics : Understanding Energy

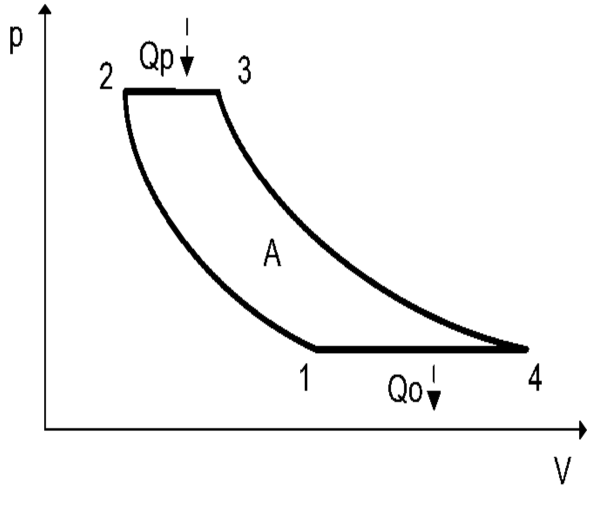
- **Energy Cycles : Automotive and Generator**
  - **Diesel Cycle**
    - **(Working Fluid: Air)**

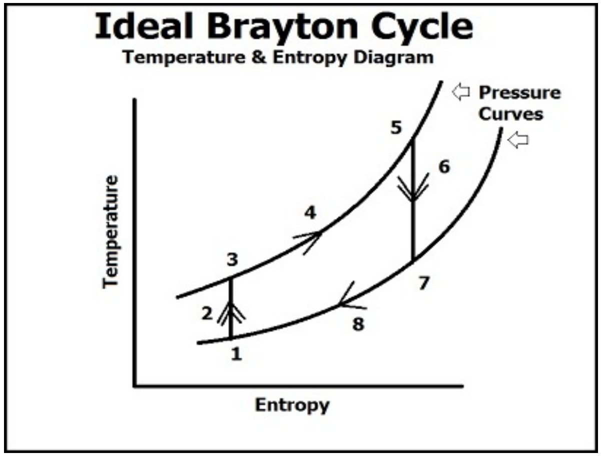




The Basics : Understanding Energy

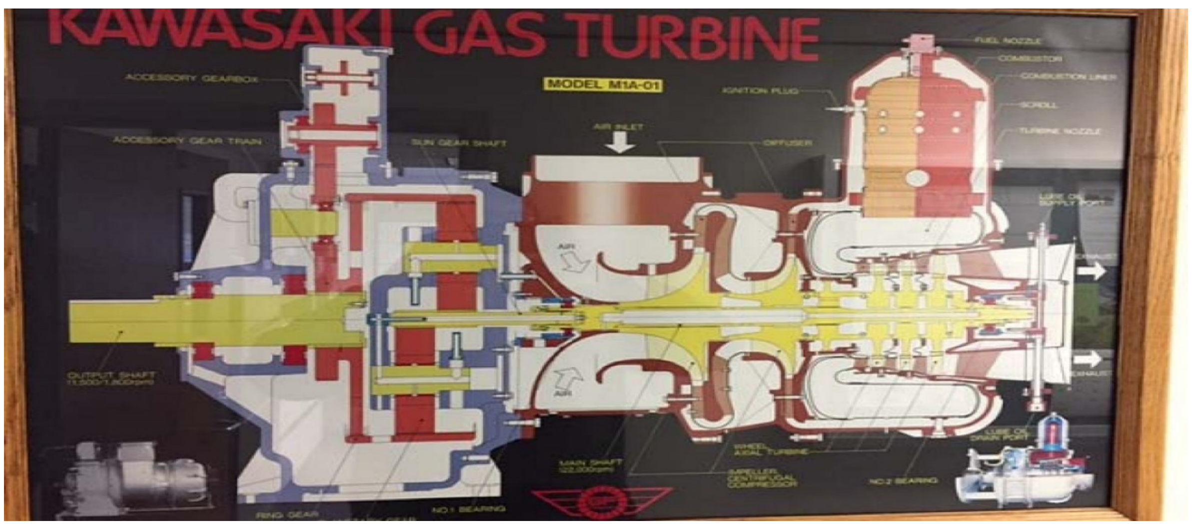
- **Energy Cycles : Gas Turbine and Jet Engines**
  - **Typical : Natural Gas (CH_4) Fuel Source**
  - **Brayton Cycle**
    - **(Working Fluid: Air)**





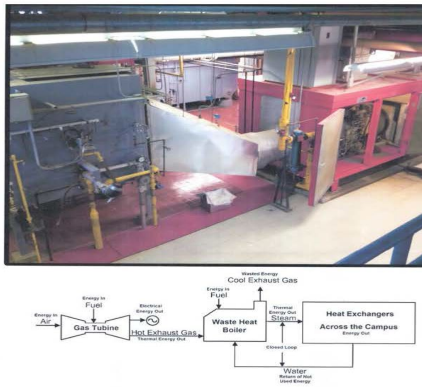
The Basics : Understanding Energy

- **Energy Cycles :**
  - **Brayton Cycle**
    - **(Working Fluid: Air)**
    - **The Larger the System the Higher the Gas Pressure**



The Basics : Understanding Energy

- **Energy Cycles : (Nominal: 1,000 kW)**
  - **Brayton Cycle**
    - **(Working Fluid: Air)**
    - **Combined Heat and Power:**
    - **Output: 800 kW in Hot Weather, 1200 kW in Cold Weather**

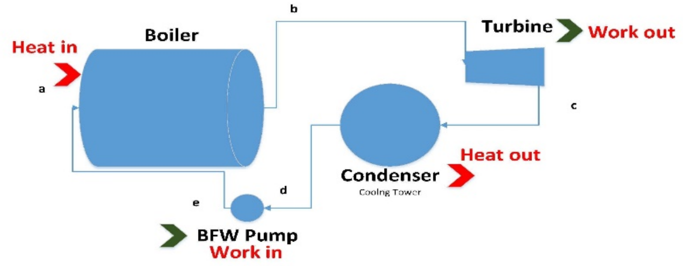


The Basics : Understanding Energy

- **Energy Cycles : (30,000 kW)**
  - **Brayton Cycle**
    - **(Working Fluid: Air)**
    - **Simple Cycle Effective in Cold Environments**

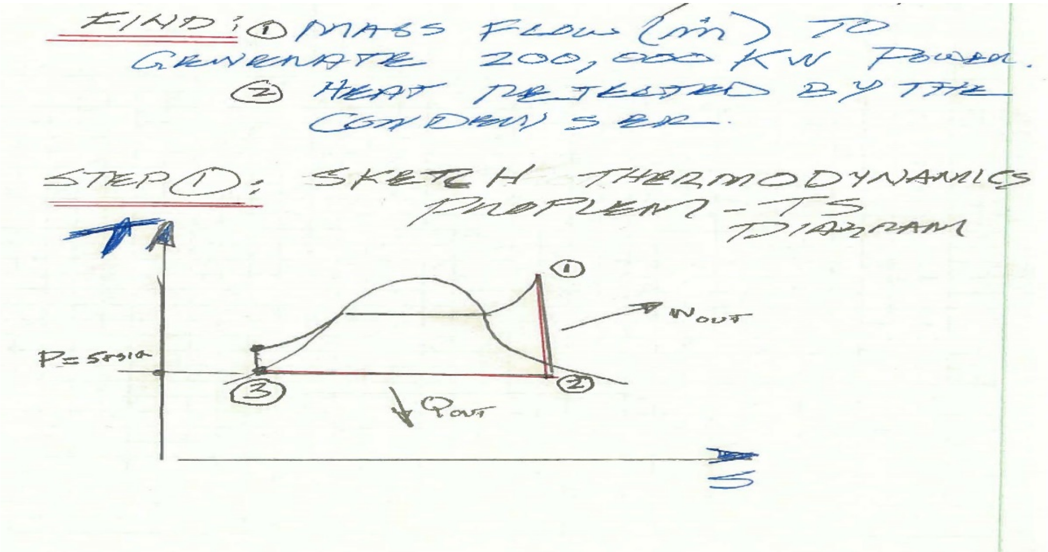
The Basics : Understanding Energy

- **Energy Cycles : Steam Power Plant**
  - **Typical : Coal & Nuclear Fuel Source**
  - **Rankin Cycle**
    - **Conventional Power Plant**
    - **(Fluid: Water)**



The Basics : Understanding Energy

- **Energy Cycles : Steam Power Plant**
  - **Typical : Coal & Nuclear Fuel Source**
  - **Rankin Cycle**
    - **Higher Level to Lower Level (Fluid: Water)**



The Basics : Understanding Energy

- Energy Cycles : Coal Driven Steam Power Plant
  - Rankin Cycle
  - Cooling Tower Condenser Heat Rejection

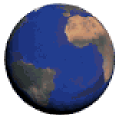
The Basics : Understanding Energy

- Renewable Energy:
  - Wind Turbines
    - Wind Capacity Factor
  - Solar Energy
    - Solar Constant
  - Hydro-Power
    - River and Stream Dam System
    - One of first sources of power to produce electrical energy
  - Geothermal
    - Volcanic Systems
    - Iceland

The Basics : Understanding Energy

- **Hybrid Forms of Energy:**
  - **Fuel Cell Systems**
    - **Typical Fuel Source: Natural Gas**
    - **Hydrogen bond separation**
    - **Battery concept**
    - **Hydrogen Economy of the year 2000**
  - **Bio-Fuels**
    - **Typical Fuel Source: Wood/Vegetation**
    - **Rankin concept**
  - **Demand-Side Energy**
    - **Conservation**

The Past : Twentieth Century



<u>The Advent of Power Plants</u>

- In 1882 was the first Coal-Fired Power Plant : Edition Electric Light Station (New York)
- In 1882 was the first Hydroelectric Power Plant (Wisconsin)
- Detroit Edison Company Founded in 1903
- Consumer Power Company Founded in 1910
- Dayton Power and Light Founded in 1911

The Past : Twentieth Century

”1920s” –Electrical Power System Expansion

Wilson Dam: Alabama: 1924 (650 MW)

In 1923, National Electric Light Association, experimented with electricity to agricultural farms connecting 20 farms by a six-mile electrical distribution system.

Farms Connected to Power in Michigan:

1929 Consumers Power Company had 7000 Farms connected to Power

1930 Consumers Power Company had 27000 Farms connected to Power

1935 Detroit Edison Power Company had 4700 Farms connected to Power

The Past : Twentieth Century

” 1930s” –Power Systems during Great Depression

Hardy Dam: Michigan: 1930 (30 MW)

Wheeler Dam: Alabama: 1935 (400 MW)

Hover Dam: Nevada/AZ: 1931 (2080 MW)

Grand Coulee Dam: Washington: 1933 (6800 MW)

1930 Hardy Dam Construction (100 foot Head) can generate up to 30,000 kilowatts (30 MW) of electricity, enough to serve a community of **16,600** people. Approximately 10 miles south of Big Rapids.

The Past : Twentieth Century

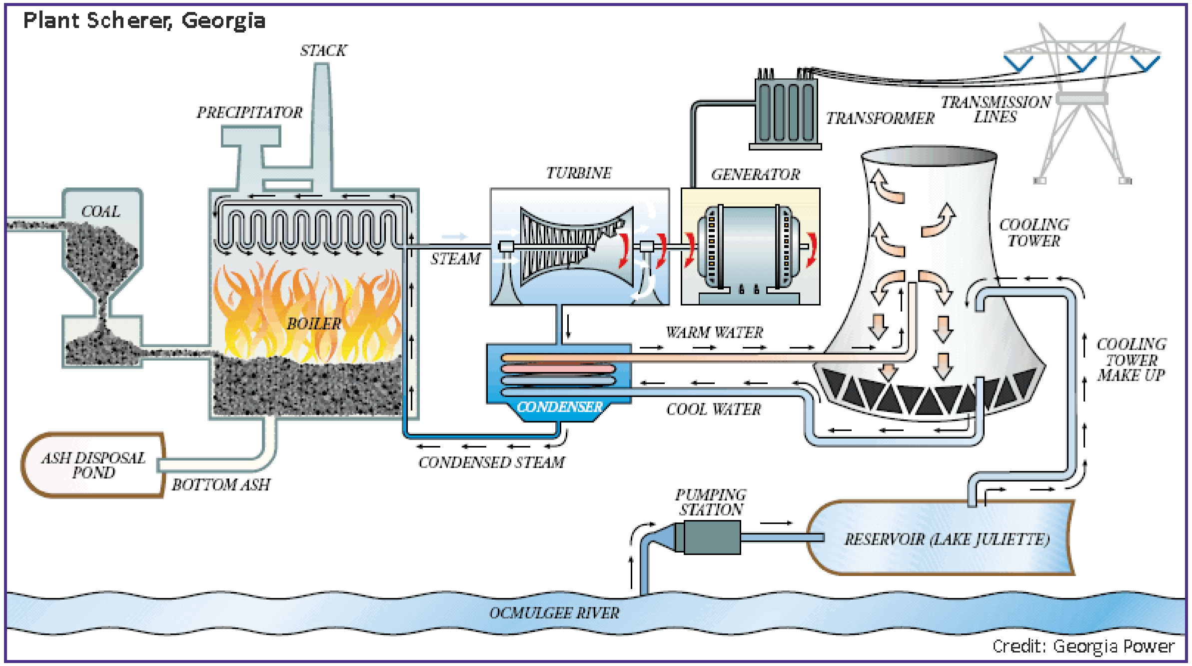
- **Rankin Cycle – Coal "Energy"**

Coal Plants Became More Popular
During the 1940's, 50's, 60's and 70's

- **8,000 BTU per Pound of Wood**
- **12,500 BTU per Pound Coal**
- **91,000 BTU per Gallon Propane**
- **100,000 BTU per 100 -CuFt Natural Gas (1CCF)**
- **138,500 BTU per Gallon of #2 Fuel Oil**
- **3,412 BTU per 1 kWh**

The Past : Twentieth Century

- **Rankin Cycle – Coal "Energy"**



The Past : Twentieth Century

<u>1940s Recognition : Greatest Generation</u>

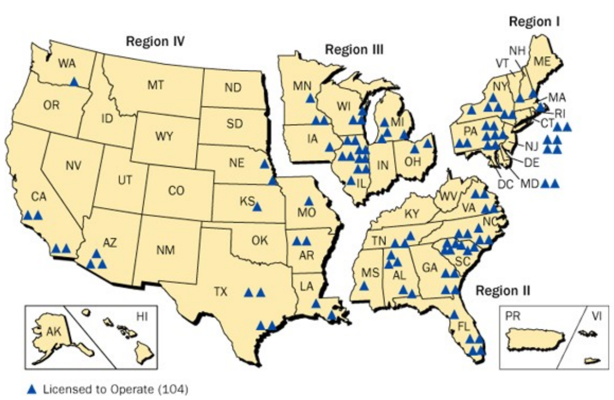
Ben - 96

Marie- 100

The Past : Twentieth Century

”1950s-1960s” – Nuclear Energy

Electricity too Cheap to Meter



- Coal and Nuclear Plant Construction Phase
- Accounts for 19.50% of electric energy generation in 2015.
- Three-mile Island – Started in 1968, opened in 1974, failed in 1979.

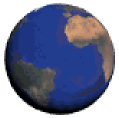
The Past : Twentieth Century

”1973” – Oil Embargo

(U.S. Air Force Enlistment Year)

- **Oil crisis** began in October 1973. Created by OAPEC.
- Organization of Arab Petroleum Exporting Countries
- Embargo Created by Arab – Israeli Conflict
- Price of oil from $3 to $12 per barrel , globally
- Natural gas at FSU from $0.75 per MCF to $5.00 per MCF in one year1979 to 1980

The Past : Twentieth Century



“1980” – Carter Administration

(EADC – UD Energy Analysis and Diagnostics Center)

(Beginning of the Energy Conservation Era)

Industrial Assessment Centers (formerly called the Energy Analysis and Diagnostic Center (EADC) program) were created by the Department of Commerce in 1976 in response to the oil embargo and rising energy costs. It was specifically focused on helping small and medium-sized manufacturing facilities cut back on unnecessary costs from inefficient energy use.

The Past : Twentieth Century

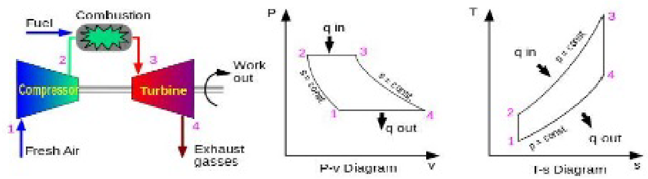
“1990s” –Natural Gas Deregulation

(Gas Turbine Era Begins – Brayton Cycle)

In 1985, FERC issued Order No. 436, which was the beginning of Natural Gas Deregulation.

- **Simple Cycle**

Gas Turbine Generator: M1A-01-K01



Brayton Cycle for Gas Turbine Generation

Based on Test Data for FSU's M1A-01-K01, January 1989:

- State 1 : Fresh Air enters the Gas Turbine:
  - On 1/4/1989 the air temperature at 9:10 am is 81.4 deg F at 14.4 psia.
- State 2 : Fresh Air is compressed by internal compression system
  - The air is compressed to 92.4 psig (106.8 psia)
- q-in : Natural Gas is injected into the combustion section with the compressed air.
  - Natural Gas pressure is measured at 155 psig, and the air is at 92.4 psig.
- State 3 : Combustion air is used as the working fluid
  - The Air is used to rotate turbine between State 3 and State 4
- State 4 : Pressure is Reduced to near atmospheric pressure at high temperature.

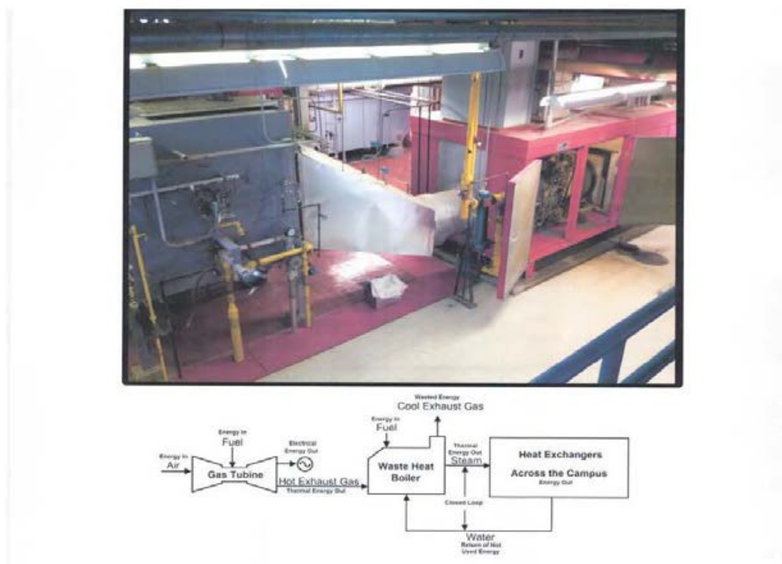
Note that the FSU Gas Turbine operated adequately at 155 psig natural gas pressure in 1989.

The Past : Twentieth Century

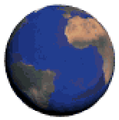
“1990s” –Natural Gas Deregulation

(Gas Turbine at FSU Installed in 1988 – Brayton Cycle and Heat Reclaim from High (800 degF) Temp O2)

- **Combined Heat and Power Cycle**



The Past : Twentieth Century



“2000” – LEED Certification

(Emphasis on the Environment)

- Sustainable Site
- Water Efficiency
- Energy & Atmosphere
- Material & Resources
- Indoor Environmental Quality

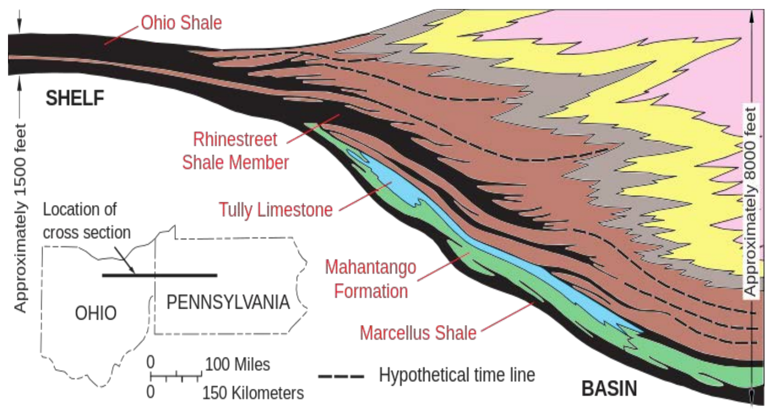
- LEED has evolved since 1998 to more accurately represent and incorporate emerging green building technologies.
- New State of Michigan Academic Buildings in State of Michigan Require LEED Certification

Present: Twenty-first Century

“2010” : Marcellus - Utica Gas Shale

The Marcellus Shale is an organic-rich rock unit that historically attracted limited commercial interest because of its low permeability. However, with improvements in horizontal drilling, production has increased.

The Utica Shale is located a few thousand feet below the Marcellus Shale but has potential of more yield than the Marcellus Shale region.



Present: Twenty-first Century

Ferris State University
Demand-Side of Energy

3,378,000 Square Feet

Central Steam Plant
Serves 95% Campus

Heat & Domestic Hot Water

Backup - Generation

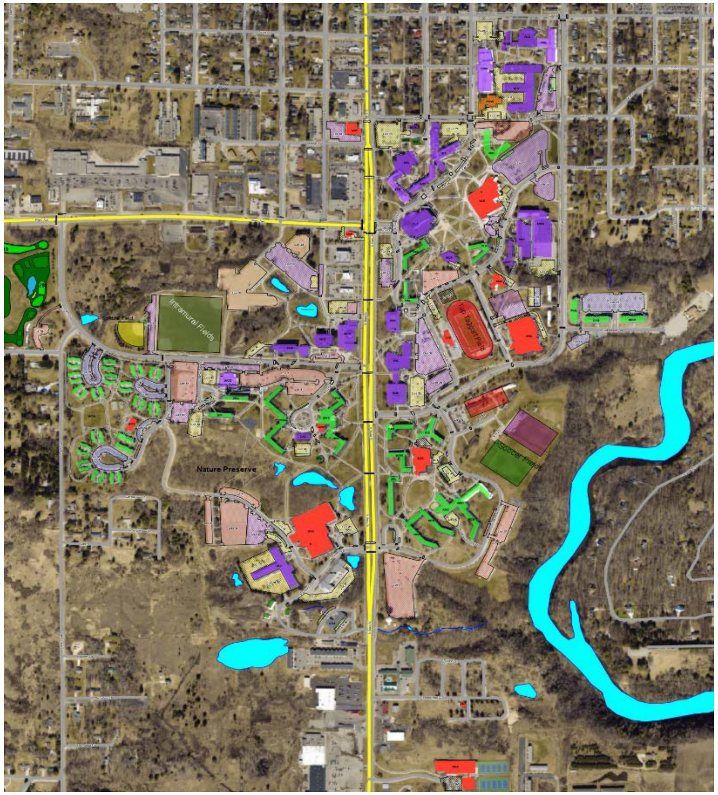
250 kW Black Start Generator

Present: Twenty-first Century

Ferris State University
Demand-Side of Energy

3,378,000 Square Feet

- ***1.5 Miles Steam (from CHP to farthest point***
- ***8 MW Max Demand***
- ***Medium Voltage (7200 V Delta)***
- ***85,000,000 BTUh Winter Peak***
- ***1MW Gas Turbine Generation***



Present: Twenty-first Century

“Effective” Engineering

1. ***“Safety”***
2. ***“Reliablity”***
3. ***“Efficiency”***

Present: Twenty-first Century

“Safety – First”

Present: Twenty-first Century

- ***<u>Demand-Sided : Reliablity and Efficiency</u>***

VFD Driven Boiler Feedwater Pumps Maintaining Constant Pressure.
Pumping Variable Energy Flow (90,000 lb/h to 10,000 lb/h), regardless of drum level valve position

Present: Twenty-first Century

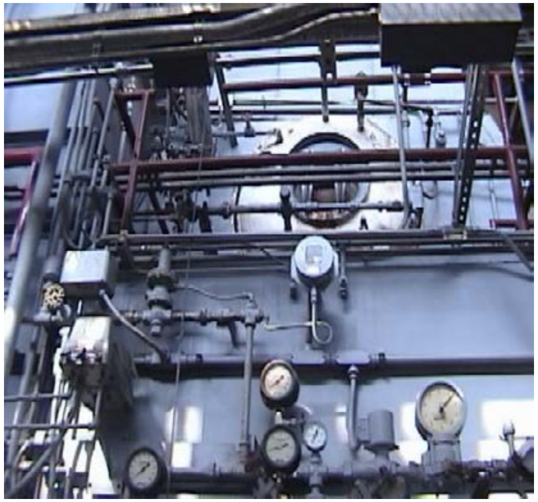
- ***Demand-side : Reliablity and Efficiency***

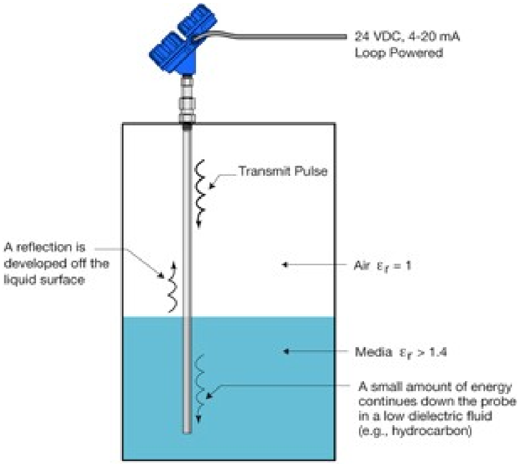
Increasing the Net Positive Suction Head Available (NPSHA) Reducing Cavitation due to Vapor Pressure
Feed water from DA is maintained at 6 psig at 228 degree F (Reliability Improvement)

And provides "energy recovery" for make-up water system to campus DHW. (Efficiency Improvement)

Present: Twenty-first Century

- ***Demand Side: Reliablity and Efficiency***





Drum Level Control using Wave-Guide Radar versus Differential Pressure (DP) Control

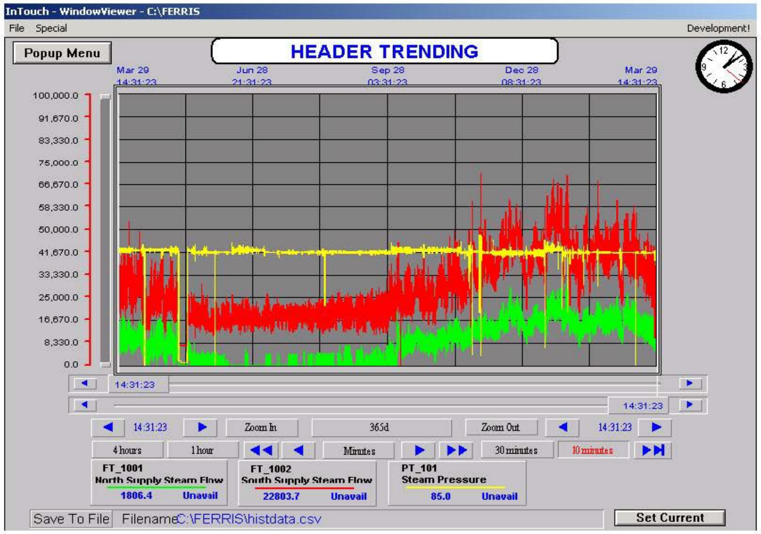
Present: Twenty-first Century

Demand Side – Reliability Control

- ***<u>Internal Intranet - no Internet Access</u>***

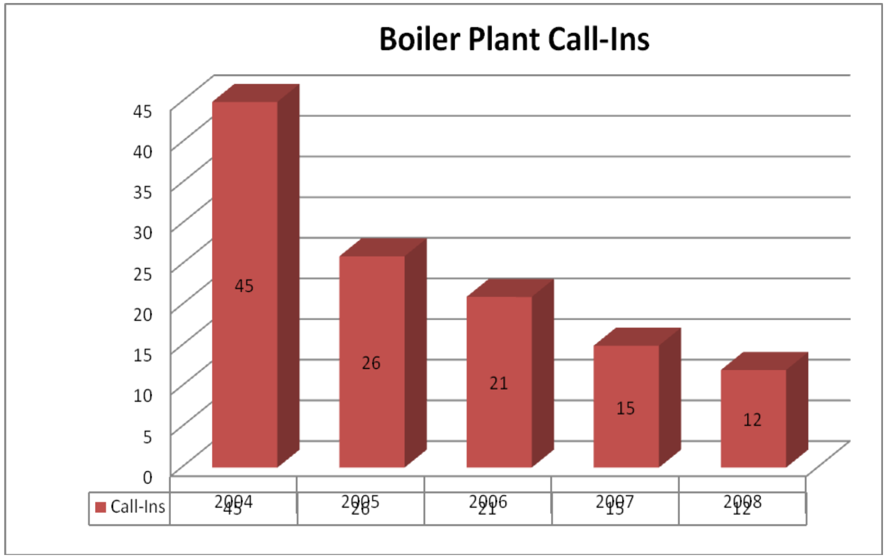
- Removed Single-Element Loop Controller with PLCs

- Removed internet access



Present: Twenty-first Century

- ***Reliablity produces Efficient Results***
  - ***Meaningful Metrics***



Un-Planned Steam Outage at FSU based on Boiler Operator Call-in

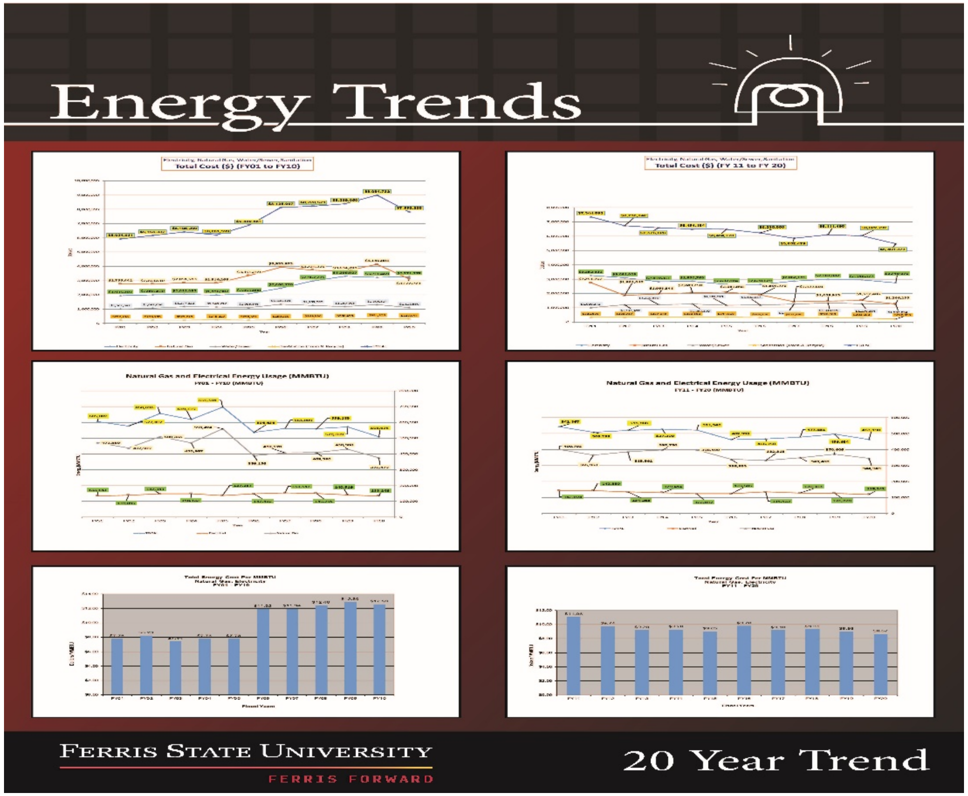
Present: Twenty-first Century

- **Supply Side : "Price Certainty"**

Key Metric:

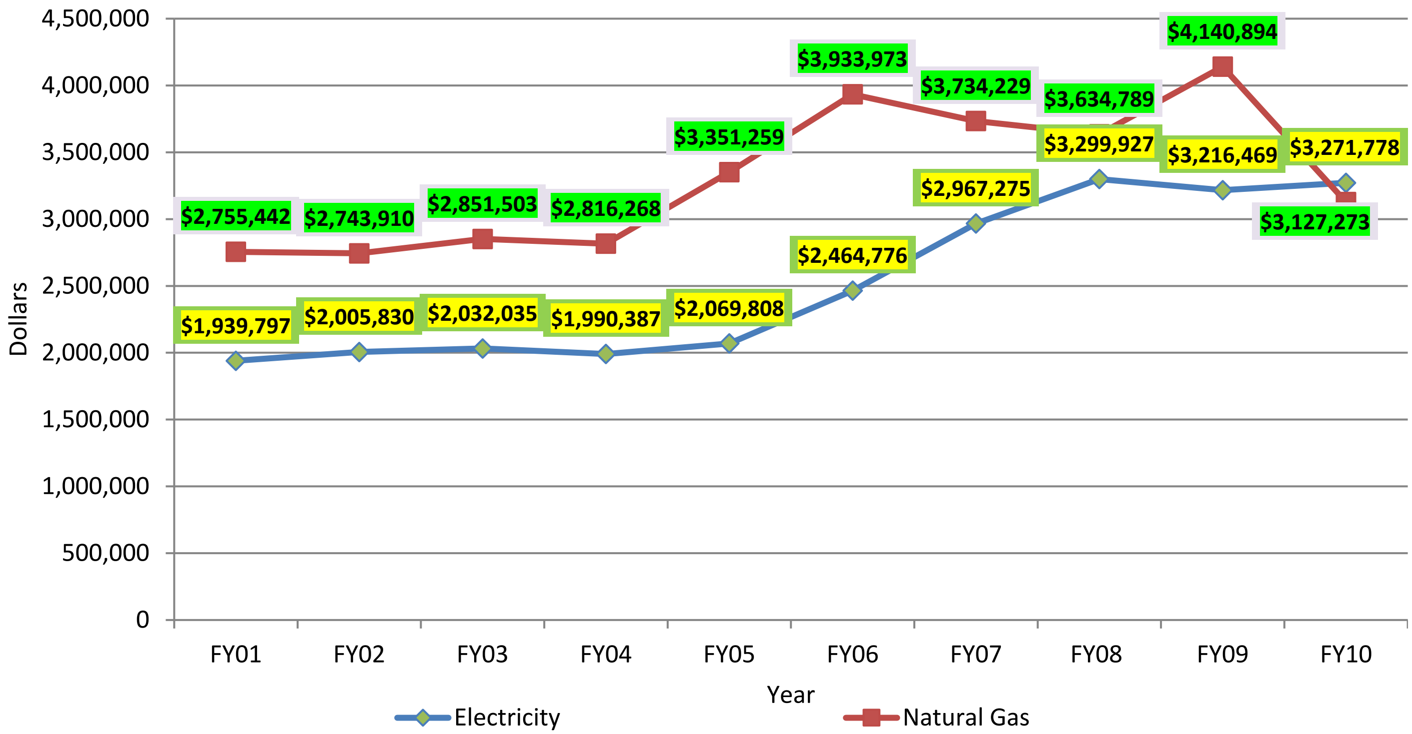
The graphic illustrates a 20-year trend

Use common unit of Rate for Electricity and Natural Gas based on **$/BTU**.



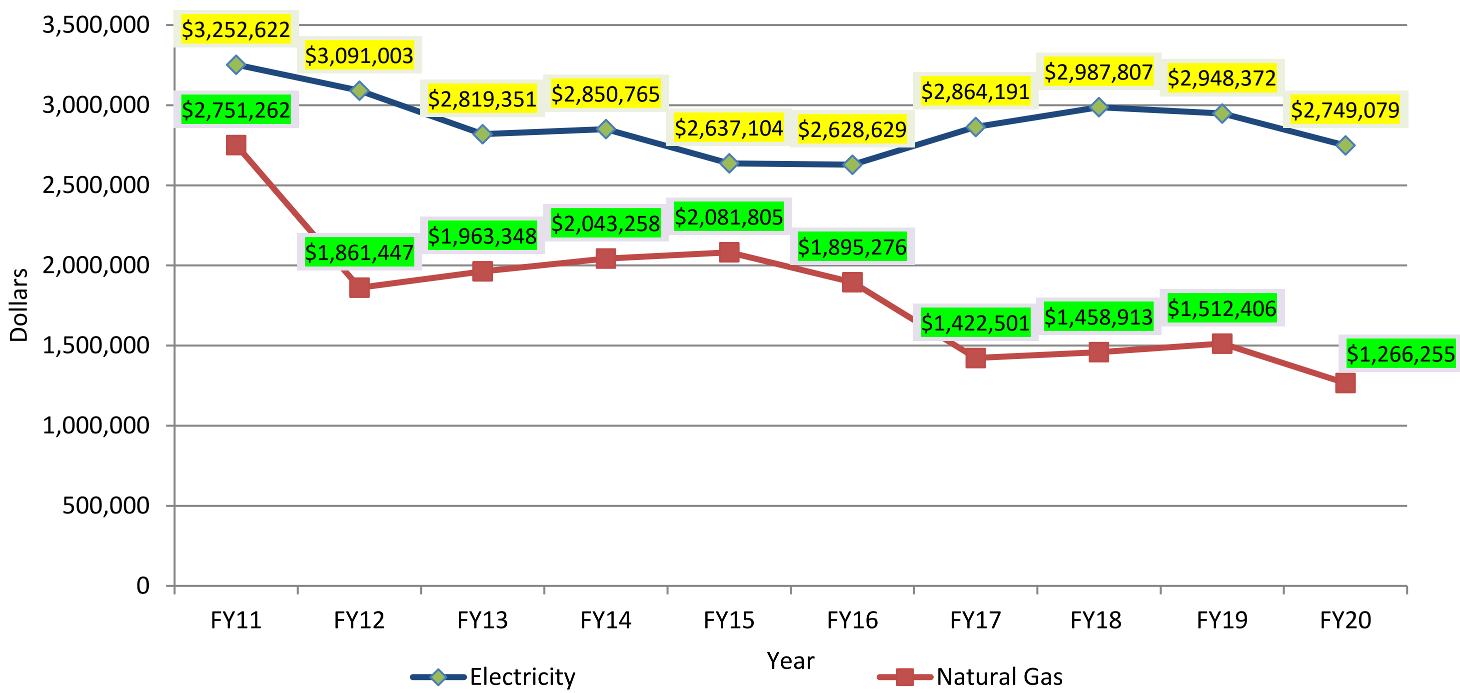
Present: Twenty-first Century

- ***Supply Side : "Price Certainty – 2001 to 2010"***



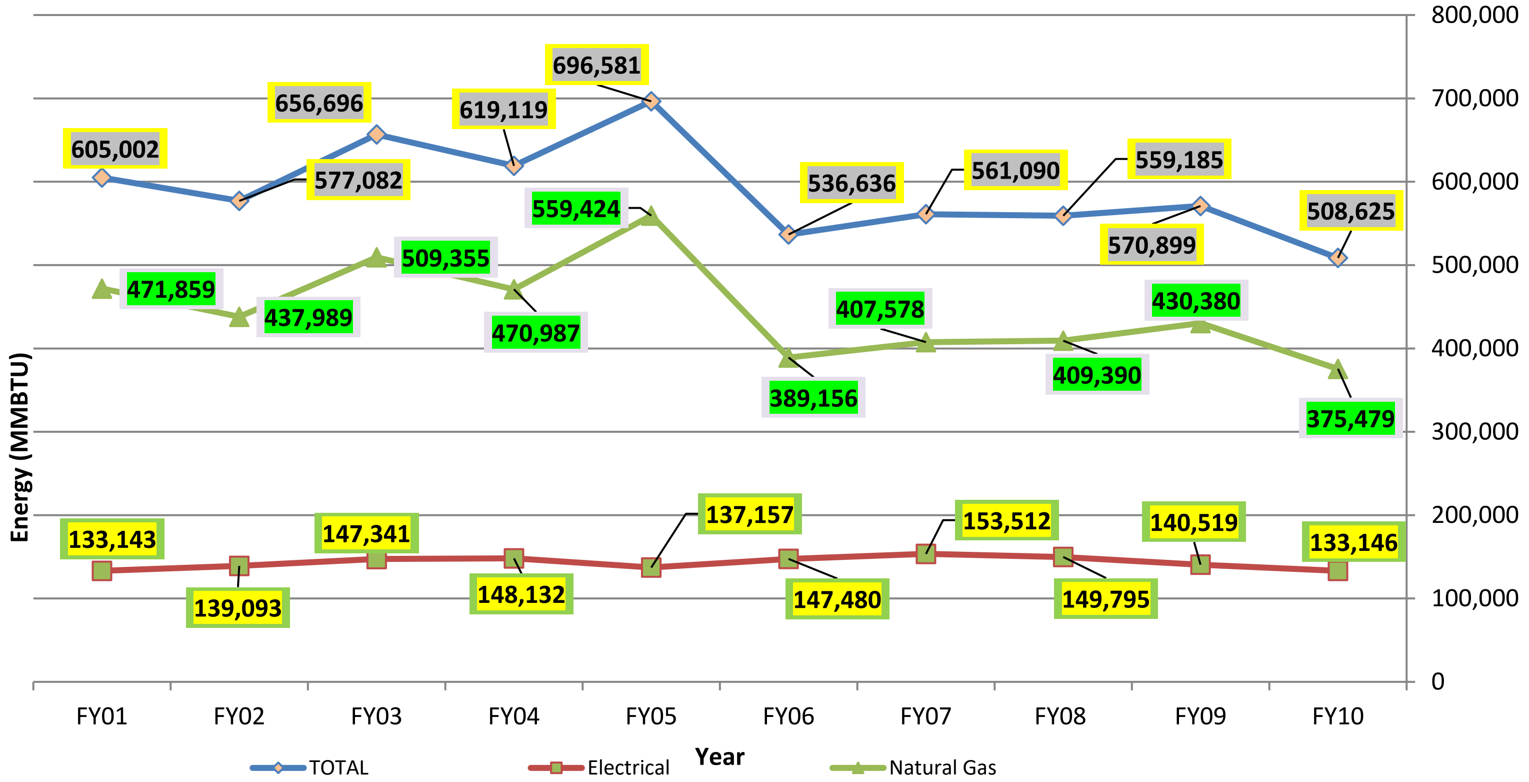
Present: Twenty-first Century

- ***Supply Side : "Price Certainty – 2011 to 2020"***



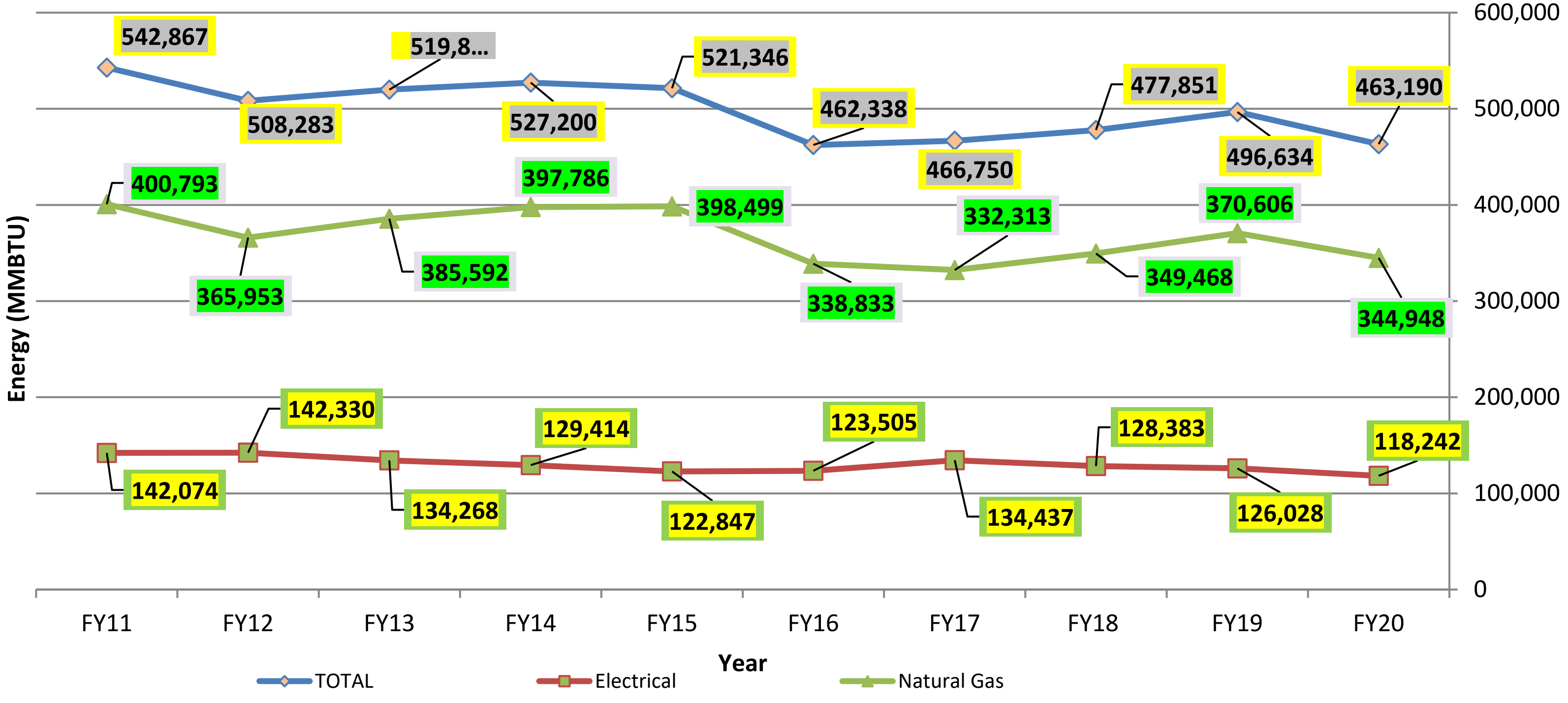
Present: Twenty-first Century

- ***Demand Side : "BTU Certainty – 2001 to 2010"***



Present: Twenty-first Century

- ***Demand Side : "BTU Certainty – 2011 to 2020"***



Present: Twenty-first Century

- ***Supply/Demand Side : "$/BTU Certainty – 2001 to 2010"***

	Total Cost per MMBTU	Electric Cost per MMBTU	Natural Gas Cost per MMBTU
FY01	**$7.76**	**$14.57**	**$5.84**
FY02	**$8.23**	**$14.42**	**$6.26**
FY03	**$7.44**	**$13.79**	**$5.60**
FY04	**$7.76**	**$13.44**	**$5.98**
FY05	**$7.78**	**$15.09**	**$5.99**
FY06	**$11.92**	**$16.71**	**$10.11**
FY07	**$11.94**	**$19.33**	**$9.16**
FY08	**$12.40**	**$22.03**	**$8.88**
FY09	**$12.89**	**$22.89**	**$9.62**
FY10	**$12.58**	**$24.57**	**$8.33**

Rise of NG Recession

Scale Feeds Discovery

Present: Twenty-first Century

- **Supply/Demand Side : "$/BTU Certainty – 2011 to 2020"**

	Total Cost per MMBTU	Electric Cost per MMBTU	Natural Gas Cost per MMBTU
FY11	**$11.06**	**$22.89**	**$6.86**
FY12	**$9.74**	**$21.72**	**$5.09**
FY13	**$9.20**	**$21.00**	**$5.09**
FY14	**$9.28**	**$22.03**	**$5.14**
FY15	**$9.05**	**$21.47**	**$5.22**
FY16	**$9.78**	**$21.28**	**$5.59**
FY17	**$9.18**	**$21.31**	**$4.28**
FY18	**$9.31**	**$23.27**	**$4.17**
FY19	**$8.98**	**$23.39**	**$4.08**
FY20	**$8.67**	**$23.25**	**$3.67**

The Future : Twentieth-First Century

- Demand Side : "Conservation & Efficiency"
- Demand Side : "Load Monitoring and Control"
- Supply Side: "Brayton Cycle Systems"
  - Natural Gas
- Supply Side : " Renewable Energy"
  - Hydro, Wind and Solar
- Supply Side: "Conventional Rankin Systems"
  - Coal, Nuclear

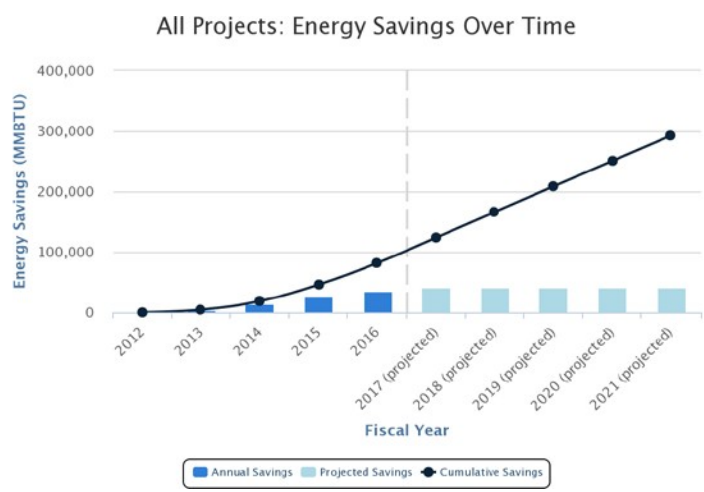
The Future : Twentieth-First Century

- <u>**Demand Side : "Conservation & Efficiency"**</u>

- **Extreme Insulation (Reduce Conduction)**
- **Air Heat Recovery (Reduce Convection)**
- **Foil Wrapping (Reduce Radiation)**
- **High Efficiency Boilers for Heating**
- **Geothermal Heatpump Systems for heating and cooling**
- **LEDs**
- **VFDs**
- **Innovative Reliability Processes (Radiant Heat Pipes)**

The Future : Twentieth-First Century

- ***Demand Side : "Monitoring and Control"***



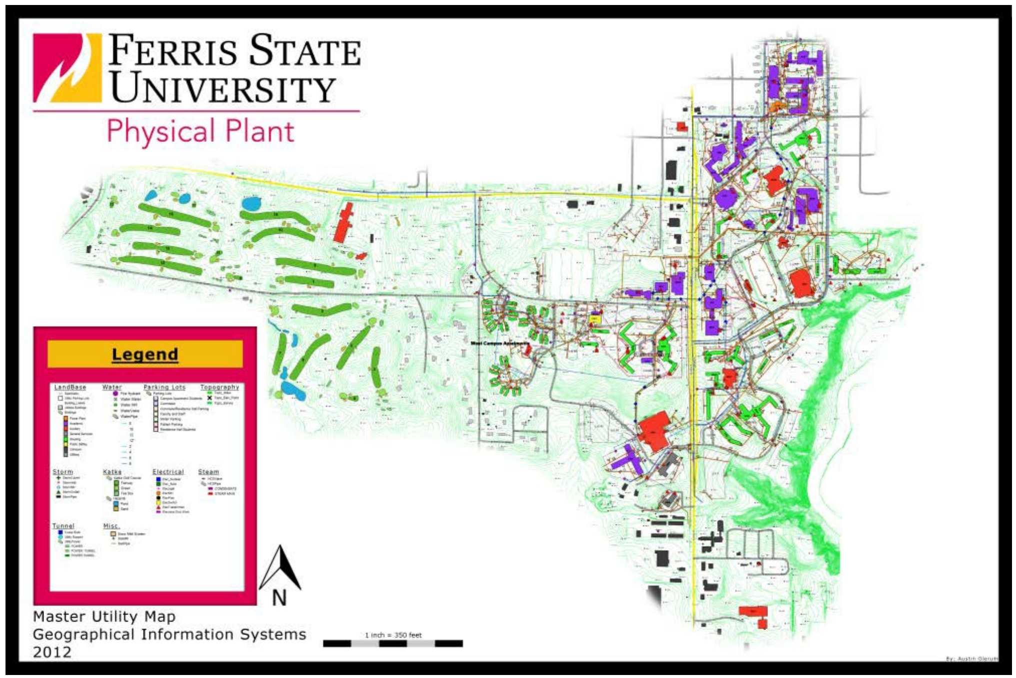
GRITS
Green Revolving Investment Tracking System

http://greenbillion.org/grits/

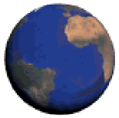
The Future : Twentieth-First Century

Integrating Energy Systems & Infrastructure into Geospactial Tracking

- **Infrastructure Systems – GIS**
  - Topography
  - Electrical
  - HP Steam
  - Condensate
  - Natural Gas
  - Sanitary Sewer
  - Water
  - Storm Sewer
  - Buildings
  - Roads
  - ADA
  - Points of Interest



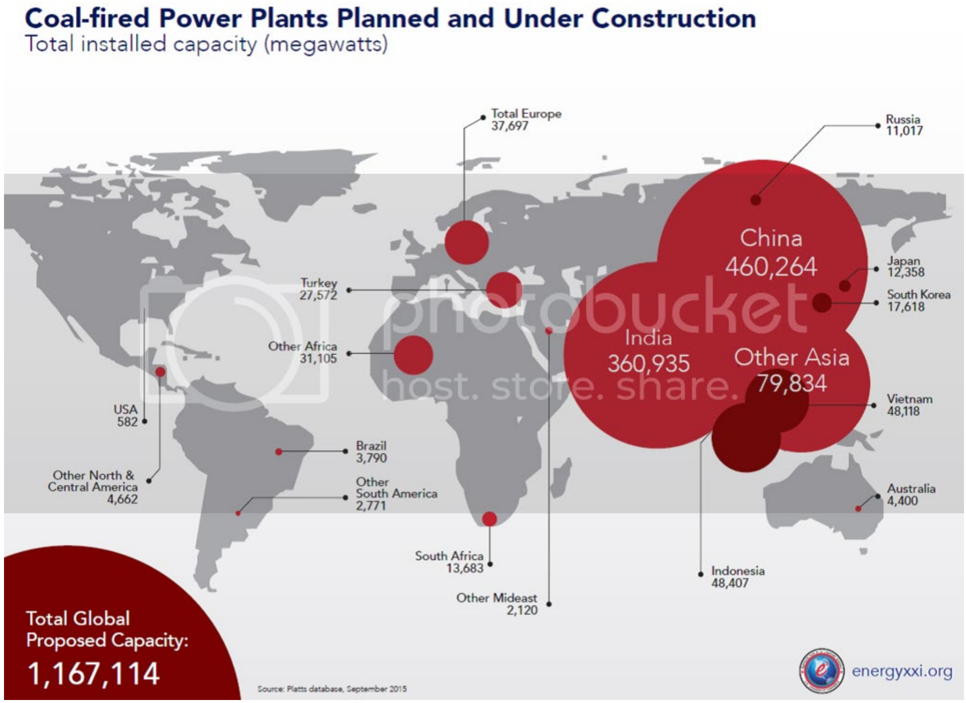
The Future : Twentieth-First Century



- **Rankin Cycle – Coal “Energy”**
- **No Coal Plants Planned or Under Construction in the USA**

<u>Top 10 Operational Coal</u>
Power Plants
(by Country)

<u>China : 1082</u>
<u>India: 281</u>
<u>USA : 252</u>
<u>Japan: 87</u>
<u>Russia : 85</u>
<u>Indonesia : 77</u>
<u>Germany : 74</u>
<u>Poland : 50</u>
<u>Turkey : 32</u>
<u>Czechia : 29</u>



The Future : Twentieth-First Century

- **Rankin Cycle – Nuclear "Energy"**

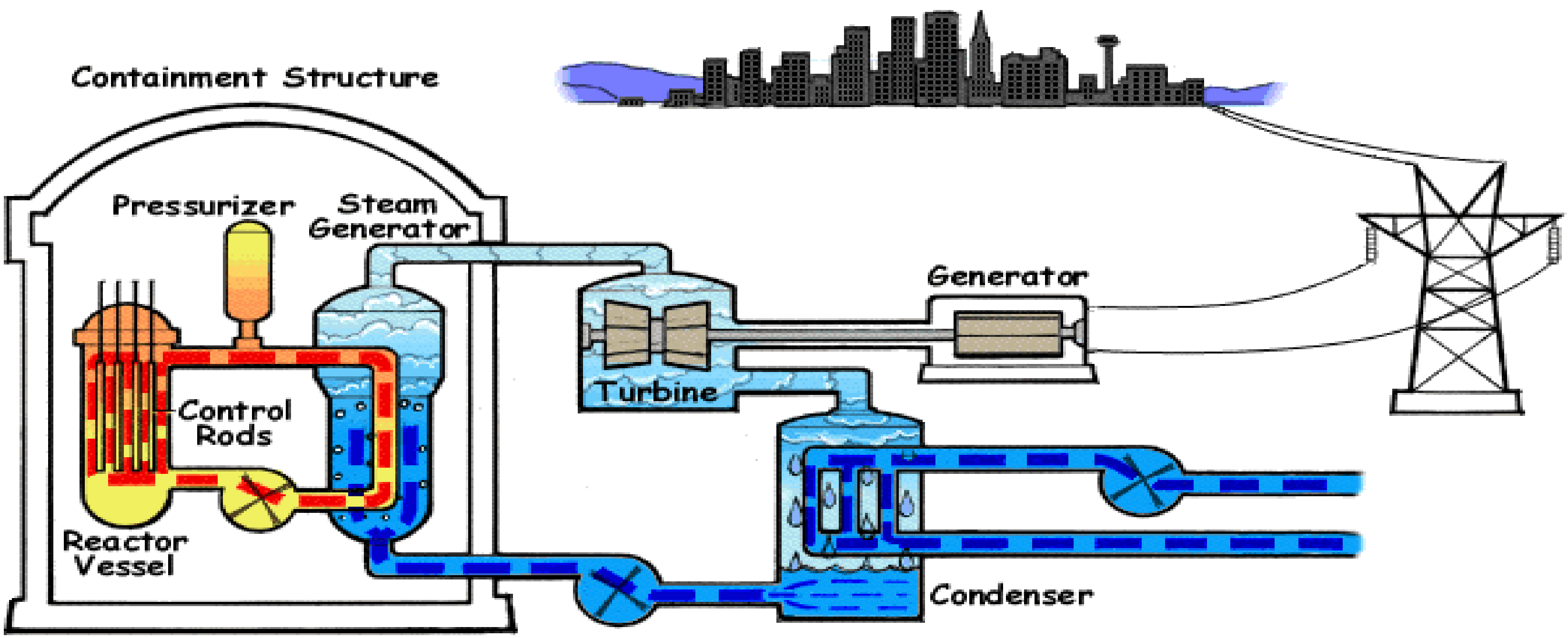
Top five nuclear electricity generation countries, 2019

Country	generation capacity (million kilowatts)	generation (billion kilowatthours)	country's total electricity generation
United States	98.12	809.41	19%
France	63.13	382.40	70%
China	45.52	330.12	5%
Russia	28.37	195.54	18%
South Korea	23.09	138.81	25%

Source: U.S. Energy Information Administration, International Energy Statistics, as of March 24, 2021

The Future : Twentieth-First Century

- **Rankin Cycle – Nuclear "Energy"**
- Nuclear waste is stored on-site



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- **Energy Cost Comparison**

Energy Resource Cost Comparsion					
ENERGY SOURCE	Unit	09-Apr-21 $/Unit	Equivalent BTU/Unit	Eqivalent MMBTU	09-Apr-21 $/MMBTU
2 Nuclear		(EST. Control Rods)			**$0.22**
1 Coal	Ton	$12.10	28,000,000	28.0000	$0.432
1 Natural Gas	MMBTU	$2.44	1,000,000	1.0000	$2.440
2 Wood (2500 lb per Cord)	Cord	$200.00	20,000,000	20.0000	$10.000
1 US Crude Oil	Barrel	$58.73	5,800,000	5.8000	$10.126
1 Heating Oil (#2)	Gallon	$1.87	139,000	0.1390	$13.453
2 Kerosene (#1)	Gallon	$2.00	134,000	0.1340	$14.925
2 Wood Pellets	Ton	$250.00	16,500,000	16.5000	$15.152
1 Highway Diesel	Gallon	$3.13	139,000	0.1390	$22.518
1 Highway Gasoline	Gallon	$2.94	124,000	0.1240	$23.710
1 Residential Propane	Gallon	$2.30	91,500	0.0915	$25.137
2 Electricity (Wind/Solar)	kWh	$0.10	3,412	0.0034	$29.308

1 www.electric.coop/weekly-fuel-price-watch

2 Estimates

Current bids for new nuclear power plants in China were estimated at between $2800/kW and $3500/kW https://en.wikipedia.org/wiki/Economics_of_nuclear_power_plants

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- **Brayton Cycle – Natural Gas “Energy” Replacing Coal**
  - **Gas Turbine Inlet Cooling**
  - **Texas 2021 Electrical Failure**

As coal power plants are taken of service, natural gas plants replace them. Moving from peaker plants to base load plants.

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- **Hydro "Energy" in Michigan**

Effective Form of Energy

Plant	Location	Power (MW)	Notes
Ludington Pumped Storage Power Plant	Ludington (Lake Michigan)	2172	Peak Power Control

Plant	Location	Power (MW)	Notes
Hardy Dam Edison Sault Ada Dam Hydro	Newaygo County (Muskegon) Sault Ste. Marie (Lake MI/Ontario) Ada (Thornapple)	30 27 30	50 year Enviro-Permits

Note: 55 Dams in Michigan and water levels determine actual capacity (Hardy = 10 MW : 30%)

From Wikipedia, the free encyclopedia

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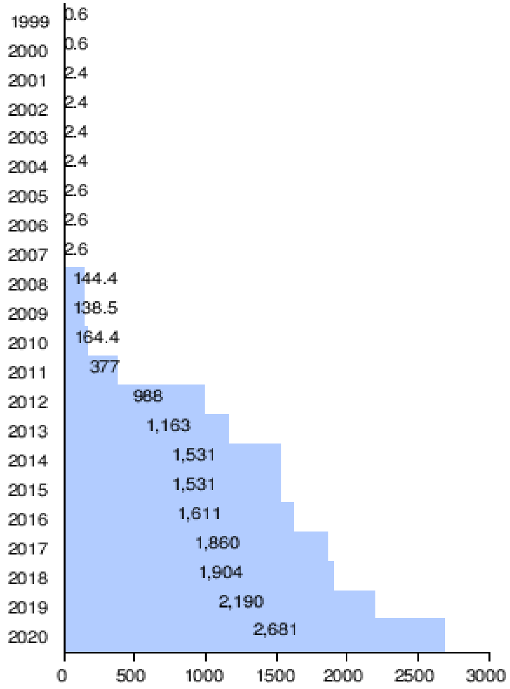
- **Wind Capacity Factor: Wind "Energy"**

Note: Wind Capacity Factor Ranges from 10 to 35 % & Big Wind is current focus.



From Wikipedia, the free encyclopedia

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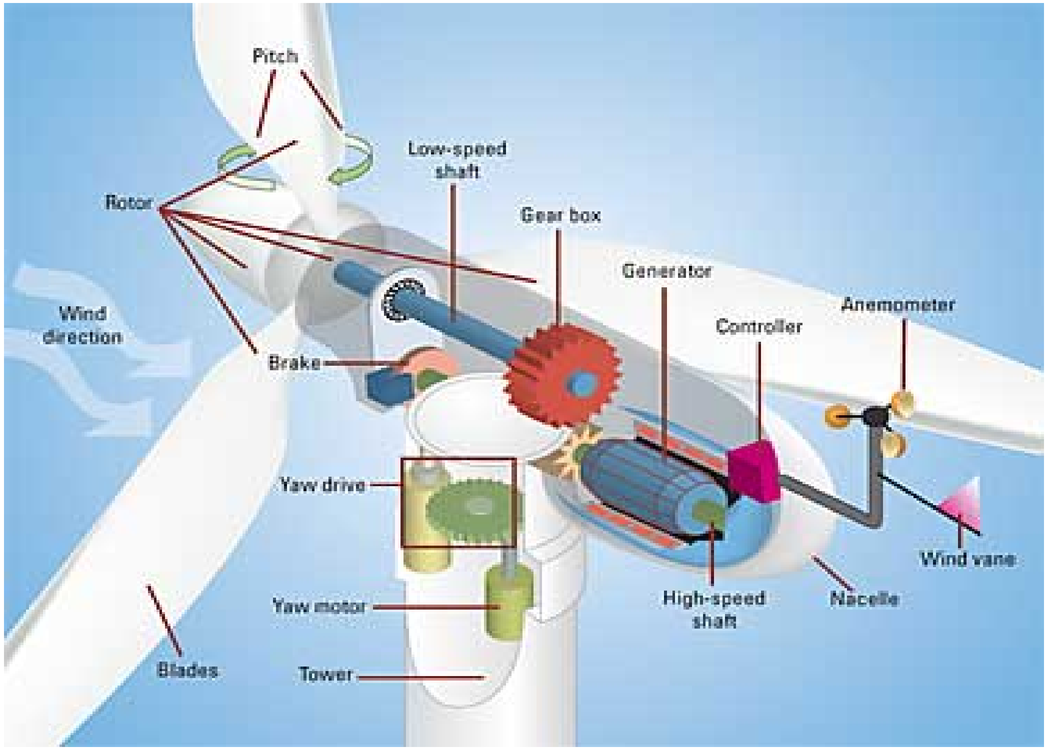
- **Wind Mechanical Factors: Wind**



From Wikipedia, the free encyclopedia

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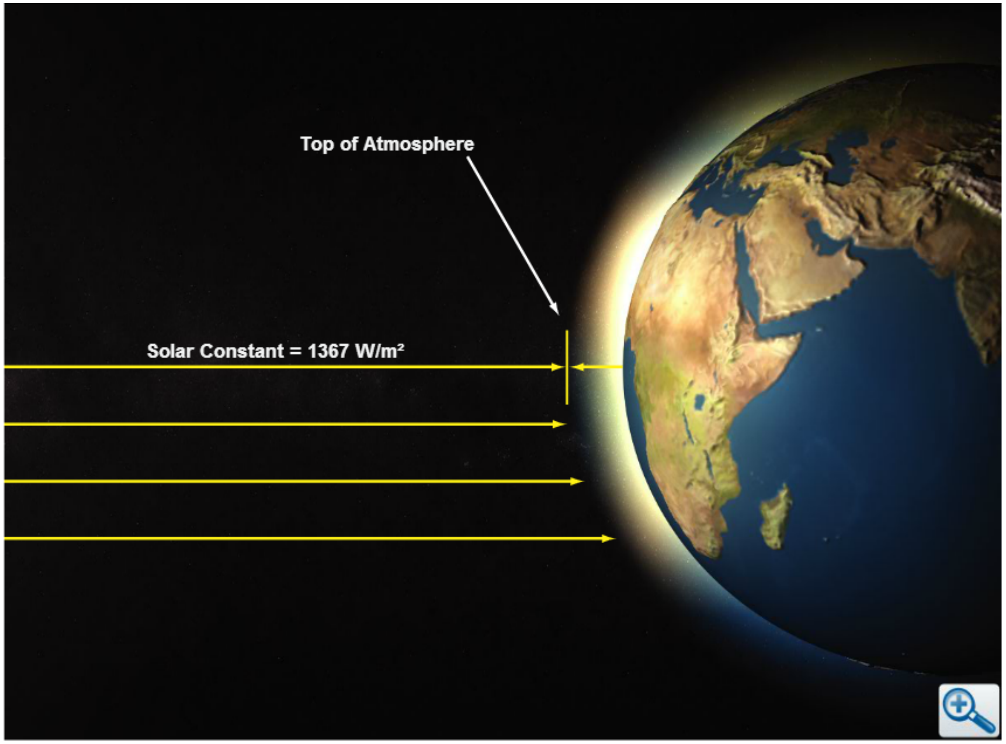
- **Solar Constant: Solar "Energy"**

Radiation outside of the atmosphere is called extraterrestrial solar radiation. The extraterrestrial solar radiation measured just outside Earth's atmosphere at the Top of Atmosphere (TOA), is called the solar constant. This is the measurement of solar radiation at the point just before it enters Earth's atmosphere.

The solar constant is 1367 W/m^2. It is taken from the average irradiance levels measured at various satellites in Earth's orbit over the course of a year. It is theoretically the maximum solar power available to a solar energy system if atmosphere were not a factor.



From Amatrol

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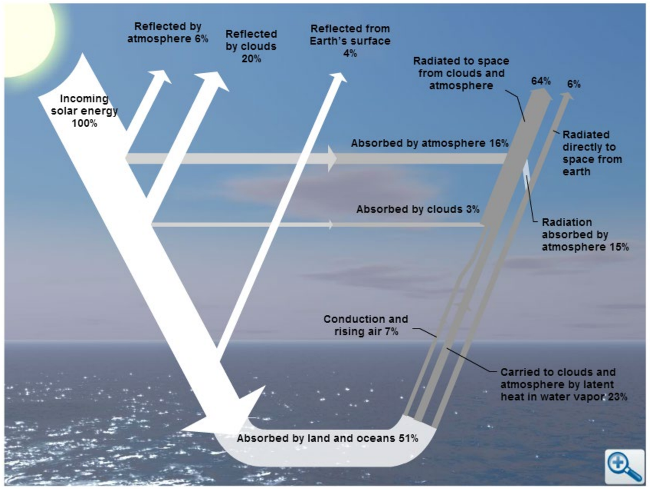
- **Solar Constant: Solar "Energy"**

Factors affecting Solar Energy



PV Material Efficiencies		
Material	**Typical Efficiencies (%)**	**Best Laboratory Efficiency (%)**
Multijunction gallium arsenide (GaAs)	33 - 38*	40.7*
Monocrystalline silicon	14 - 17	24.7
Polycrystalline silicon	11.5 - 14	20.3
Copper indium gallium selenide (CIGS)	9 - 11.5	19.9
Cadmium telluride (CdTe)	8 - 10	16.5
Amorphous silicon (a-Si)	5 - 9.5	12.1
Dye-sensitized (Grätzel)	4 - 5	11.1
Polymer (Organic)	1 - 2.5	5
* in concentrating applications		

Efficiency Table Courtesy of National Renewable Energy Laboratory (NREL)

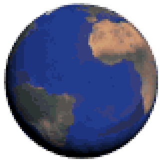
Laws and Mandates

“Michigan Energy Laws & Mandates "

- **Clean, Renewable and Efficient Energy Act: MI PA 342**
  - **Signed into law as MI PA 342, 12/16/16**
  - **Goal is the reduction of energy consumption by 2025 by 35% using renewables or energy optimization**

- **Michigan Energy Code for Buildings: ASHRAE 90.1 – 2013**
  - **Previously ASHRAE 90.1 - 2007**

Questions



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Legacy

TEACHERS AND PUPILS

A talk to a group of children. Published in Mein Weltbild, Amsterdam: Querido Verlag, 1934.

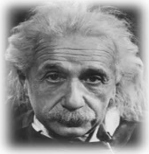
My dear Children:

I rejoice to see you before me today, happy youth of a sunny and fortunate land.

Bear in mind that the wonderful things you learn in your schools are the work of many generations, produced by enthusiastic effort and infinite labor in every country of the world. All this is put into your hands as your inheritance in order that you may receive it, honor it, add to it, and one day faithfully hand it on to your children. Thus do we mortals achieve immortality in the permanent things which we create in common.

If you always keep that in mind you will find a meaning in life and work and acquire the right attitude toward other nations and ages.

ALBERT EINSTEIN



Source: Einstein, Albert. *Ideas and Opinions*. New York: Bonanza Books/ Crown Publishers Inc., 1954. 56. Print.

100 Year Energy Pespective

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