Combined Heat & Power with Spinning Reserve - Core of a Larger MicroGrid

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AGENDA

- Observations: Macroeconomic trends
- CHP, Spinning Reserve, Microgrids: What, why & how
- Economics
- Project Development

Who is Veolia? plus a Boston area district energy CHP + microgrid

VEOLIA DESIGNS AND DEPLOYS
WATER, WASTE AND ENERGY MANAGEMENT
SOLUTIONS TO IMPROVE EFFICIENCY
FOR CITIES, INDUSTRY AND CITIZENS.

WATER WASTE ENERGY

179,000 employees on 5 continents

$28.9 billion 2014 revenue

52M MWh produced

2.4M collective housing units managed

1,802 industrial sites managed

529 heating and cooling networks managed

North American energy systems owned/operated:

14.9M lbs./hour steam capacity

631.6 MW electric generating capacity

124 miles of steam/hot water distribution pipe

433 MMBtu/Hour hot water capacity

540 MW Cogeneration capacity

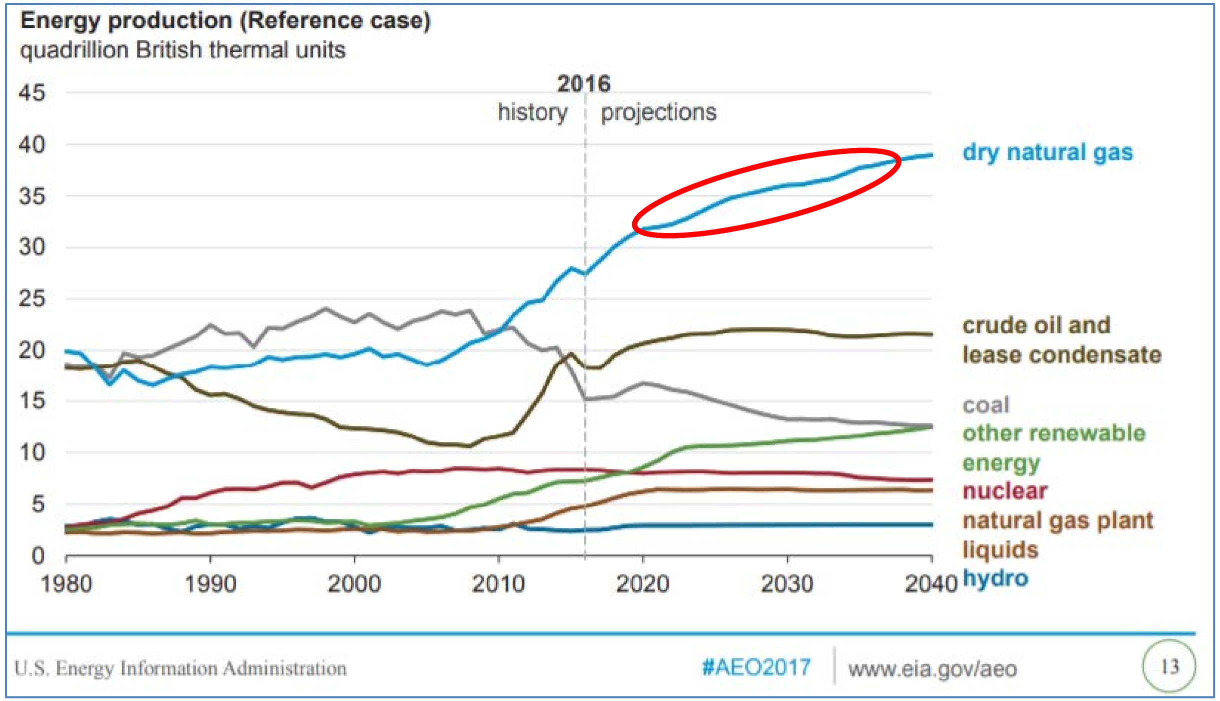
31 miles of chilled water distribution pipe

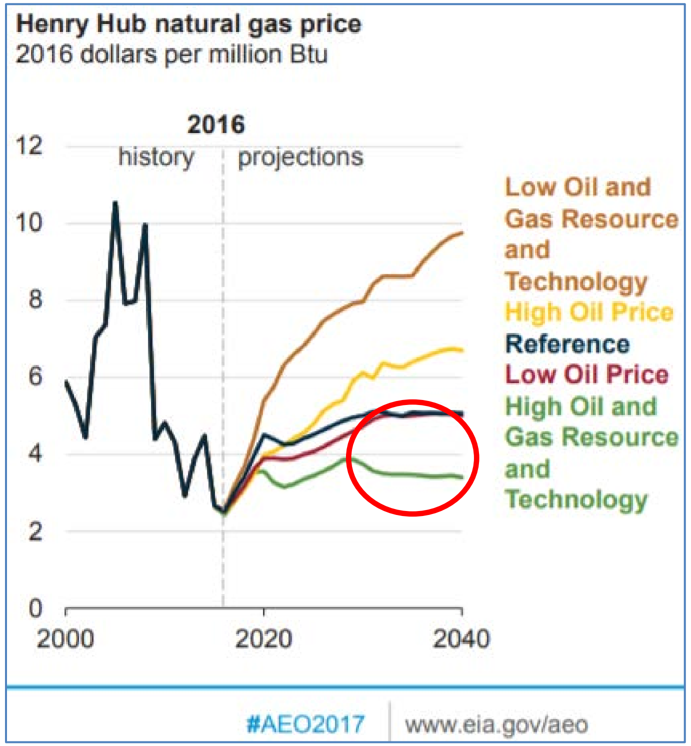
290,394 tons of chilled water capacity

A paradigm shift in primary energy supply across the USA

Growth: Natural gas, renewable energy (wind, sun, hydro etc…)

Decline: Coal, nuclear energy

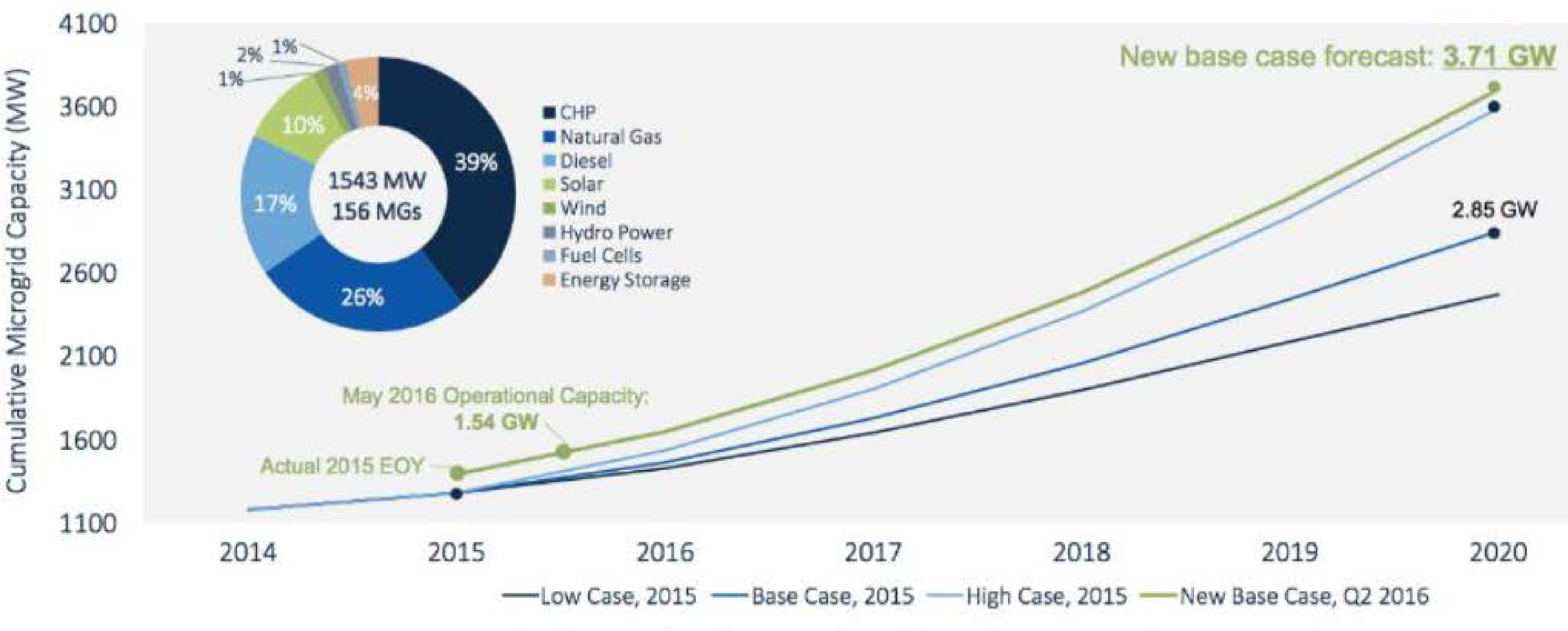




Points towards CHP + renewable energy + dynamic dispatch

Clean, reliable & inexpensive energy “powers” economic vitality.

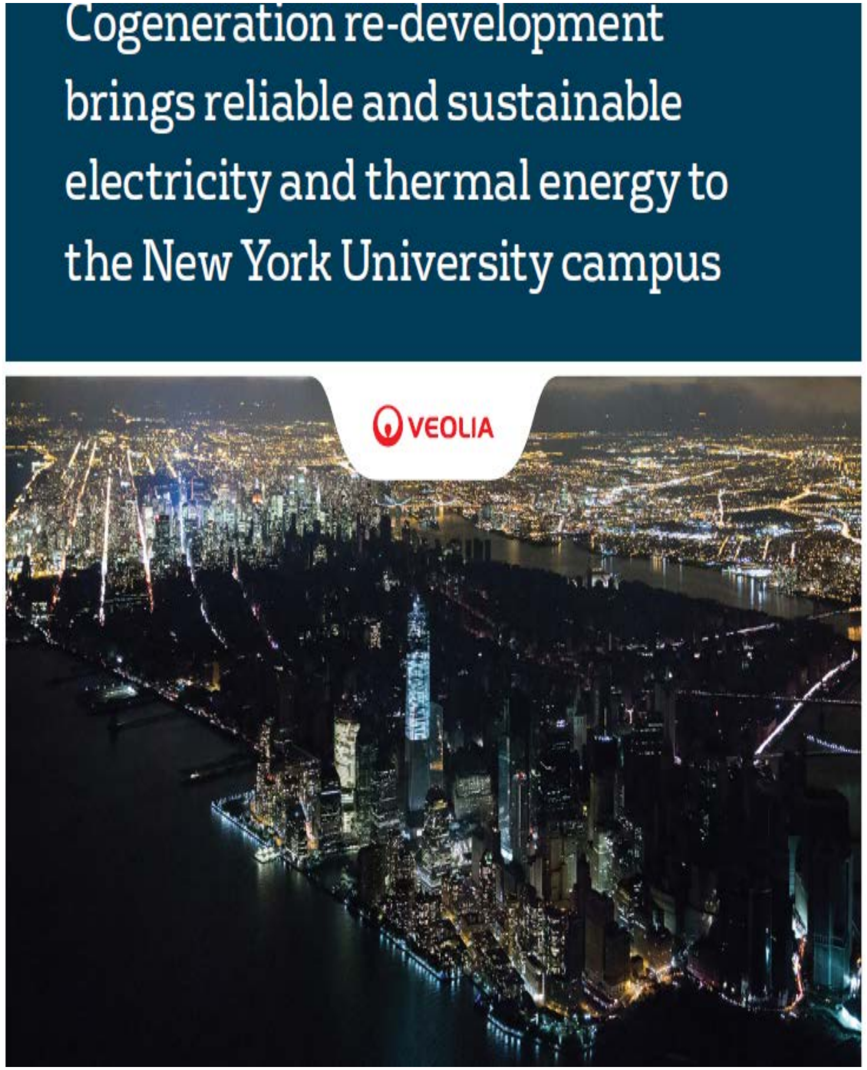
Microgrids centered around Combined Heat & Power (CHP) with Spinning Reserve (SR) are in the sweet spot of maximum energy resiliency at minimum cost.



SOURCES: www.greentechmedia.com/articles/read/u.s.-microgrid-growth-beats-analyst-estimates-revised-2020-capacity-project

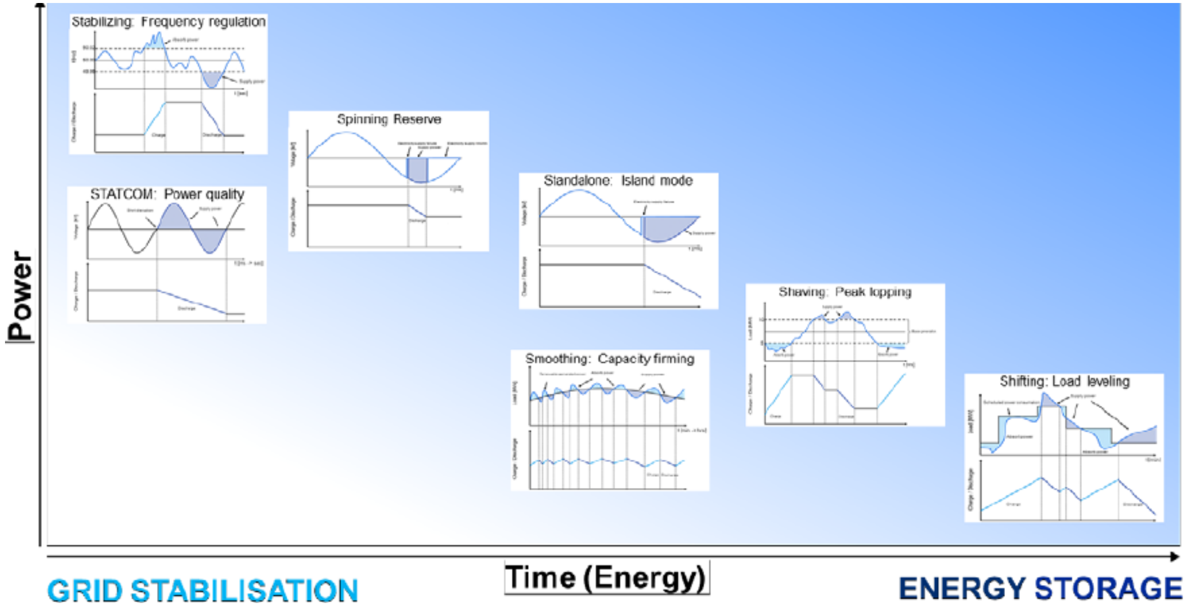
A good reason for a microgrid centered on CHP

- NYU campus CHP (13.4 MW + 90 ,000 lb/hr steam). Energy savings $5MM/yr.
- CHP is the core of a microgrid that serves 22-buildings with power, steam/hot water.
- Value during extreme events? Hurricane Sandy!
  - Total regional losses: $30-$50 billion
  - NYSE shutdown loss ~$7 billion
  - But…. CHP facilities “powered” on.
- Global warming is predicted to increase frequency of severe weather events - an argument favoring resiliency?



Wind energy is abundant, intermittent and unpredictable

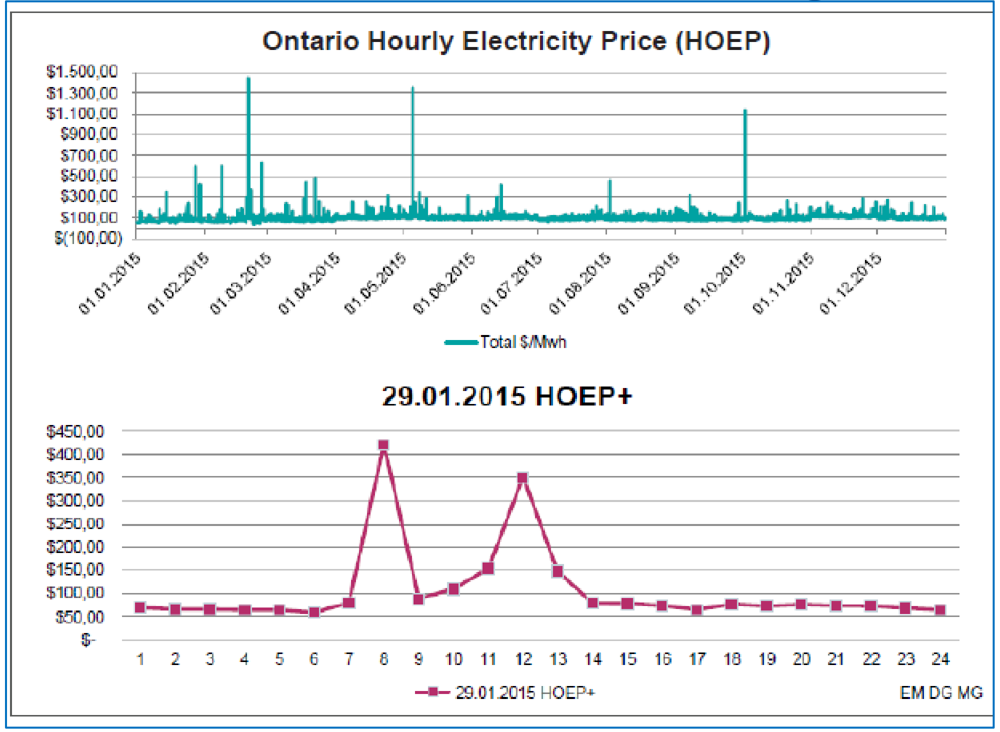
Midwest ISO (MISO)
24-hour actual wind power supply
50% supply swing in 5-hours

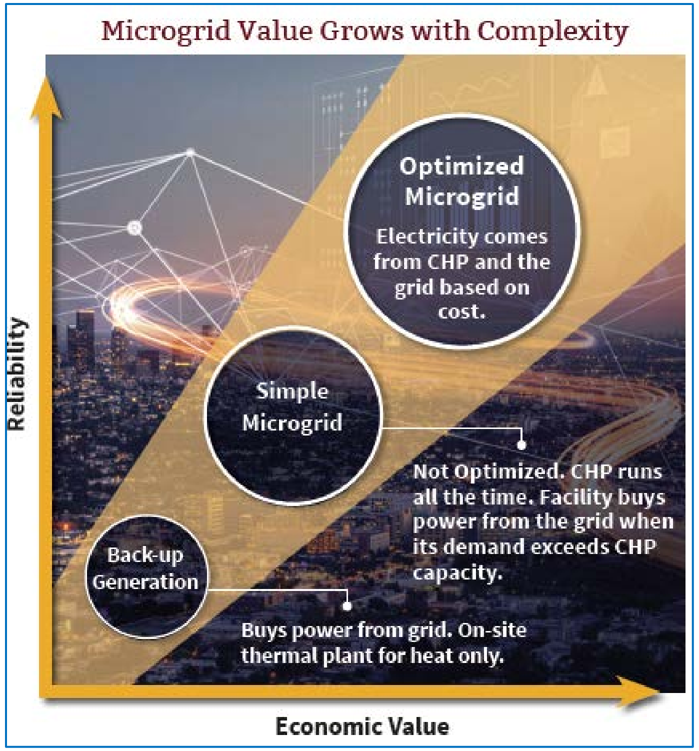


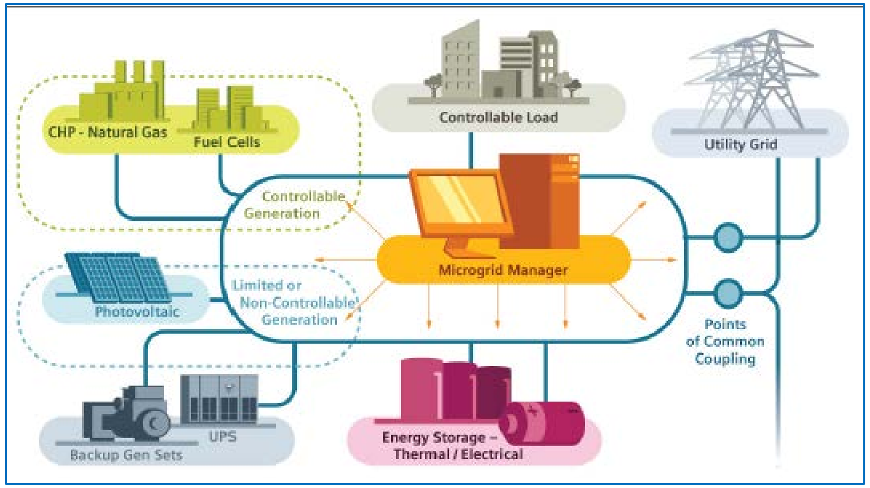
<u>Renewables & the grid</u>
Spinning Reserve
Voltage Stability
Standalone (off-grid) Operation
Peak Shaving
Load Shifting

Source: ABB White paper, “Integrating Renewables in Microgrids”

A CHP centered microgrid can rapidly “load follow”







Source: MGK White Paper; “How microgrids can achieve maximum ROI”

CHARACTERISTICS

Resiliency = Reliability + Redundancy

Distributed Generation

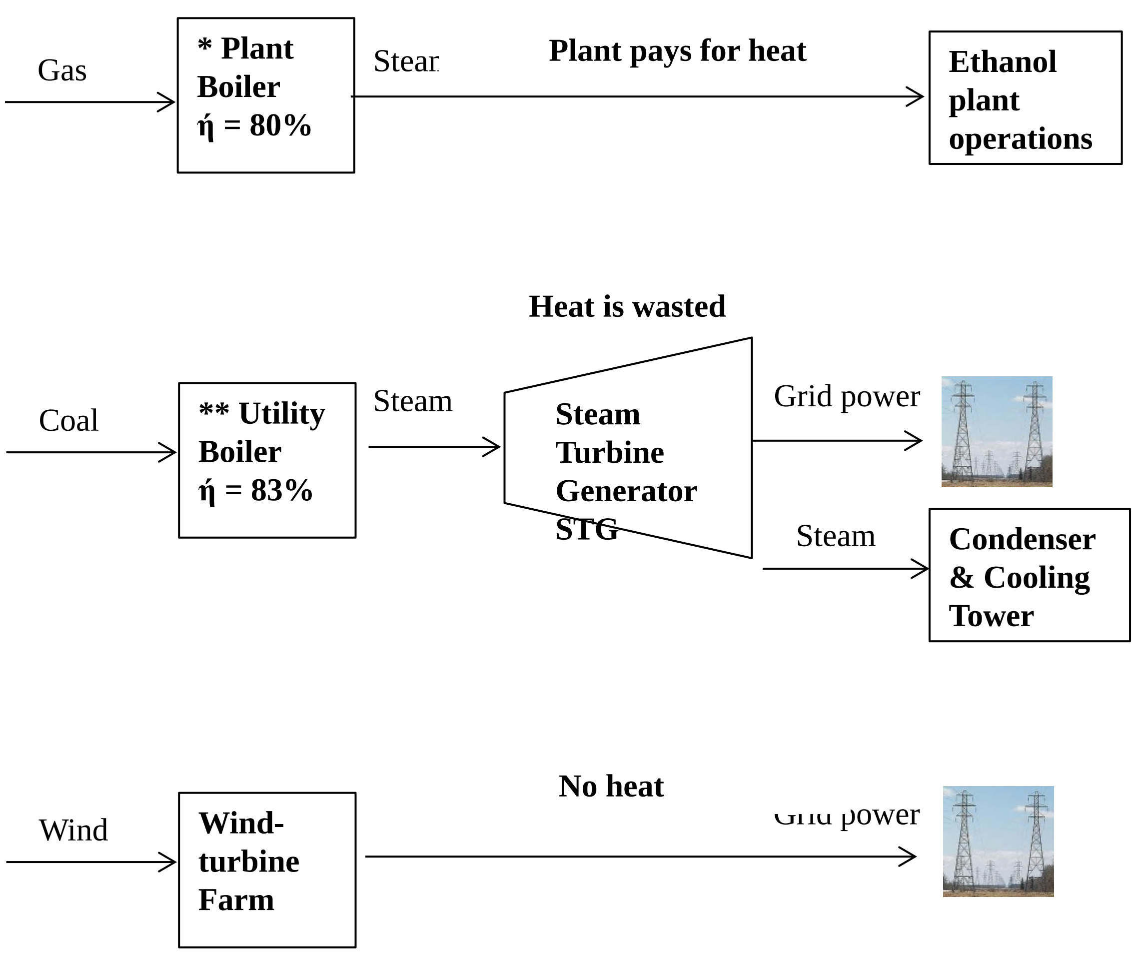
BENEFITS

Efficiency - minimize I2R loss

Security - grid hardening

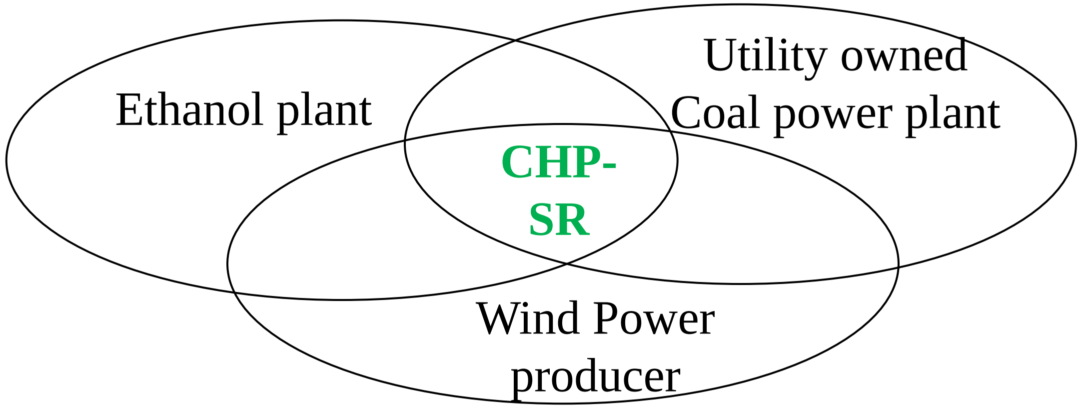
Scalability – eases resource planning

Economics & thermodynamics at a midwestern corn-to-ethanol plant, coal power plant and wind turbine farm



* Usually a Waste Heat Oxidizer Boiler. ** Typical of a pulverized coal boiler

CHP-SR mitigates overlapping concerns



Entity	Concern	Traditional solutions
Ethanol Plant	• Cost of steam • Cost of grid power	• Demand reduction measures • Preheat feed-water, improve controls
Coal Utility	• Cost of regulations • Cost of coal • Cost of O&M	• Spend on pollution control equipment • Shut down coal plant
Wind Power Producer	• Unable to deliver firm capacity • Blamed for grid instability • Blamed as a "subsidy hog"	• Spend on simple cycle Gas Turbine (GT) to **"firm"** wind • Spend on fuel + O&M for GT

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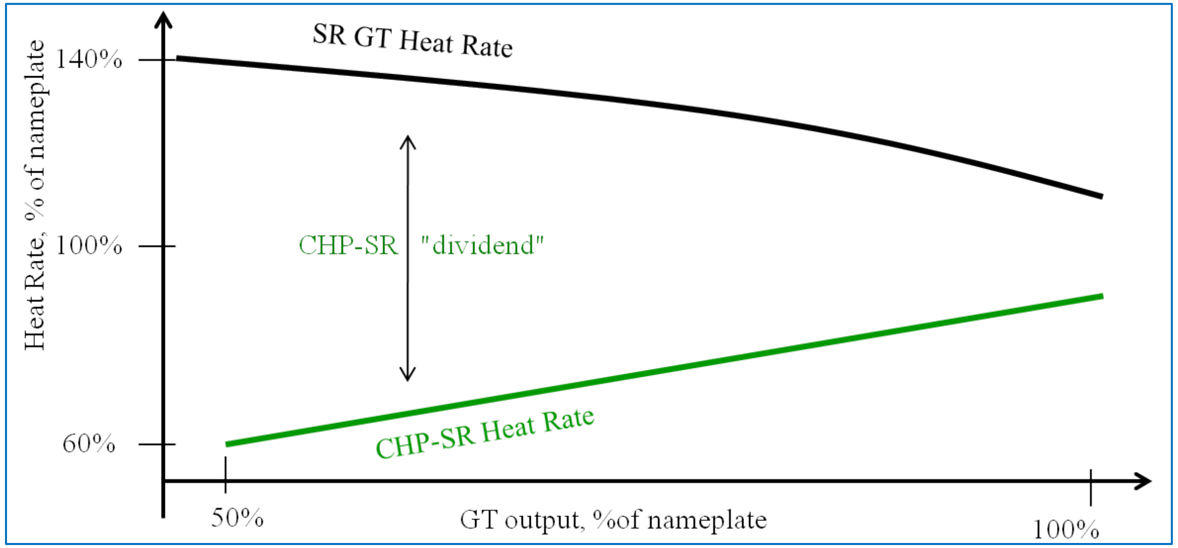
CHP with Spinning Reserve can economically balance intermittent wind energy allowing steady "load following"



Spinning Reserve Gas Turbine (SR GT)
A Gas Turbine that continually varies power output to <u>balance</u> variable wind power generation

CHP with Spinning Reserve (CHP-SR)
An "electrically oversized" thermally matched CHP system, <u>normally</u> operating at reduced power output

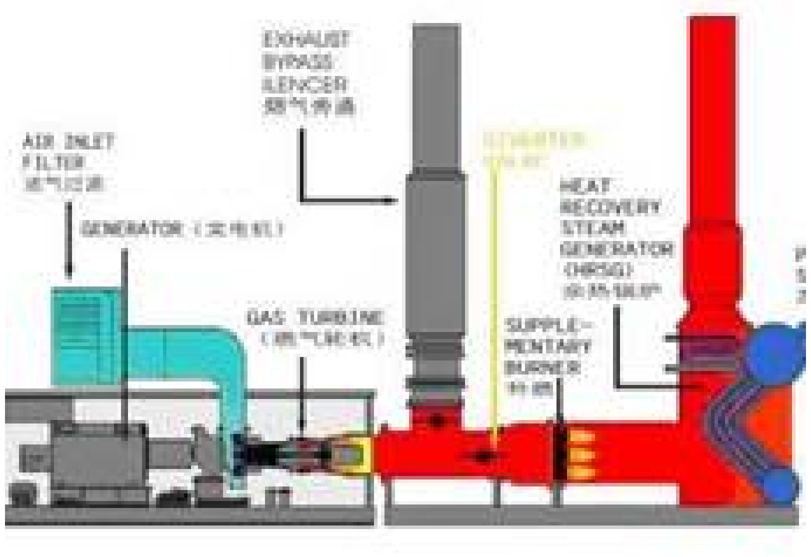


IMAGE: Solar turbines

Case	Wind energy	Gas Turbine (GT) load	GT operation to balance wind energy
A	High	Low	Spinning Reserve only (simple cycle mode)
B	Low	High	
C	High	Low	In CHP with Spinning Reserve mode
D	Low	High	

Case A: High wind + low load SR GT

Burning fuel twice is wasteful and inefficient

Fuel to power & steam; System Efficiency 48.7%

Steam Balance	MMBtu/Yr
HRSG	0
Ethanol boiler	1,890,000
TOTAL	**1,890,000**

Fuel Balance	MMBtu/Yr
SR GT	3,276,000
Ethanol boiler	2,368,800
TOTAL	**5,644,800**

Power Balance	MWh/yr
Wind Power	504,000
SR GT power	252,000
TOTAL	**756,000**

Waste heat
288 MMBtu/Hr

steam
0 MMBtu/Hr

HRSG
Heat Recov. 0%

Ethanol plant
TOTAL
STEAM
225 MMBtu/Hr

steam
225 MMBtu/Hr

Ethanol plant boiler
LHV ή 80%

Gas
282 MMBtu/H

GT exhaust
288 MMBtu/Hr

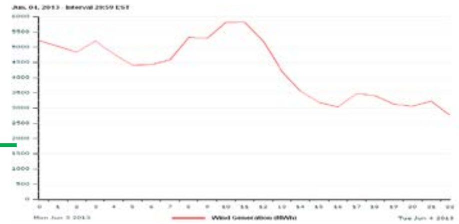
Gas
390 MMBtu/Hr

SR GT load 50%
LHV ή 26%

GT power
30 MW

Electric Grid
TOTAL
POWER
90 MW

Wind power
60 MW



Strategy? minimize lifecyle cost of power and steam

Case B: Low wind balanced by high load SR GT

Burning fuel twice is wasteful and inefficient

Fuel to power & steam; System Efficiency 48.7%

Steam Balance	MMBtu/Yr
HRSG	0
Ethanol boiler	1,890,000
TOTAL	**1,890,000**

Fuel Balance	MMBtu/Yr
SR GT	5,040,000
Ethanol boiler	2,368,800
TOTAL	**7,408,800**

Power Balance	MWh/yr
Wind Power	252,000
SR GT power	504,000
TOTAL	**756,000**

Waste heat
396 MMBtu/Hr

steam
0 MMBtu/Hr

HRSG
Heat Recov. 0%

Ethanol plant
TOTAL
STEAM
225 MMBtu/Hr

steam
225 MMBtu/Hr

Ethanol plant boiler
LHV ή 80%

Gas
282 MMBtu/H

GT exhaust
396 MMBtu/Hr

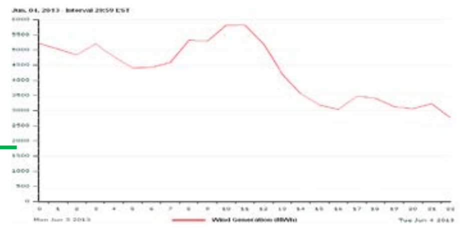
Gas
600 MMBtu/Hr

SR GT load 100%
LHV ή 34%

GT power
60 MW

Electric Grid
TOTAL
POWER
90 MW

Wind power
30 MW



Strategy? minimize lifecyle cost of power and steam

Case C: High wind and low load CHP-SR.
Waste heat satisfies thermal load.

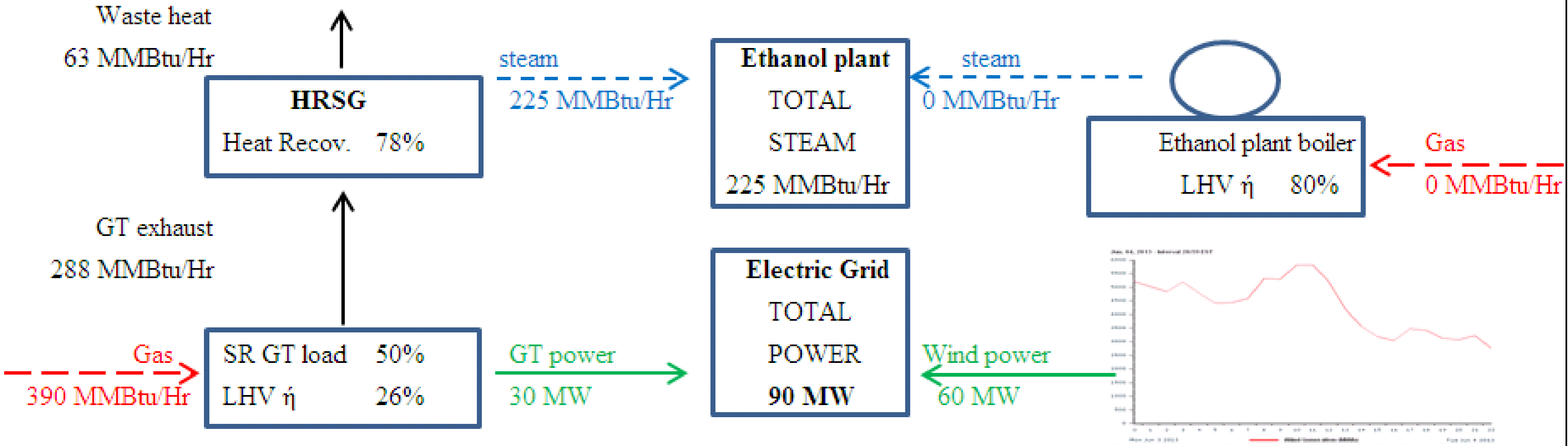
Burning fuel once and recycling waste heat is efficient and profitable

Fuel to power & steam; System Efficiency 83.9%

Steam Balance	MMBtu/Yr
HRSG	1,890,000
Ethanol boiler	0
TOTAL	**1,890,000**

Fuel Balance	MMBtu/Yr
SR GT	3,276,000
Ethanol boiler	0
TOTAL	**3,276,000**

Power Balance	MWh/yr
Wind Power	504,000
SR GT power	252,000
TOTAL	**756,000**



Strategy? minimize lifecyle cost of power and steam

Case D: Low wind balanced by high load CHP-SR. Waste heat satisfies thermal load.

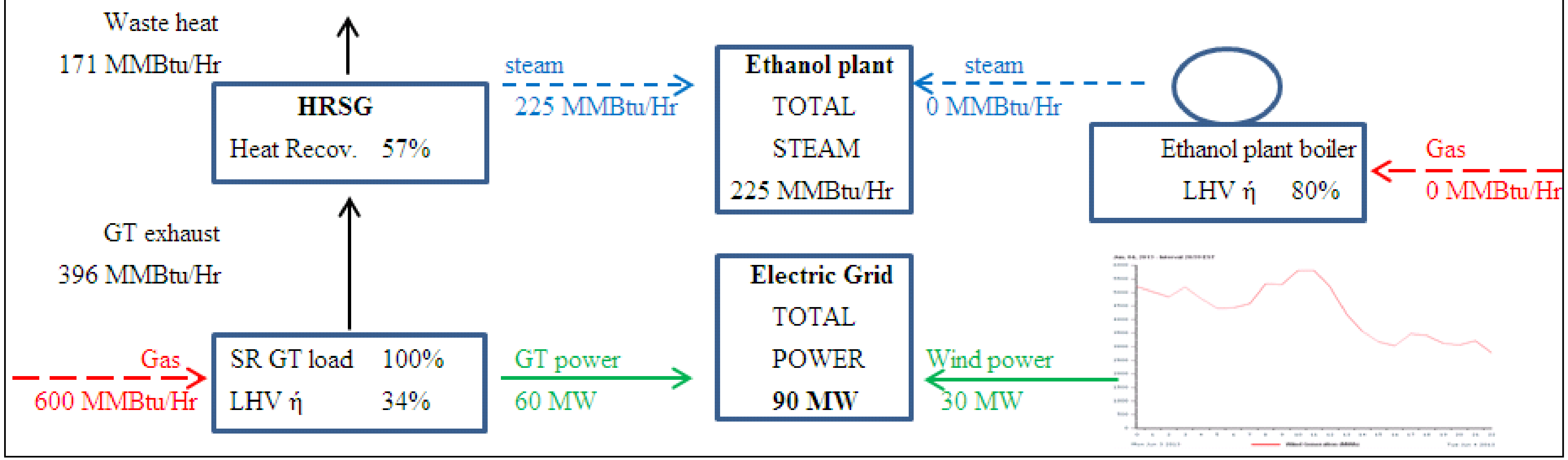
Burning fuel once and recycling waste heat is efficient and profitable

Fuel to power & steam; System Efficiency 71.6%

Steam Balance	MMBtu/Yr
HRSG	1,890,000
Ethanol boiler	0
TOTAL	**1,890,000**

Fuel Balance	MMBtu/Yr
SR GT	5,040,000
Ethanol boiler	0
TOTAL	**5,040,000**

Power Balance	MWh/yr
Wind Power	252,000
SR GT power	504,000
TOTAL	**756,000**



Strategy? minimize lifecyle cost of power and steam

Economics: operating assumptions

PARAMETER	UNIT	VALUE	COMMENT
System availability	hrs/yr	8,400	Ethanol plant, windmills, SRGT, coal power plant and CHP-SR
of which, duration of			
High wind	hrs/yr	4200	Wind *plus* SRGT or CHPSR
Low wind	hrs/yr	4200	Wind *plus* SRGT or CHPSR
Delivered fuel costs			
Natural gas	$/MMBtu, HHV	$3.0	
Coal	$/MMBtu, HHV	$3.0	$75 per ton
System non-fuel O&M			
SR GT	$/MWh	$5.0	Typical
CHP-SR	$/MWh	$10.0	Typical
Coal power plant	$/MWh	$15.0	Typical
Ethanol plant boiler	$/MMBtu steam	$1.0	Assumed
Utility Coal boiler Heat Rate	MMBtu/MWh	12	Typical for sub-critical Rankine cycle plants
Ethanol plant boiler efficiency	% LHV	80%	Assumed

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Economics: CHP-SR slashes operating costs

Ethanol Plant Boiler cost	$MM/yr		$/MMBtu steam	
Fuel: Natural gas	$7.8		$4.1	
non-fuel O&M	$1.9		$1.0	
TOTAL	**$9.7**		**$5.1**	

		Power cost	*steam credit	Net cost
CHP-SR cost	**$MM/yr**	**$/MWh**	**$/MWh**	**$/MWh**
Fuel: Natural gas	$13.7	$36.3	($20.6)	$15.7
non-fuel O&M	$3.8	$10.0	($5.0)	$5.0
TOTAL	**$17.5**	**$46.3**	**($25.6)**	**$20.7**

		Power cost	*steam credit	Net cost
SR GT cost	**$MM/yr**	**$/MWh**	**$/MWh**	**$/MWh**
Fuel: Natural gas	$13.7	$36.3	$0.0	$36.3
non-fuel O&M	$1.9	$5.0	$0.0	$5.0
TOTAL	**$15.6**	**$41.3**	**$0.0**	**$41.3**

			*steam credit	Net cost
Coal plant cost	**$MM/yr**	**$/MWh**	**$/MWh**	**$/MWh**
Fuel: coal	$13.9	$36.7	$0.0	$36.7
non-fuel O&M	$5.7	$15.0	$0.0	$15.0
TOTAL	**$19.6**	**$51.7**	**$0.0**	**$51.7**

* Steam credit reflects value of displaced Ethanol boiler steam

Economics of a CHP centered microgrid

CHP-SR power is cheaper than wind power with a simple cycle GT

CHP-SR is much cheaper than legacy coal power

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Project development = Make haste….. slowly

1. Set objectives & gather data

2. Conceptualize alternate configurations: technical & economic appraisal

3. Development requires multitasking; seek expert support

Technical:	Configuration, engineering, procurement, construction
Legal:	Structure of contracting entities (LLC, S or C Corp etc…)
Commercial:	Contracts for fuel, power, O&M, grants & incentives
Environmental:	Permits
Financial:	Financial models, equity & debt
Risks & Mitigants:	Project Execution Plan (PEP)

Successful project development = Risk mitigation

RISK	BORNE BY
CHP system CapEx	Project, LLC
CHP system OpEx	Project, LLC
CHP system performance - MW & Kpph	Project, LLC
CHP system availability (Optg hrs)	Project, LLC
CHP stand-by charge	Host, Project LLC
Gas Price change	Host
Power price change	Host
Site / mill risk	Host
Site availability (Optg hrs)	Host

QUESTIONS?

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