A BIG PICTURE LOOK: DEVELOPING A ROBUST POWER GENERATION PORTFOLIO TO MINIMIZE GREENHOUSE GAS EMISSIONS

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Siemens Energy Inc.

Summary

Renewable generation can't do it alone - Non-renewable generation is needed to maintain a stable grid and the choice of a non-renewable partnering technology is important for the environment.

We need to protect the environment while also supporting the economy with cost effective, reliable electricity.

There is technology available today that can meet the need.



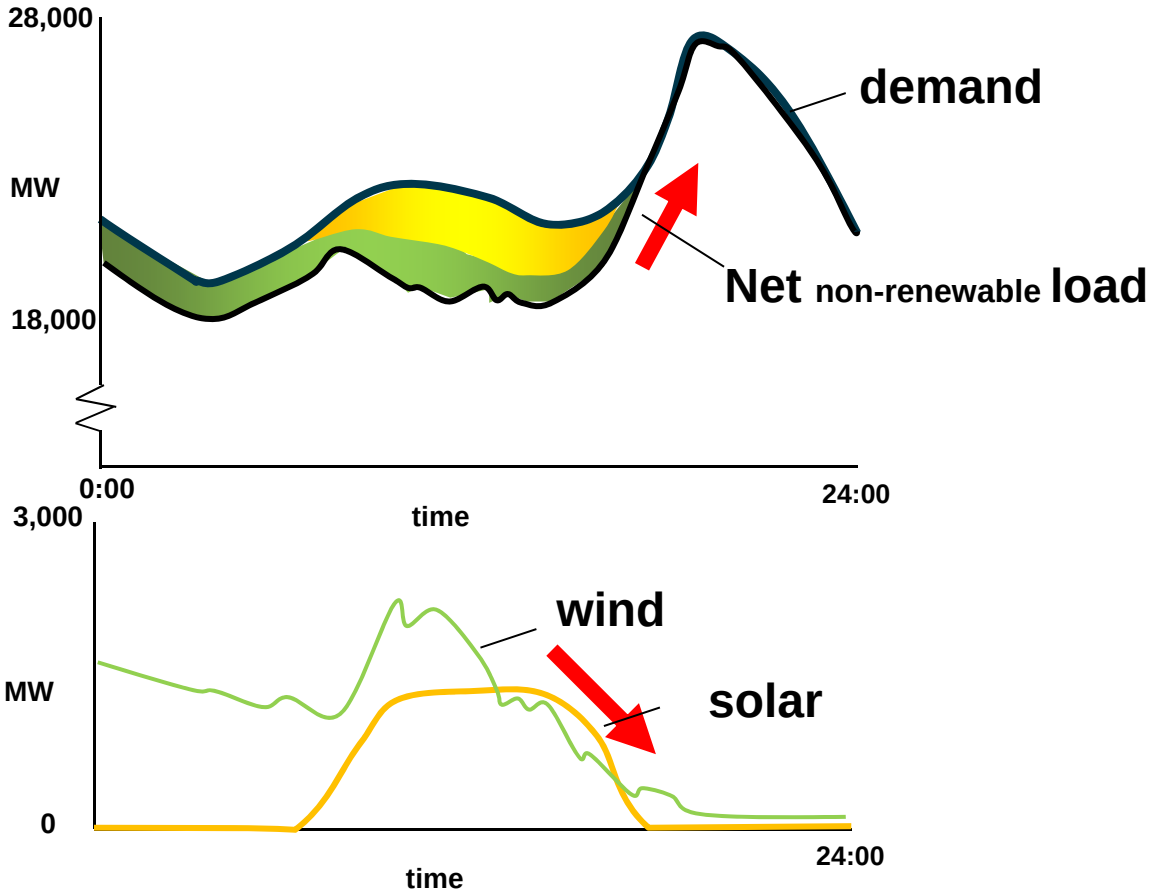


Weather dependent renewable generation has become a significant contributor on power generation grids in the US and around the world.

The dynamics of these weather dependent resources are raising questions about the needed capabilities for other generating resources on the grid.

Electricity Has to Be Made As It Is Used

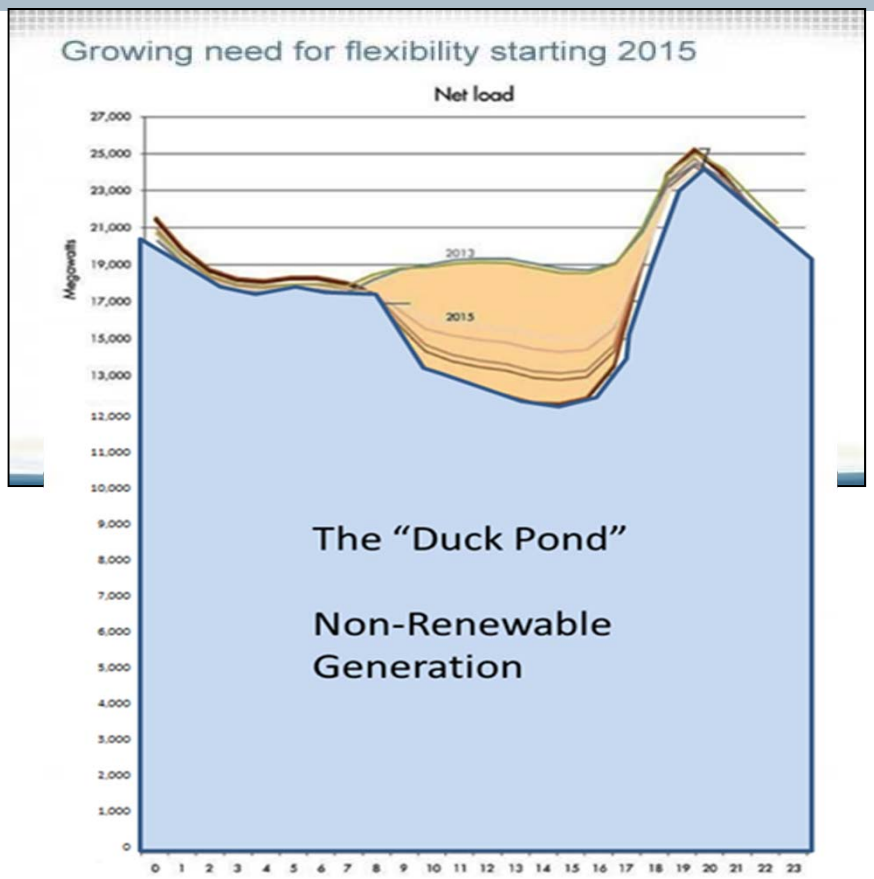
Weather Dependent Renewables Don't Always Produce Power

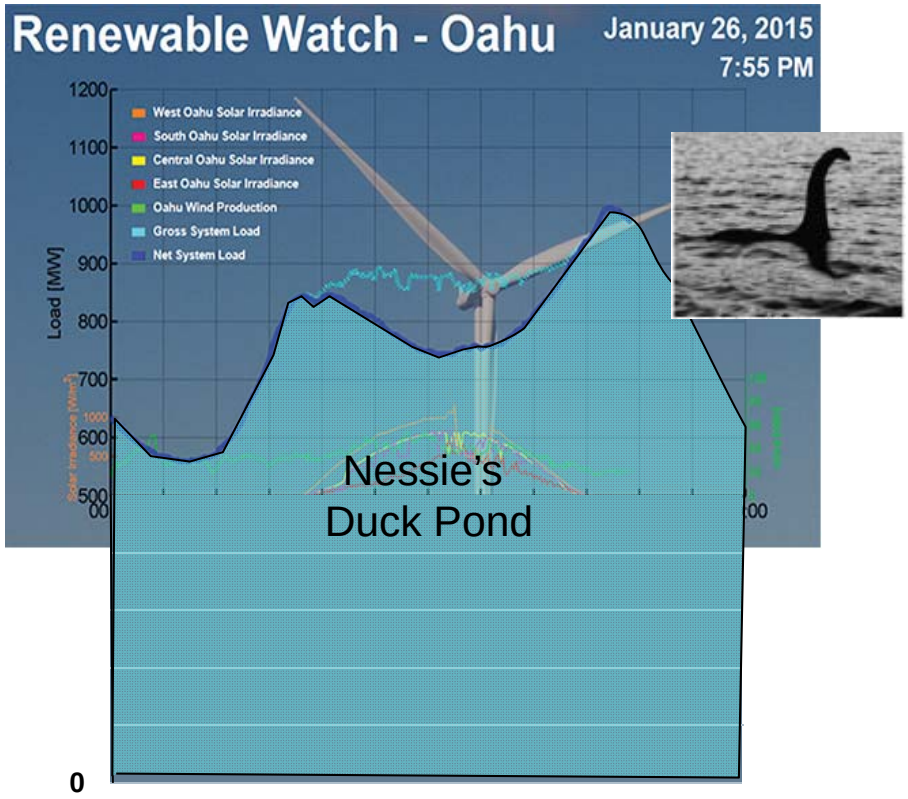


Demand typically peaks in the evening when the sun sets

Ref http://www.caiso.com/Documents/Apr5_2013InitialCommentsWorkshopIssuesR11-10-023.pdf

The Duck Pond
The non-renewable generation mix below the duck

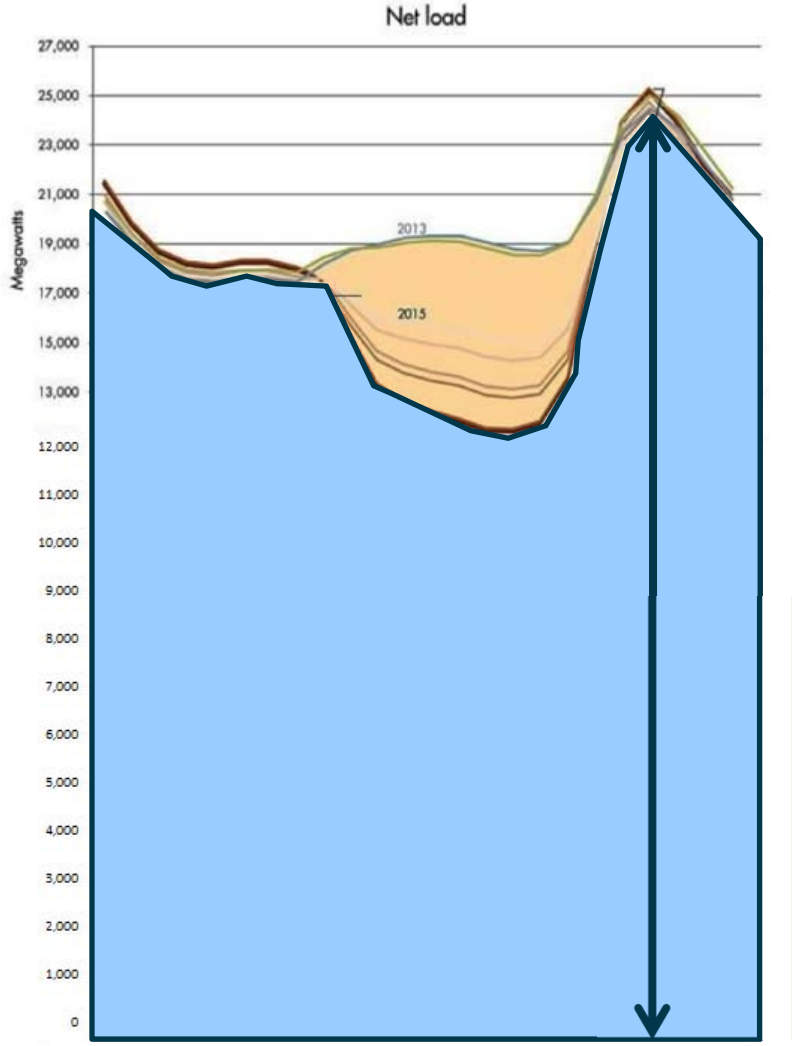




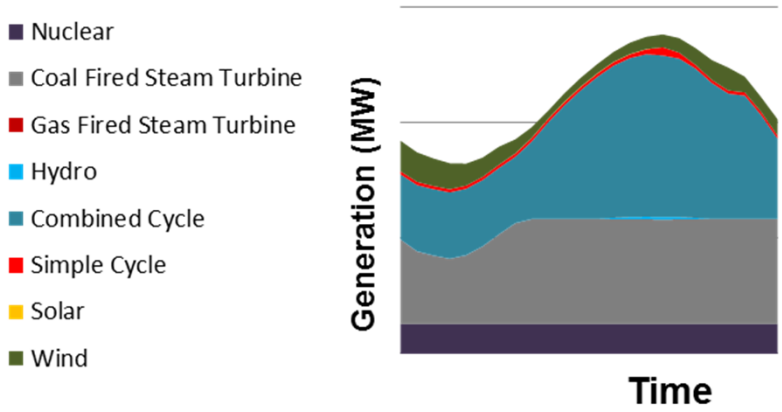
The environmental impact, the cost, and stability of generation are influenced by the underlying pond more than the duck or Nessie.

Ref: http://www.eia.gov/todayinenergy/detail.cfm?id=19731

Key Points about renewable generation partners



- **The total amount of non-renewable generation capacity needed is not significantly reduced by renewables**
- **Even with a lot of renewables, most of our electricity is generated by non-renewables**
- **The "pond" is filled with a variety of resources with varying capabilities and environmental footprints**



Example from Texas (ERCOT)

Determining How Much Greenhouse Gas (CO_2) a Power Plant Produces

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Fuel	Pounds of CO_2 emitted per million Btu of energy X
Coal	205 – 229
Diesel fuel & heating oil	160
Gasoline	157
Propane	139
Natural gas	117

Greenhouse gas production is directly dependent on fuel composition and how much fuel is burned

Plants that burn natural gas produce less CO_2/kW than plants that burn coal or oil

Low CO_2 production is achieved by choosing a low CO_2 fuel and having the highest plant efficiency

To calculate how much CO_2 a plant produces:

Unit Conversion from KW to BTU/hr

Conversion from fuel LHV to HHV

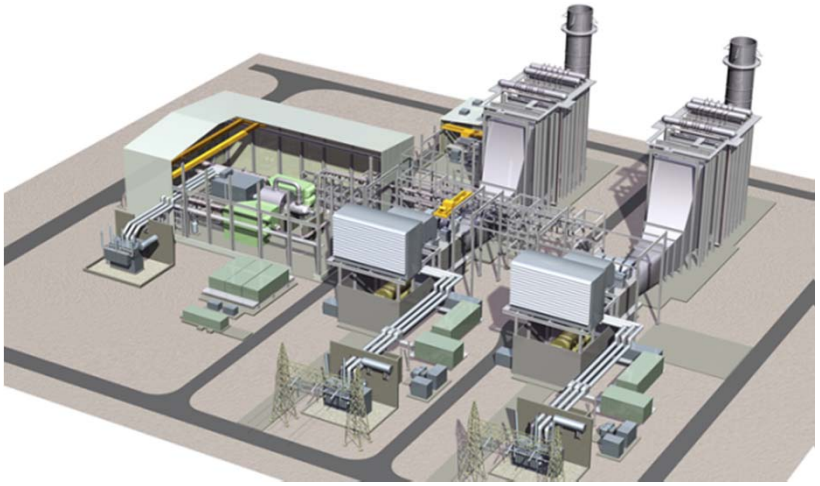
$$CO_2 = \frac{3412.142 \times X \times 1.1}{\text{Plant Efficiency} \times 1000}$$

Natural Gas is among the lowest CO_2 producing fossil fuels

ref: www.eia.gov/tools/faqs/faq.cfm?id=73&t=11

Two Types of Natural Gas Fired Power Plants

Simple Cycle



Combined Cycle

Combined Cycle and Simple Cycle Efficiencies (per GT World 2014)

Gas Turbine Technology	GT MW	Efficiency		CO_2 per MW-hr	
		SCGT	CCGT	SCGT	CCGT
Industrial GT	50.5	38.3	55.1	1147	797
Aero 1	63.5	43.4	53.5	1012	821
Aero 2	103.5	43.6	50.1	1007	876
E Class	114	34.3	51.3	1280	856
F Class	232	38.8	57.6	1132	762
H Class	274	40	60	1098	732

Combined cycle plants produce less CO_2/kW than simple cycle plants

Combined Cycles produce about 33% less CO_2 than a simple cycles with the same GT

ref: www.eia.gov/tools/faqs/faq.cfm?id=73&t=11

The traditional approach
Choosing by economics

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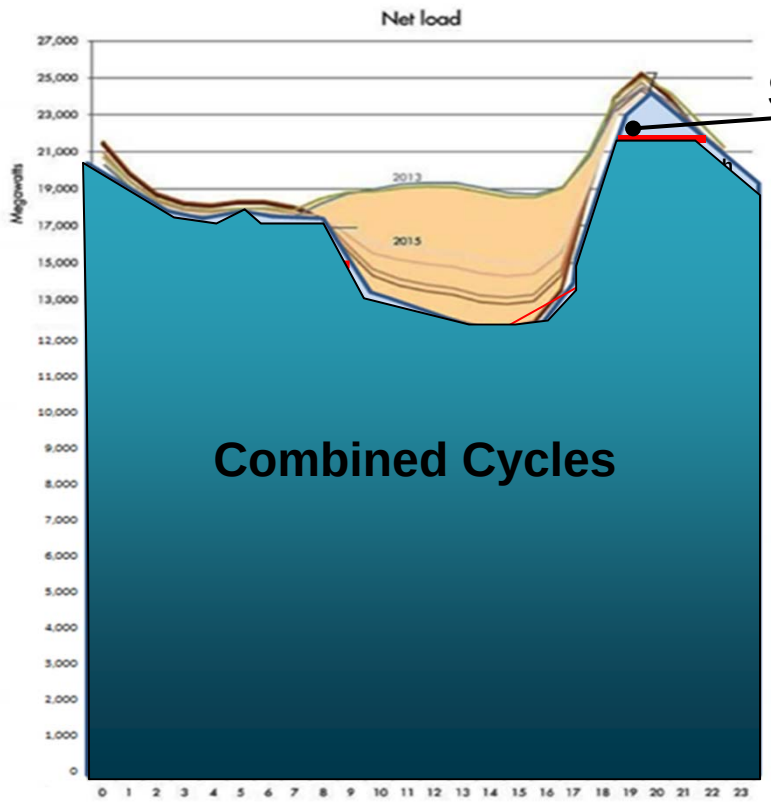
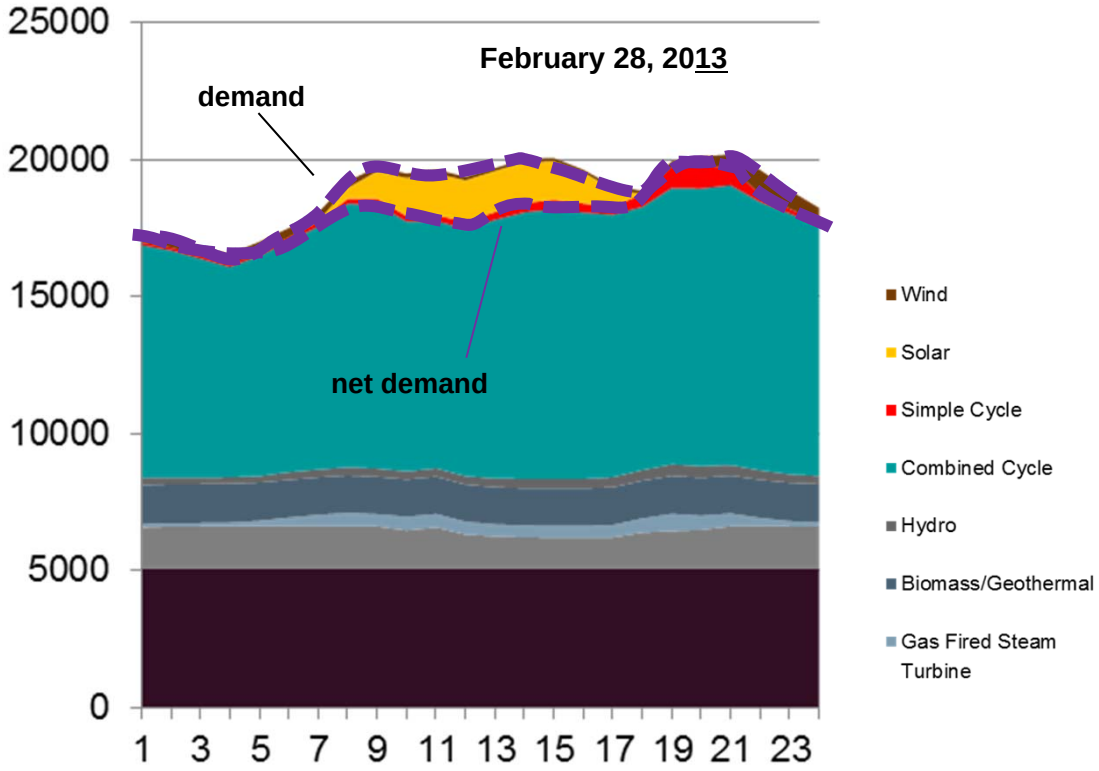


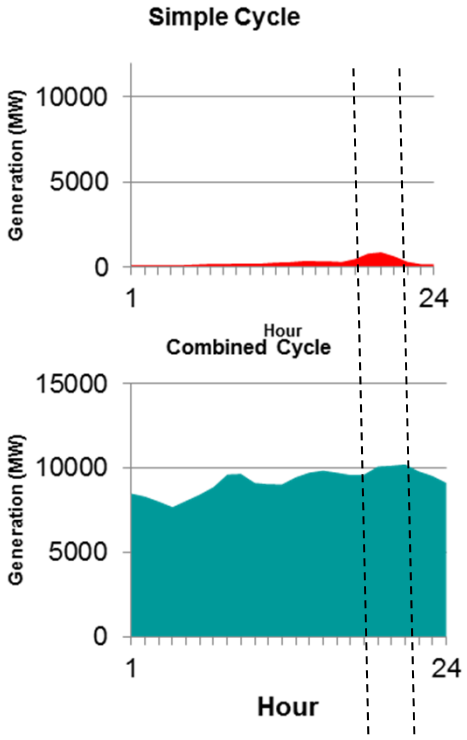
When choosing between a simple or combined cycles, economics generally show that it makes sense to use a combined cycle for plants that dispatch more than ~20% of the time.

Questions are being asked on whether the grid needs more simple cycles to support renewables… Study info suggests that the answer is no.

A Recent Winter Day

February 2013 - Huntington Beach Node



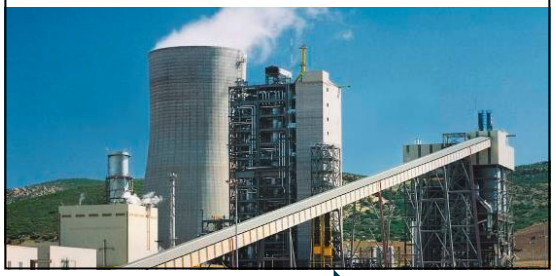


Combined Cycles are being used to meet changes in demand
Simple Cycles are used afterwards

Power Generation Market of Today and Tomorrow

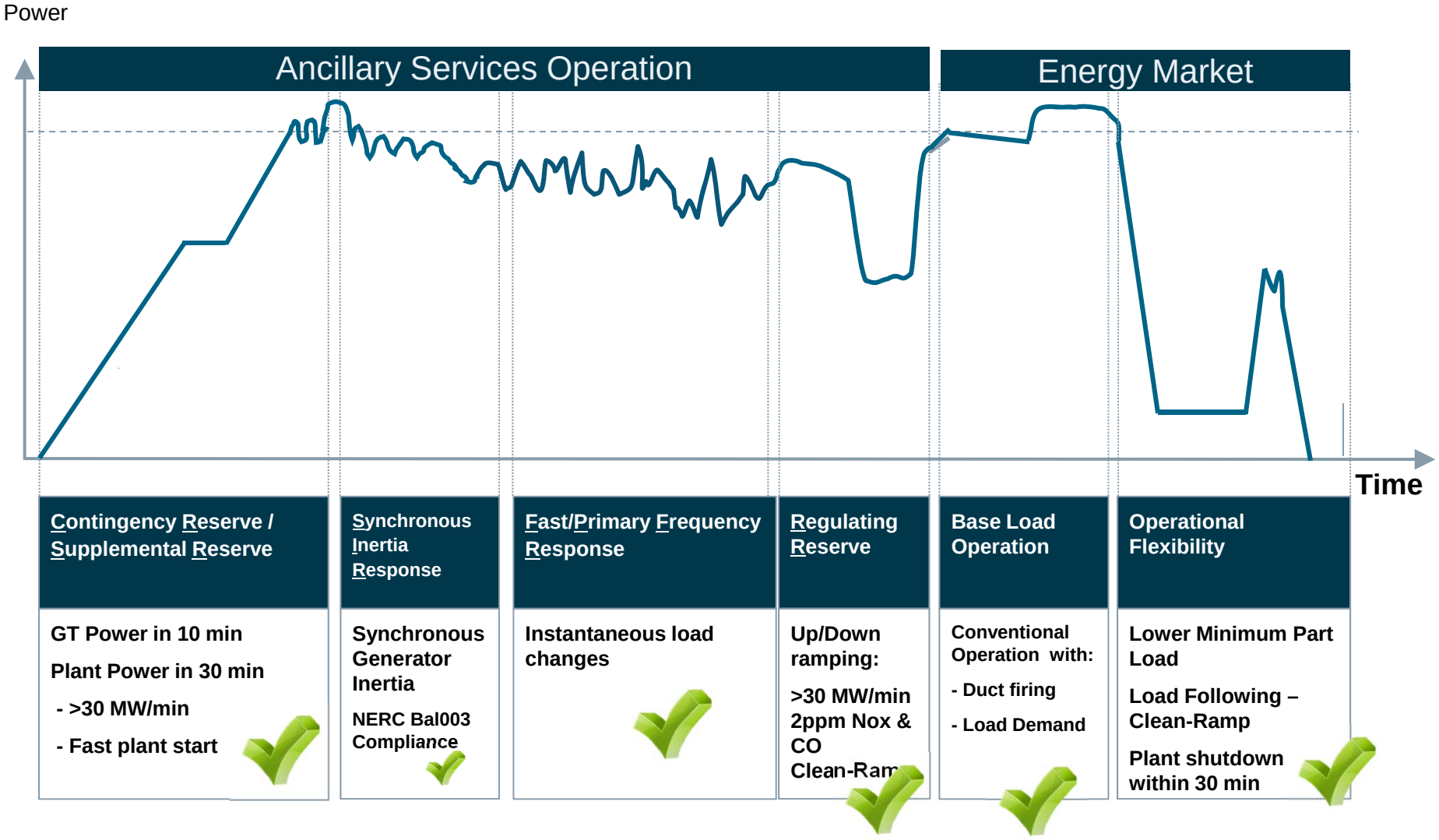
SIEMENS

Green energy but mostly intermittent supply	Siemens Flex-Plant™ combined cycles	Low flexibility base load
Wind energy Solar energy	Gas Fired Flex-Plants™ can Start Fast Load Follow Up AND Down High Efficiency Low Water Usage Low steady state Low Transient Emissions	Coal fired plants Nuclear power plants



Siemens Flex-Plant™ Combined cycles

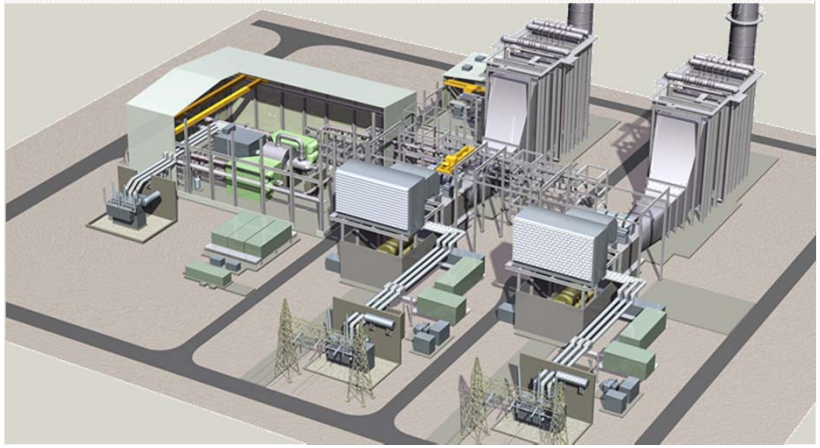
Flex-Plant contribution to Ancillary Services



Flex-Plant™ Combined Cycles
Bridge the Gap

SIEMENS

Gas fired combined cycle power plants have been a clean*, efficient, reliable way to generate electricity for decades.



Siemens Flex-Plants maintain the benefits of a combined cycle:

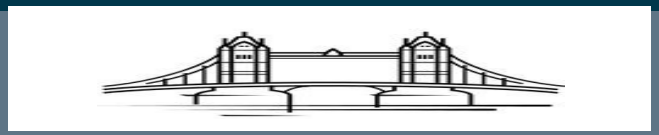
- **High Base Load Efficiency**
- **Low Steady State Emissions**
- **High Reliability**

…and add capabilities to meet today's market needs

- **Start Fast with *Co-Start™***
- **Fast Load Change Up and Down**
- **High Part Load Efficiency**
- **Low Water Usage**
- **Low Start Up Emissions**
- **Low Emissions while ramping with Siemens *Clean-Ramp™* technology**

Flex-Plants. Meeting the needs of grids with renewables.






Non dispatchable renewables | **Flex-Plant** | **Plants designed for base load**

*Clean means lower emissions than conventional technologies

Natural Gas Plants Combined Cycle: Ideal to supplement renewable power

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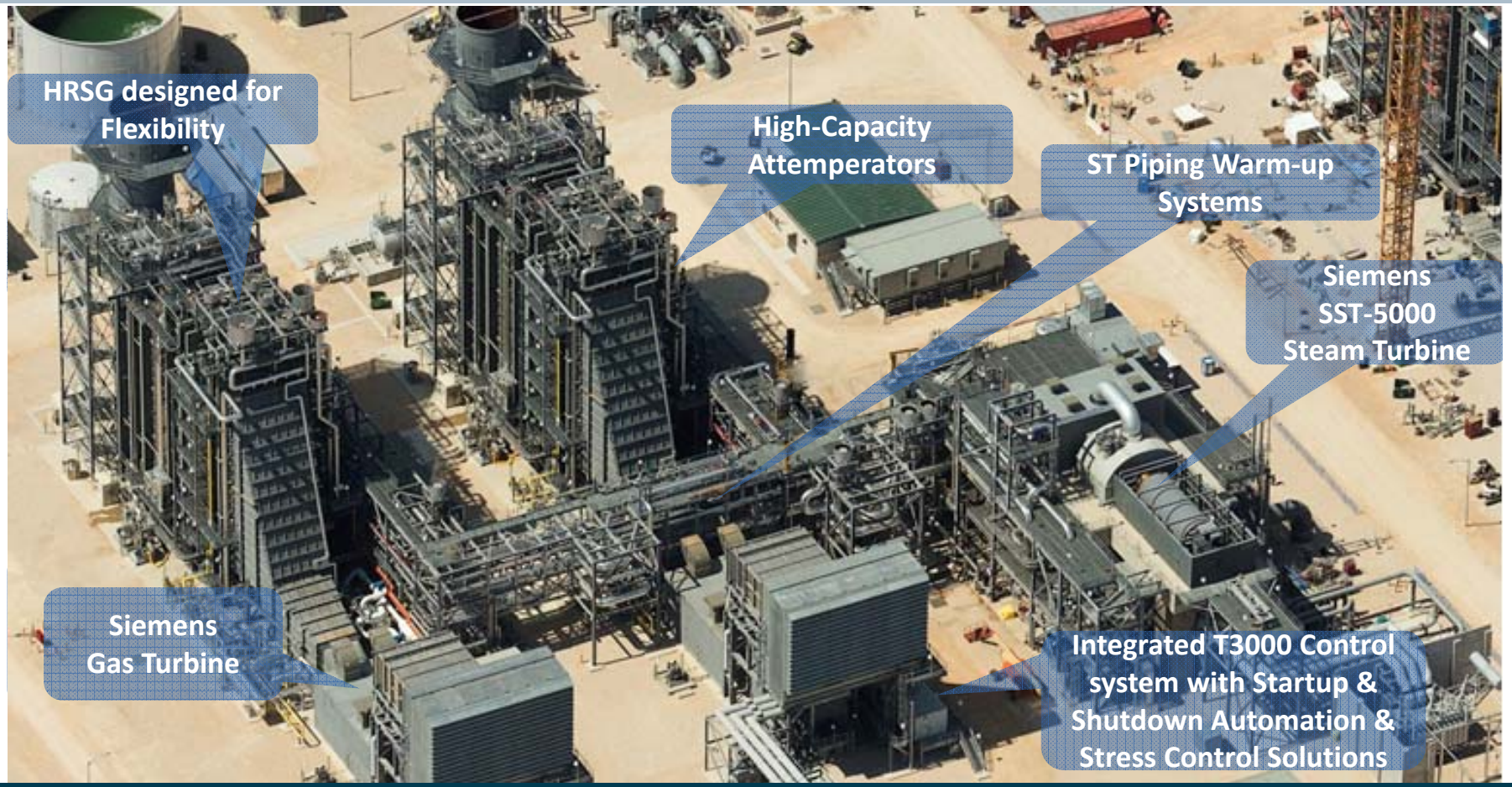
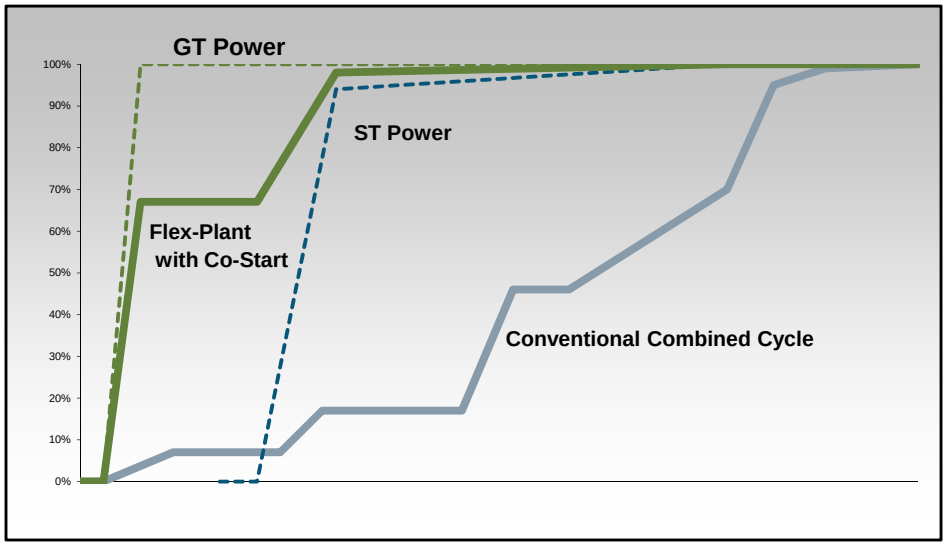


The efficiency and small environmental footprint of a combined cycle with the speed and flexibility of a simple cycle

Siemens Co-Start™ Technology
Fast Bottoming Cycle Start Up

SIEMENS

Co-Start uses an integrated hardware and control package which enables the steam turbine to ramp up early and quickly, while protecting equipment for reliable operation over the life of the plant.

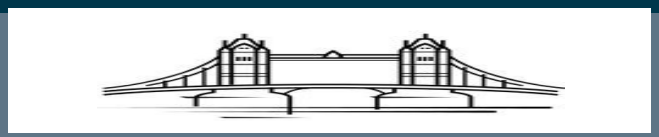
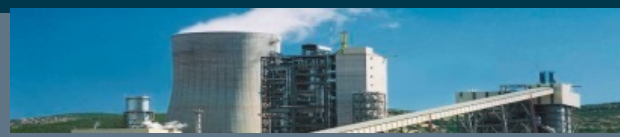


Faster Power means shorter time to profitability

- **No low load gas turbine hold points**
- **Fast Ramp of the steam turbine**
- **Base load power in about 30 minutes**

Co-Start means lots of power, fast



Non dispatchable renewables | **Flex-Plant** | **Plants designed for base load**

*Clean means lower emissions than conventional technologies

Sloe Centrale
2x1S SCC5-4000F
FLEX-PLANT™ Technology
COMMERCIAL OPERATION: 2009

Fast start, flexible combined cycle in operation since 2009

SCC5-4000F Proven

2010 Power Magazine Top Plant

““There is nothing slow about the fast-track operations at the new 870-MW Sloe Centrale Power Plant….The new plant’s CO_2 emissions are approximately 25% lower than emissions from conventional fossil plants.” Power magazine 9/1/2010

SIEMENS

Ulrich Hartmann
1S SCC5-8000H
FLEX-PLANT™ Technology
COMMERCIAL OPERATION: 2011

A High Efficiency Combined Cycle with the Flexibility of a Simple Cycle

- **500 MW in 30 min**
- **low start up emissions**
- **clutched power train**

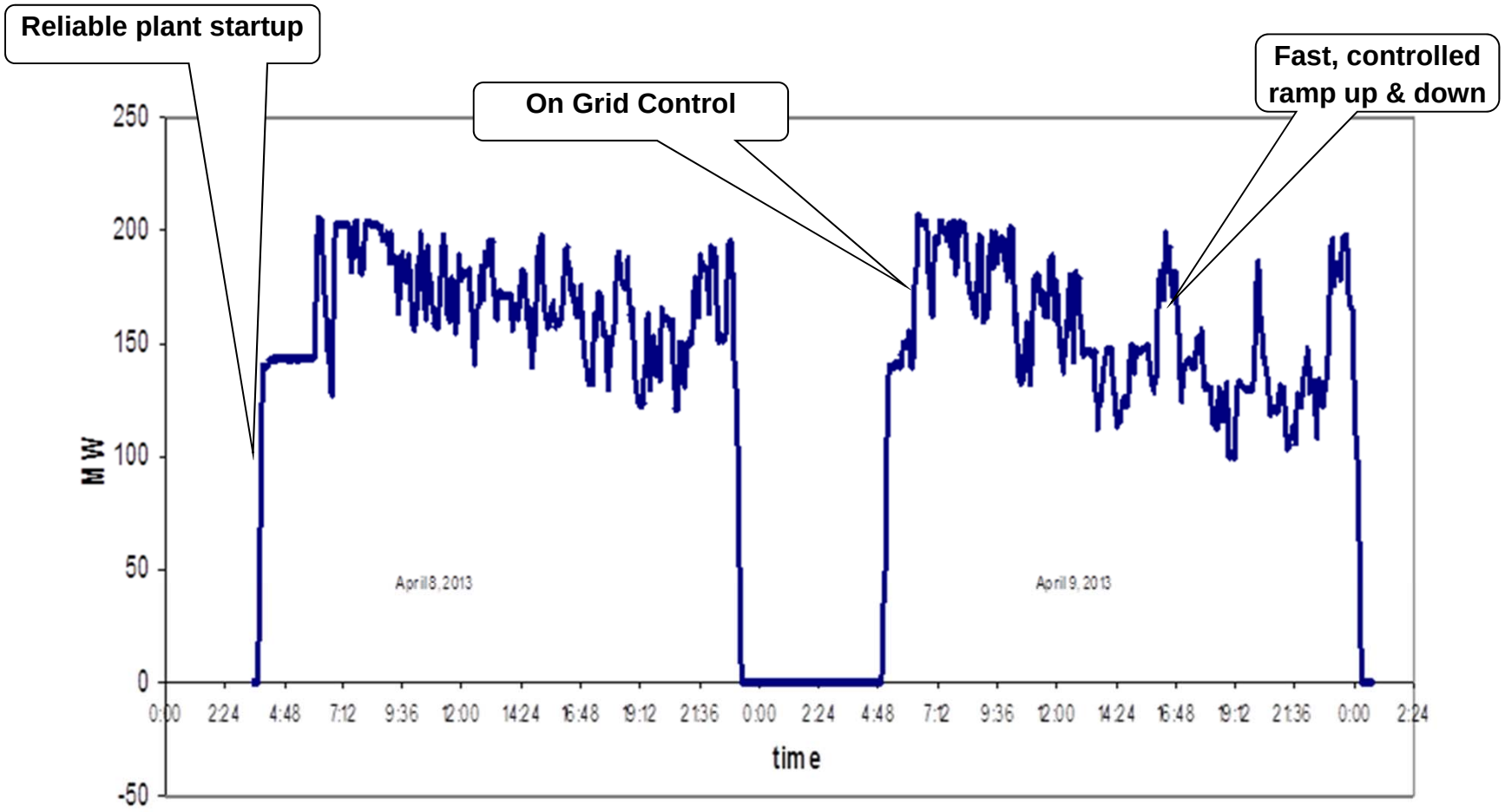
SCC5-8000H

The first combined cycle in the world to exceed 60% net plant efficiency

Proven

2011 Power Magazine Top Plant

Load Following Capability



Fast MWs on the Grid and Fast Response - Proven in Operation

SIEMENS

Lodi Energy Center

1x1 SCC6-5000F FLEX-PLANT™

COMMERCIAL OPERATION: 2012

A High Efficiency Combined Cycle with the Flexibility of a Simple Cycle

- **200 MW in 30 min**
- **low start up emissions**

SCC6-5000F

The first flexible combined cycle in the US

Proven

2012 Power Magazine Top Plant

Are Flexible Generation Plants Performing as Expected?

Highly flexible, fast-ramping, fast-cycling combined cycle plants hit the market with a big splash a few years ago. But are they performing as advertised? Though the few operational plants are still new and still learning, the initial results are encouraging.

Thomas W. Overton, JD

The Lodi Energy Cent… MW 1 x 1 combine… Lodi, Calif., just north… east of the San Joaquin River… From the outside, there's litt… it from the many other combi… large and small that power the… dependent System Operator (C…

On the inside, though, there'… this plant, which began comm… …MW plants), started up in …ller, …ary …as …n- …s …rman plants

In the case of LEC, at least, according to Plant Manager Michael DeBortoli, the answer is an unqualified yes.

"It has lived up to our expectations," he told *POWER* in an interview in January. "So far, the plant has been running very well. We cycle a lot and have a lot of starts and stops almost on a daily basis, and everything has been running fine."

of variable wind and solar generation.

But Does It Work?

All that, at least, was the intent. But are LEC and the new highly flexible plants like it living up to the hype?

The question is not an idle one. A 2012 study by the National Renewable Energy Laboratory and Intertek APTECH found that shifting to faster ramping and startups from a

Published in Power Magazine March, 2015

SIEMENS

El Segundo
1x1 SCC6-5000F
FLEX-PLANT™ Technology
COMMERCIAL OPERATION: 2013

A small footprint, air cooled Flexible Combined Cycle with Clean-Ramp™ technology for low emission while ramping

SCC6-5000F

The first air cooled flexible combined cycle in the US

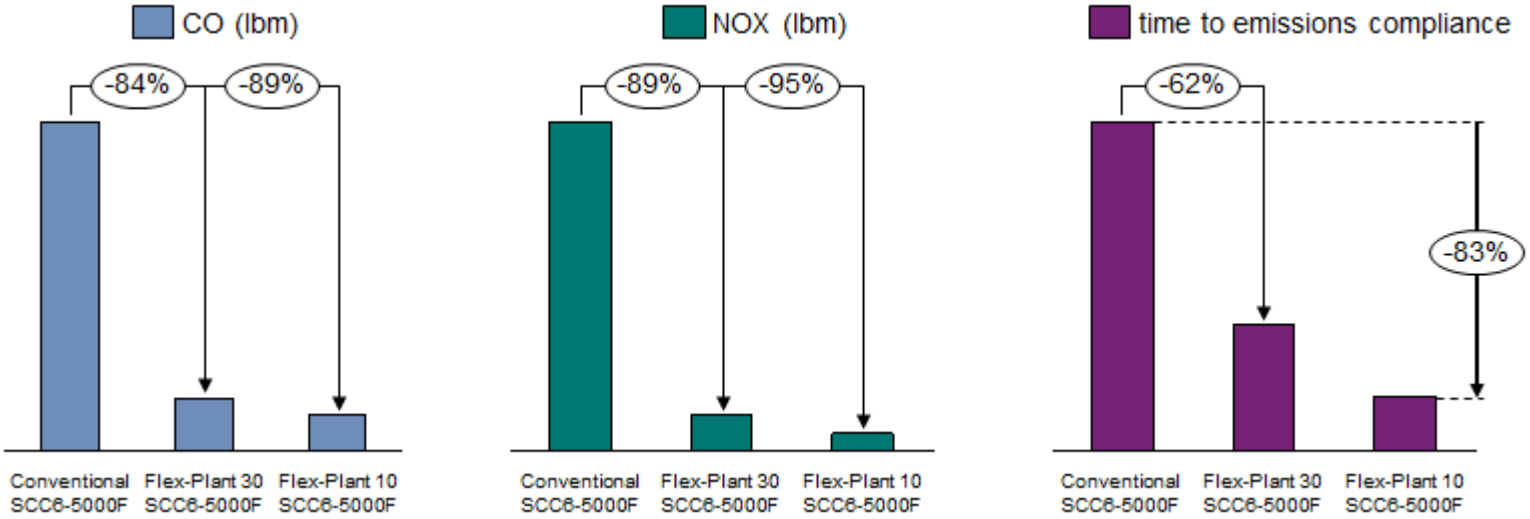
Proven

2013 Power Engineering Project of the Year Runner Up

1st place Winner was Canaveral 3x1 powered by Siemens SGT6-8000H gas turbine

Flex-Plants options add more than load following
Fast start technology is cleaner

SIEMENS



Comparison of a conventional combined cycle startup, with actual test results for a Flex-Plant™ 30 start up and a Flex-Plant™ 10 start up. Test results exceeded expectations, indicating real benefit in excess of guarantees.

This is specific test data from actual site test runs. Results are for information only.

Emissions results are dependent on several factors including shutdown time between starts.

Project-specific guarantees for various conditions can be provided on a case-by-case basis.

Proven in Operation
Flex-Plants have a much smaller eco-footprint than conventional plants
Small changes to a base plant configuration can add these benefits

Siemens Clean-Ramp™ Technology for units with SCRs Enables Low Emissions while on Grid Control

SIEMENS

The transient emissions challenge:

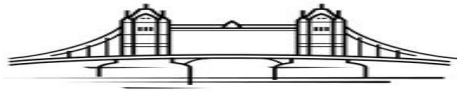
- **The emissions produced by a gas turbine will change when the gas turbine changes load**
- **The feedback loop on a conventional emissions control system is typically much too slow to keep up during transients, resulting in a peak in emissions while changing load**
- **Engines on grid control change load often.**

The Solution – Siemens Clean-Ramp integrated system

- ***Clean-Ramp*** **is an integrated system that anticipates the behavior of the gas turbine during load changes and proactively reacts to keep emissions out of the stack low, even when the gas turbine is moving**
- ***Clean-Ramp*** **has been operated in the field and demonstrated the ability to maintain NOx, Co, and ammonia slip at less than 2 ppm**
- ***Clean-Ramp*** **is only available on a Siemens Flex-Plant**

Clean-Ramp enables low emissions while on grid control

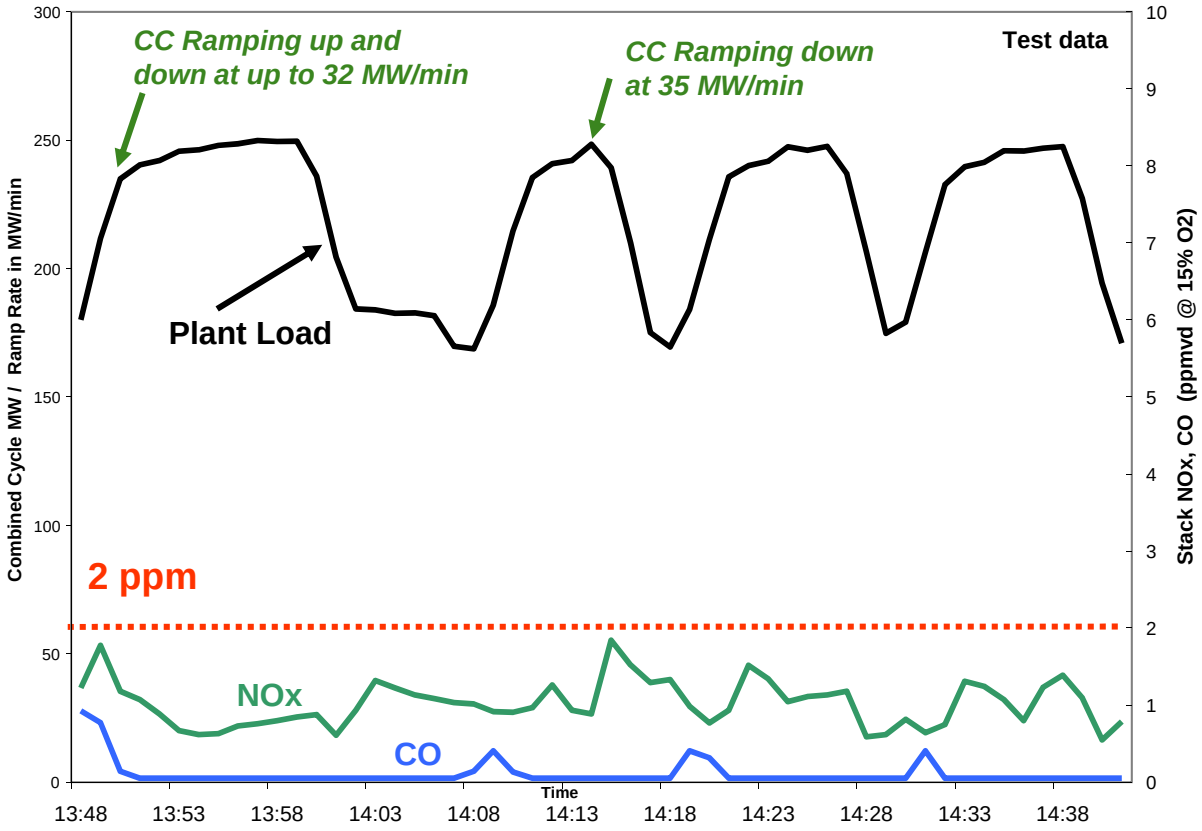
Non dispatchable renewables



Flex-Plant

Plants designed for base load

Advancements in Ramping and Load Following Emissions
Siemens Clean-Ramp™ Technology



- Gas turbines typically produce high emissions when ramping
- Clean-Ramp technology enables Flex-Plants to keep emissions low - at base load levels - while ramping
- Clean-Ramp is only available on Siemens Flex-Plants

This is specific test data from actual site test runs. Results are for information only. Emissions results are dependent on several factors including shutdown time between starts.

Siemens will guarantee the ability to maintain emissions while load following a Flex-Plant with *Clean-Ramp*

PLATTS GLOBAL ENERGY AWARDS

2014 Platts Leading Technology Award

Andong
1S SCC6-8000H
FLEX-PLANT™ Technology
COMMERCIAL OPERATION: 2014

A Flexible Combined Cycle
Powered by the SGT6-8000H

- **>60% Efficiency**
- **Full Loan in < 30 minutes**
- **Available with Clean-Ramp™**

SCC6-8000H

Flexible single shaft design
Erected in <24 months

Proven

2014 Power Magazine Top Plant

SIEMENS

Panda Temple

2x1 SCC6-5000F FLEX-PLANT™
COMMERCIAL OPERATION: 2014

Panda Sherman

2x1 SCC6-5000F FLEX-PLANT™
COMMERCIAL OPERATION: 2014

Panda Power Funds April 2013

Siemens Flex-Plant™

Flexible reliable operation to support the changes of the wind

- **Low load operation in compliance**
- **>200 MW in 30 minutes**
- **Load following with low emissions**

SCC6-5000F

The first flexible combined cycles in the Texas

Proven

Each state-of-the-art plant will also utilize the latest, most advanced combustion turbine and emissions control technology, making them two of the cleanest, most efficient natural gas-fueled power plants in the United States.

Ansan
2x1 SCC6-8000H
FLEX-PLANT™ Technology
COMMERCIAL OPERATION: 2015

2x1 Multi shaft configuration
The latest plant to reach commercial operation

SCC6-8000H Proven

La Caridad I & II

2x1x1 SCC6-5000F
COMMERCIAL OPERATION: 2014

High Efficiency Turnkey Combined Cycle

- **Modular Construction to Reduce Schedule Risk**

& Improve Construction Flexibility

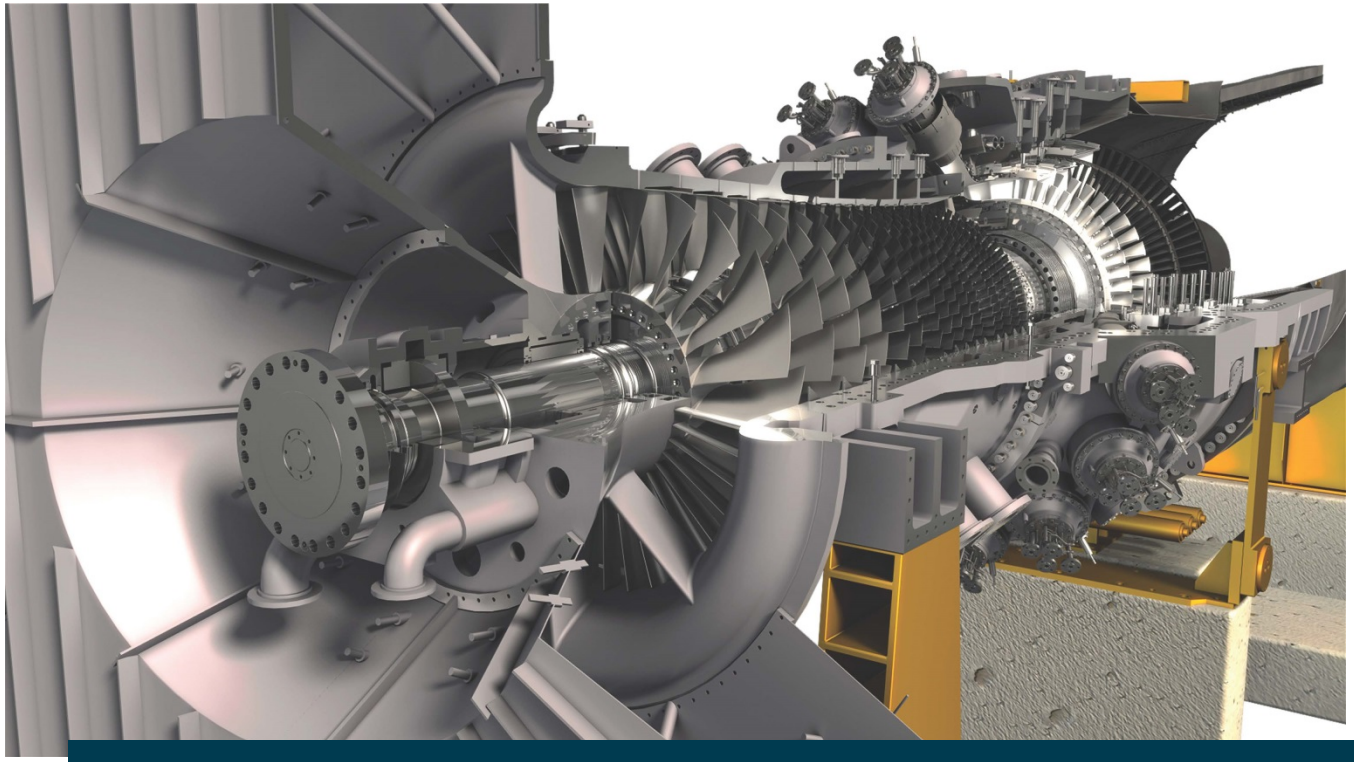
- **More than 4.5 Million Project hours without a lost time accident**

SCC6-5000F

Flexible single shaft design
Erected in <24 months

Proven

Engines Designed to Cycle



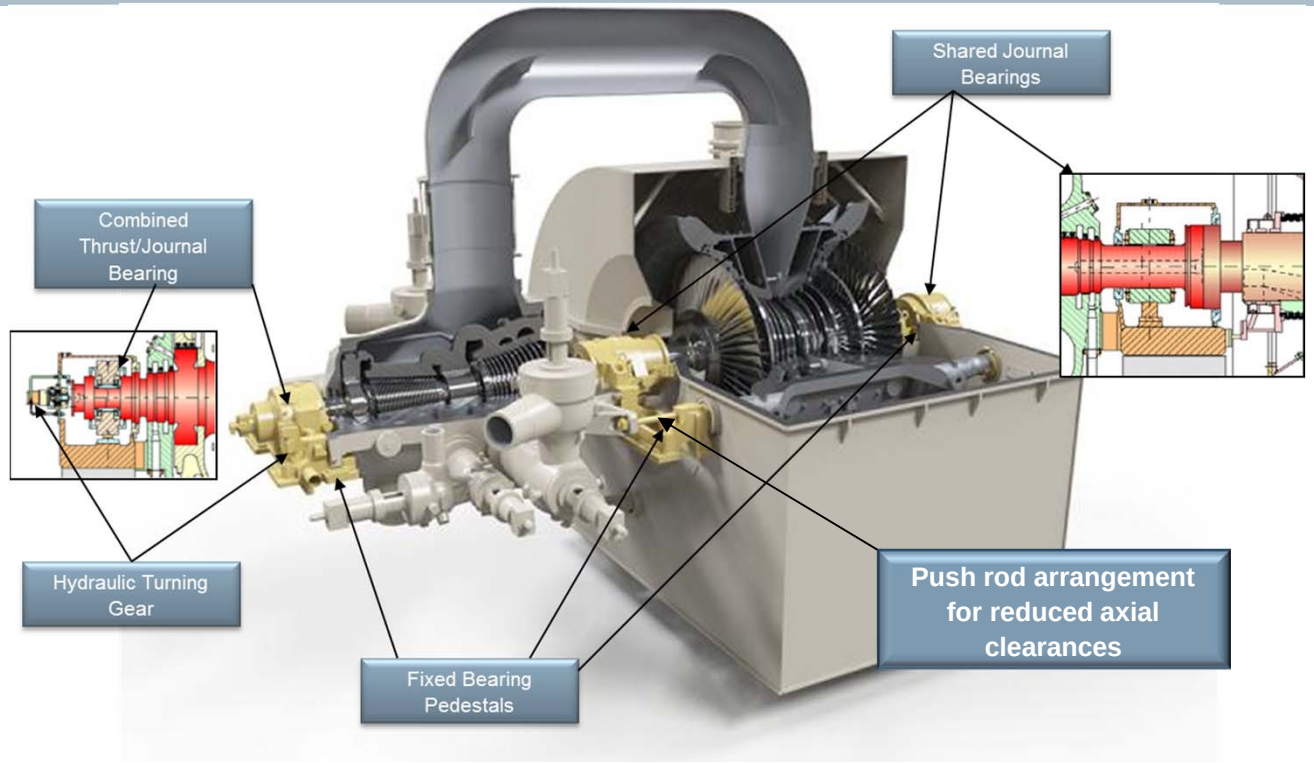
Flexibility Features Built In

- **Hirth Serrations**
- **Four stages of variable compressor vanes**

Gas Turbines Designed to Cycle

Siemens' latest portfolio of has turbines has more than 2x the cycling life

Engines Designed to Cycle



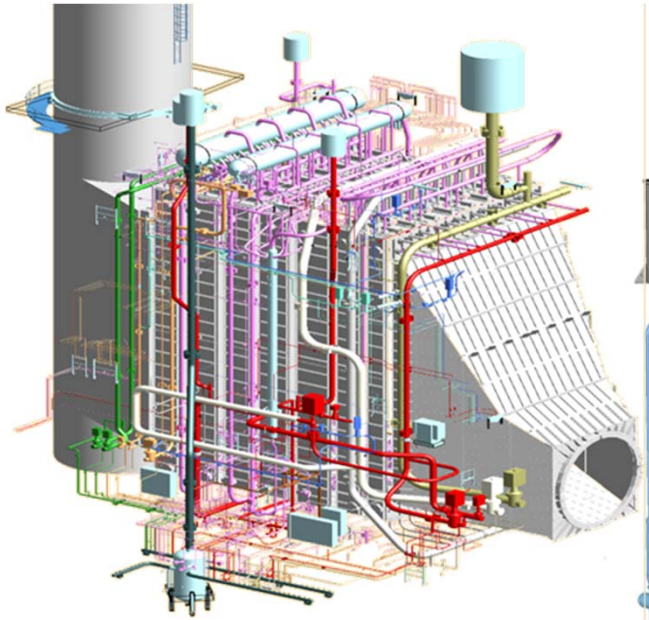
Flex-Plants are available with steam turbine Co-Start™ So your bottoming cycle can come up fast

Steam Turbines Designed to Cycle

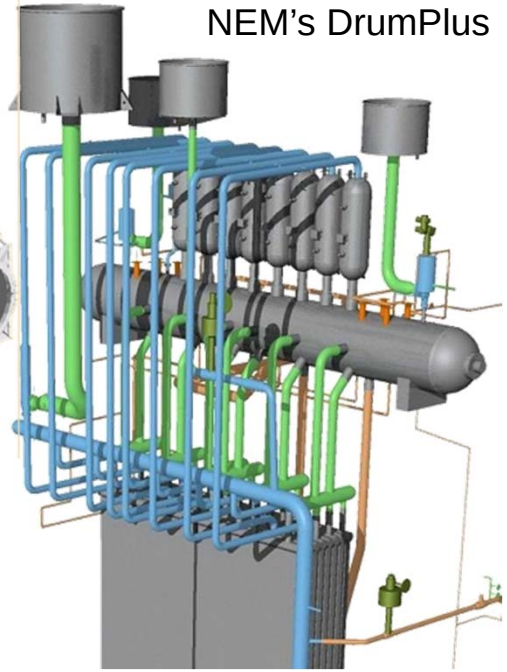
Siemens Flex-Plants use steam turbine stress controllers to enable long engine life using of the full capability of the design

Boilers Designed to Cycle

Once-through Benson



NEM's DrumPlus

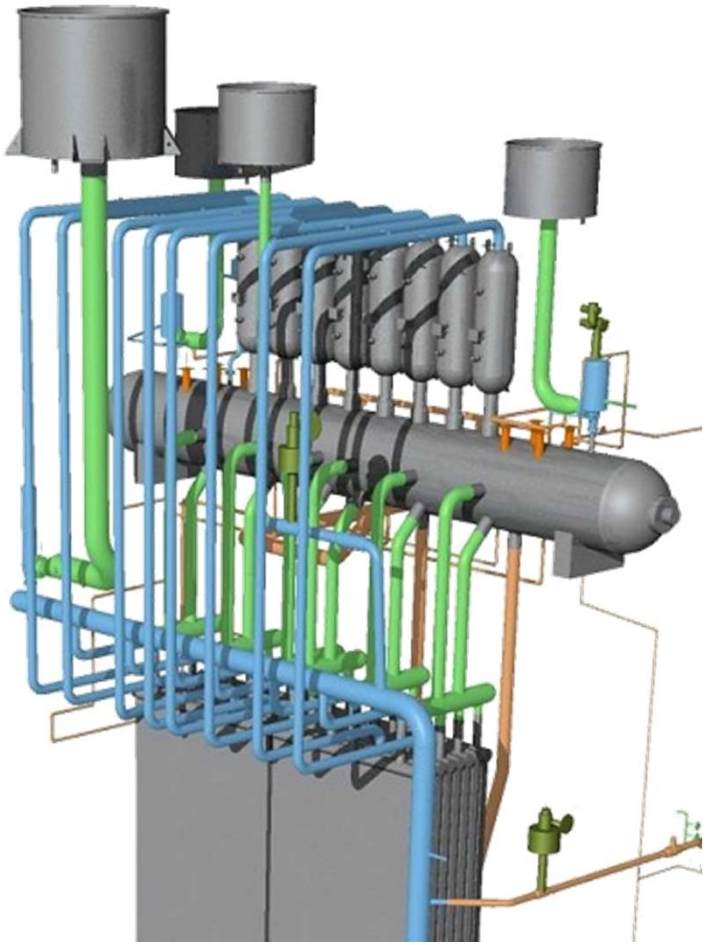


Flexibility by design:
Avoidance of thick walled components

- **Benson HRSG** operates once-through and needs no HP drum
- **DrumPlus** reduces wall thickness of drum by adding bottles to separate water and steam
- Operation principle of natural circulation remains unchanged

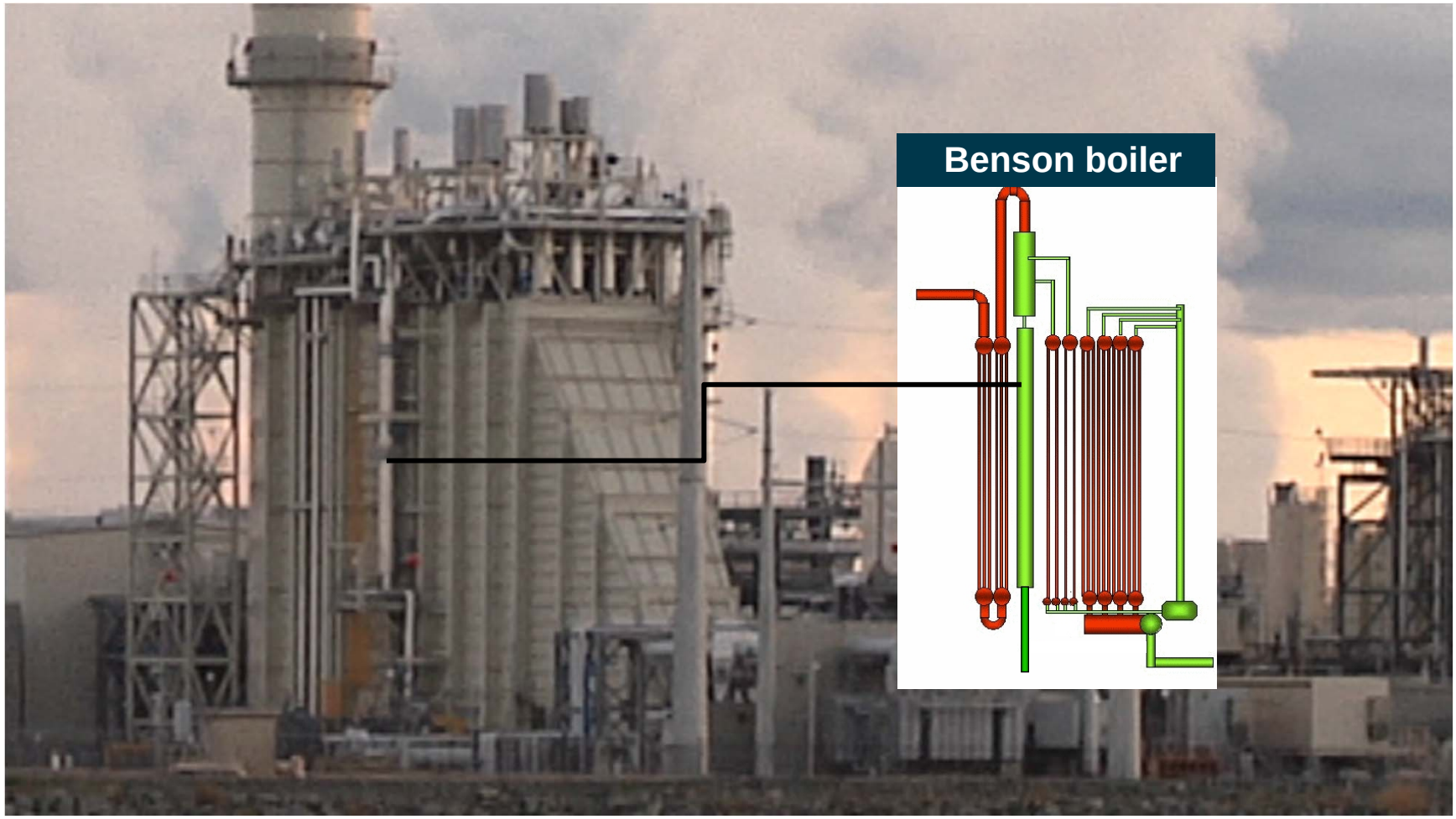
Benson and Drum Plus: Designed to Cycle

El Segundo Energy Center



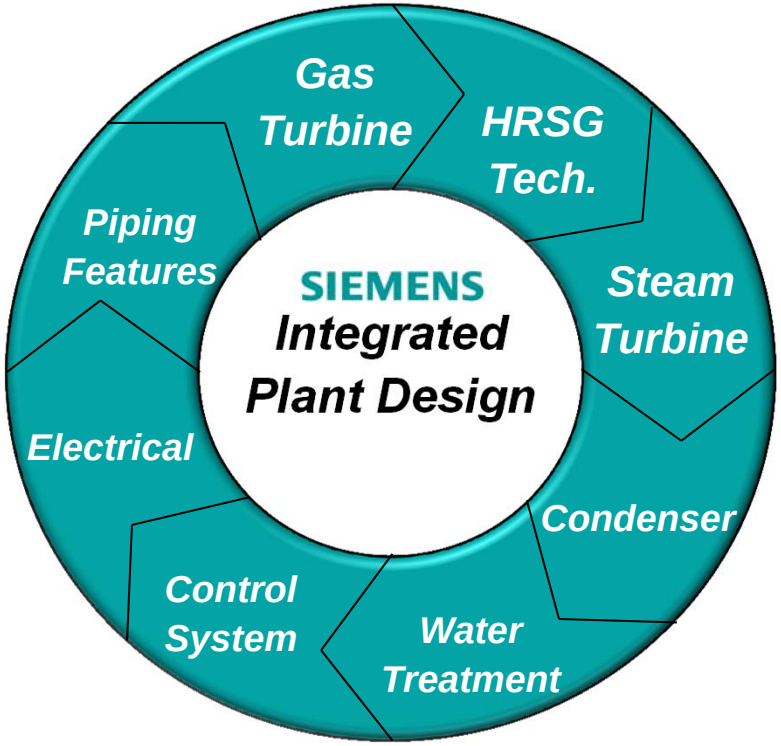
NEM DrumPlus boiler

Benson once-through HRSG
Lodi Energy Center



Integration

The key is integrating the parts into a system that works



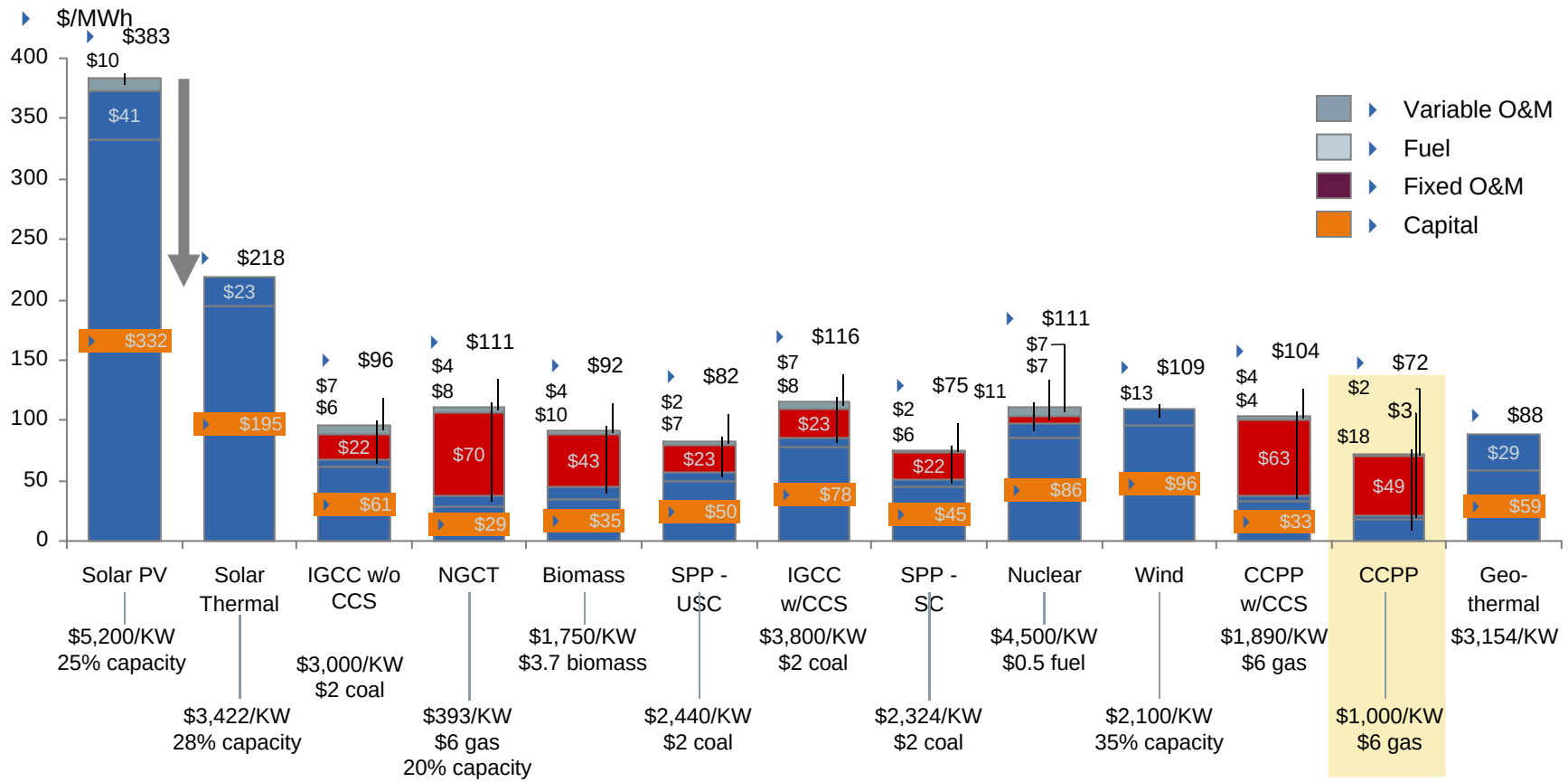
Flex-Plants are integrated combined cycle power plant designs

When you design the components to meet the needs of the power plant, you can access additional benefits

Today's Combined Cycles are Designed to do it all

Levelized Cost of Electricity Technology Comparison

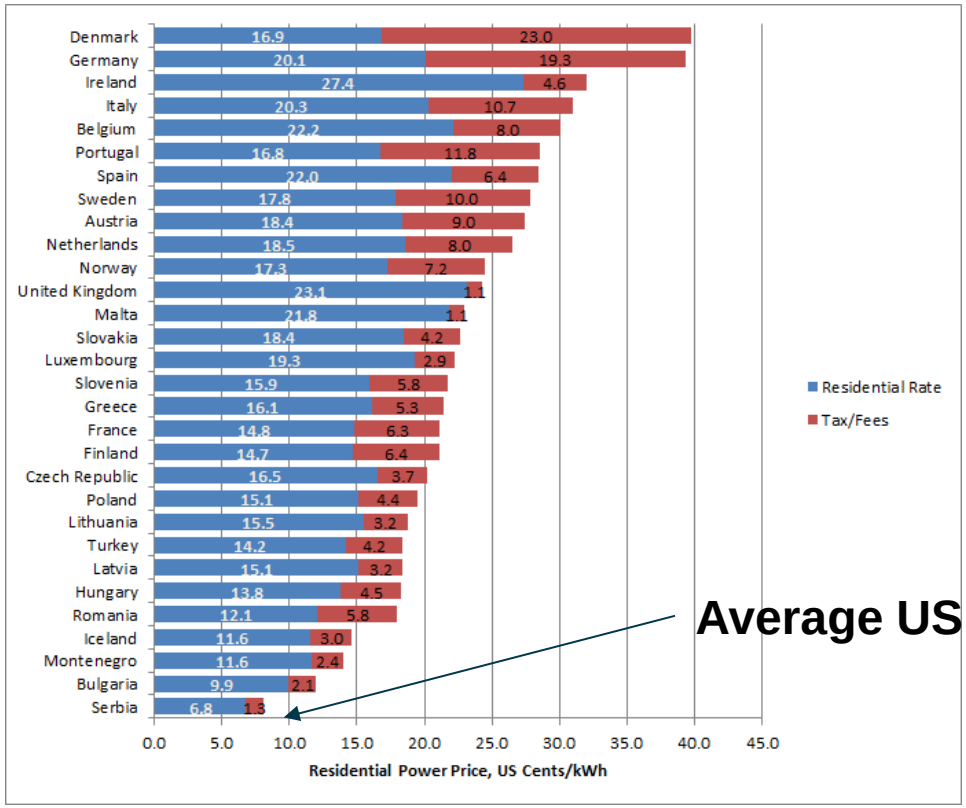
SIEMENS



Note: Assumed cost of equity of 12%, cost of debt 7.5%, 55% debt and escalation of 4.5%; general inflation rate of 2.5%; analysis excludes tax benefits; assumes baseload capacity if not stated ICGG – Integrated Gasification Combined Cycle; CCS – Carbon, Capturing and Storage; NGCT – Natural Gas Combustion Turbine; USC – Ultra Super Critical; SC – Super Critical

Source: EIA; multiple industry reports and company filings; Booz & Company analysis

Electricity Costs Around the World



In 2014, the average retail price of electricity in the United States was 10.45 cents per kilowatt-hour (kWh).[1]

The average prices by major type of utility customers were:

- **Residential: 12.50 cents per kWh**
- **Commercial: 10.75 cents per kWh**
- **Industrial: 7.01 cents per kWh**
- **Transportation: 10.27 cents per kWh**

Ref:EIA

Low Electricity Costs Are Good for Business

Summary

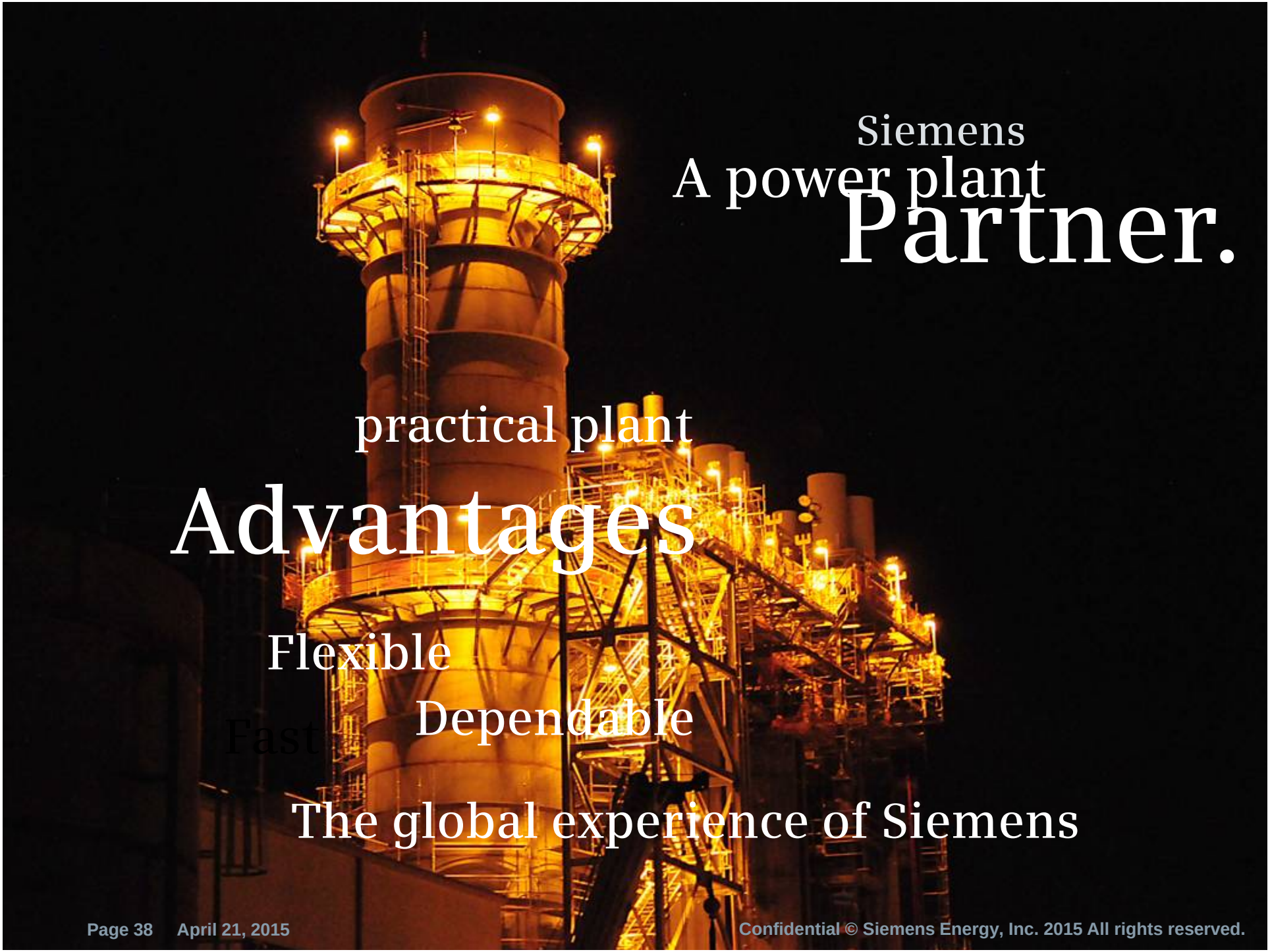
Flex-Plant Gas Fired Combined Cycles produce lower amounts of greenhouse gas than other generation choices

Flex-Plant Gas Fired Combined Cycles Support Renewable Integration

Flex-Plant Gas Fired Combined Cycles use Low cost domestic fuel and enable a low cost of generation







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