



TEXAS TECH UNIVERSITY

Wind Science and Engineering
Research Center

NAWEA Presentation
by
Dr. Chris Pattison

Texas Tech University
Wind Science & Engineering

Co-location of Wind and Solar Power
Plants and Their Integration onto the
US Power Grid



Outline

Approach and Methodology

Data

Wind Power

Solar Only

Combining Technologies

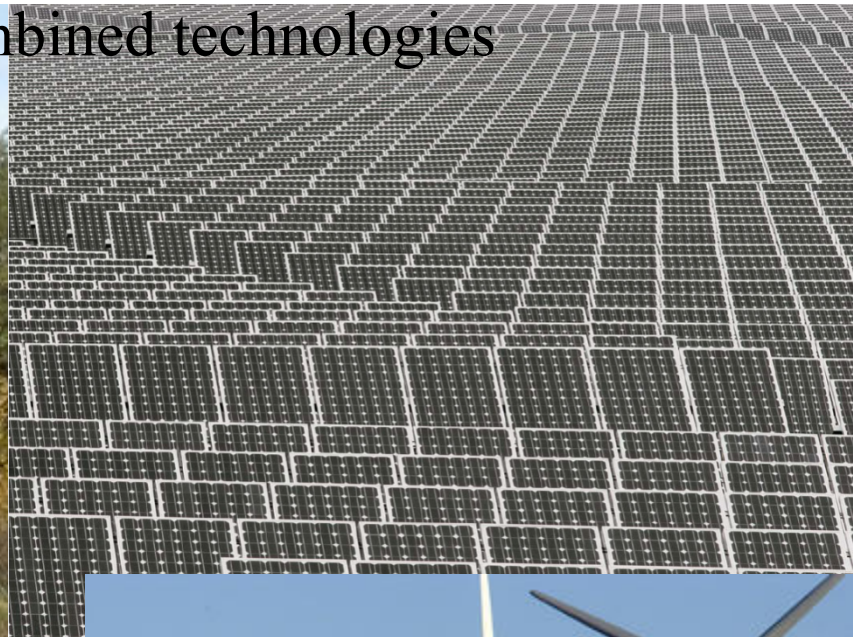
Design Options

Conclusion

Approach and Methodology



To date, no Utility-scale study of the combined technologies



High-fidelity, hub-height wind data with co-located 5-minute solar data (MesoNet)

Estimate wind, solar, and combined output for 2009





Data



Photo curtsey Dr. Ian Giammanco

High-fidelity Wind data at 10-199 m and at 74 meters

Correlated with 78-meter tower and 3-cup anemometer

10-meter wind speeds and solar from West Texas MesoNet

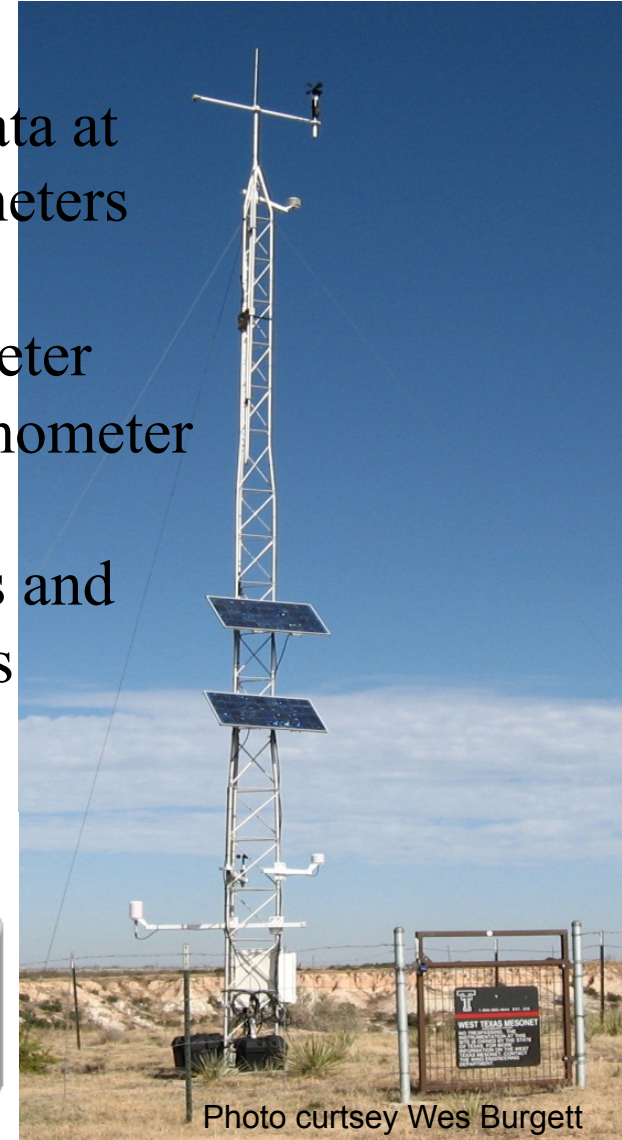
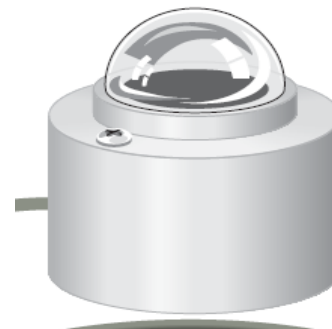
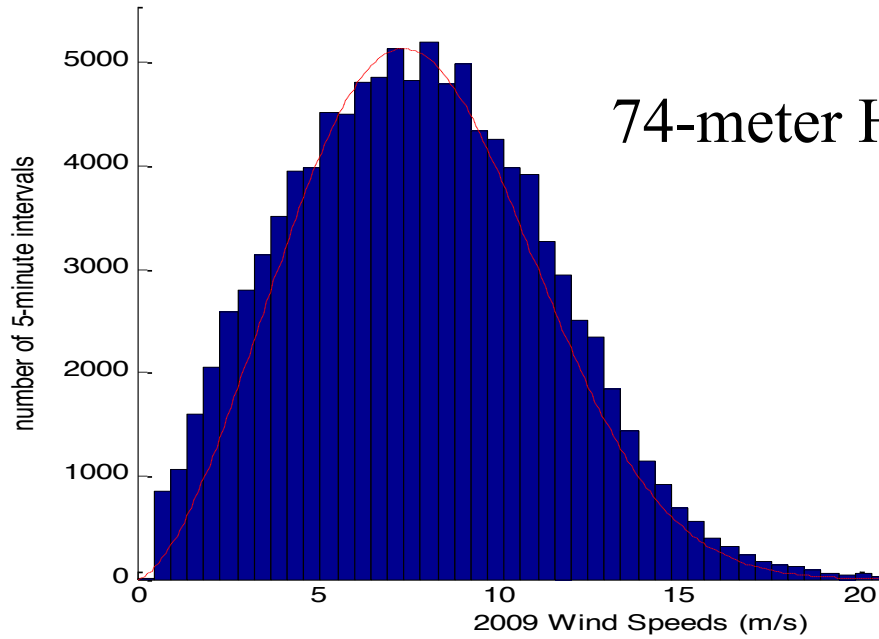


Photo curtsey Wes Burgett



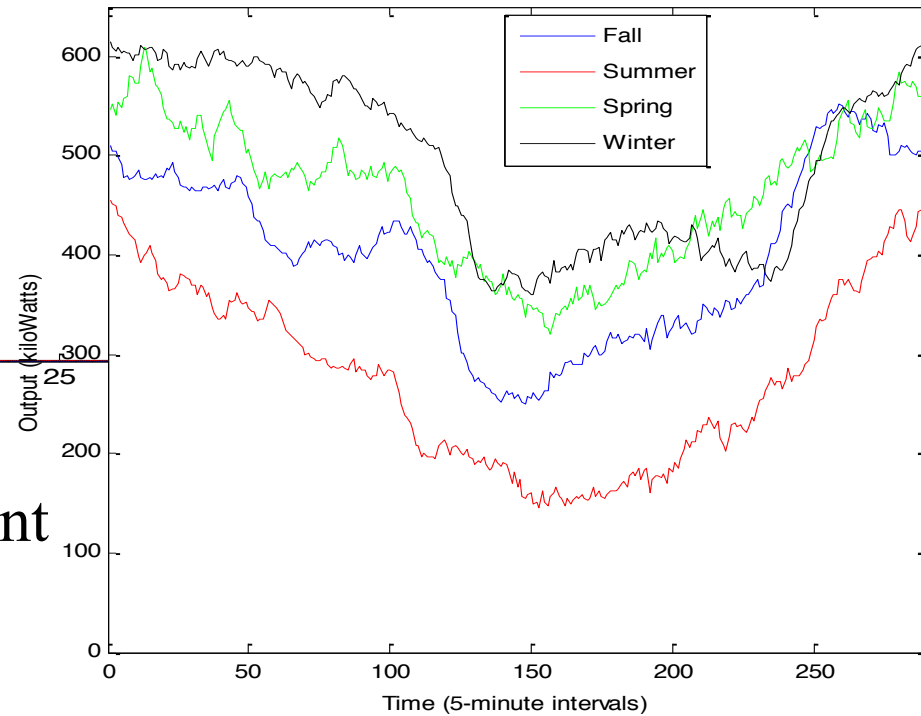
Big Data

Histogram of 74-meter Wind Speeds for 2009

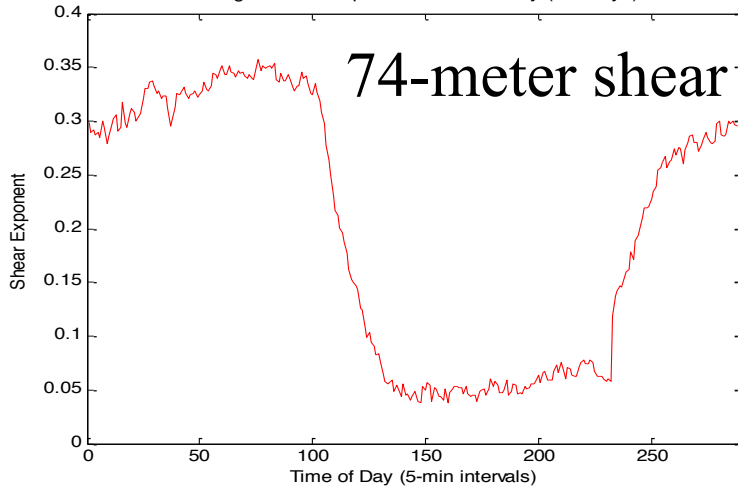


74-meter Histogram Seasonality by location

Average Seasonal Turbine Output vs. Time of Day



Average Shear Exponent vs. Time of Day (222 days)

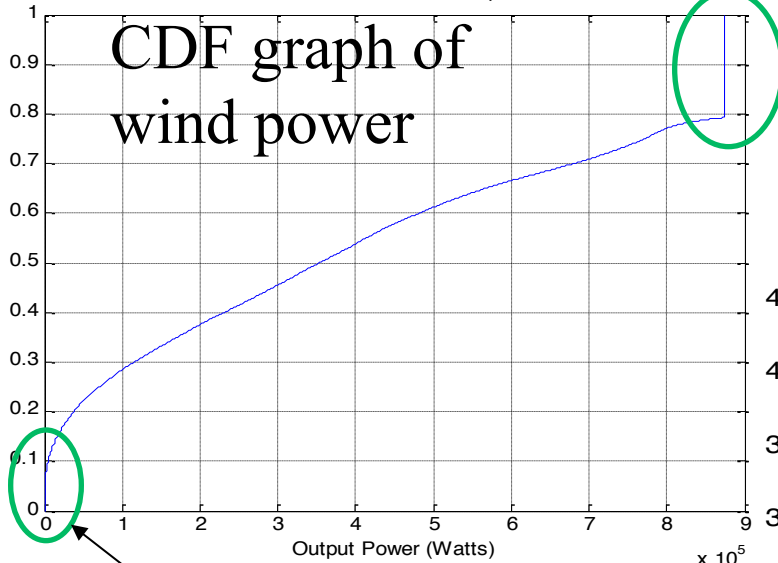


74-meter shear exponent



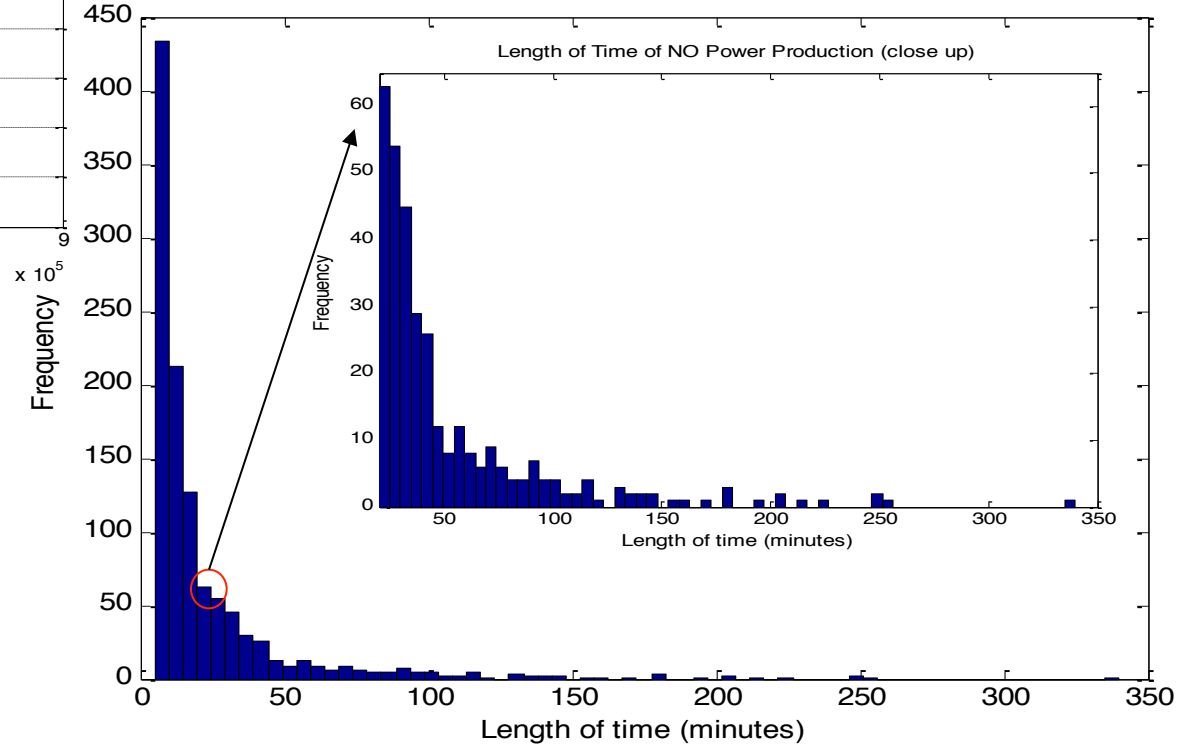
Wind Power

CDF of Transformer Output



Firming wind with diesel or natural gas generation

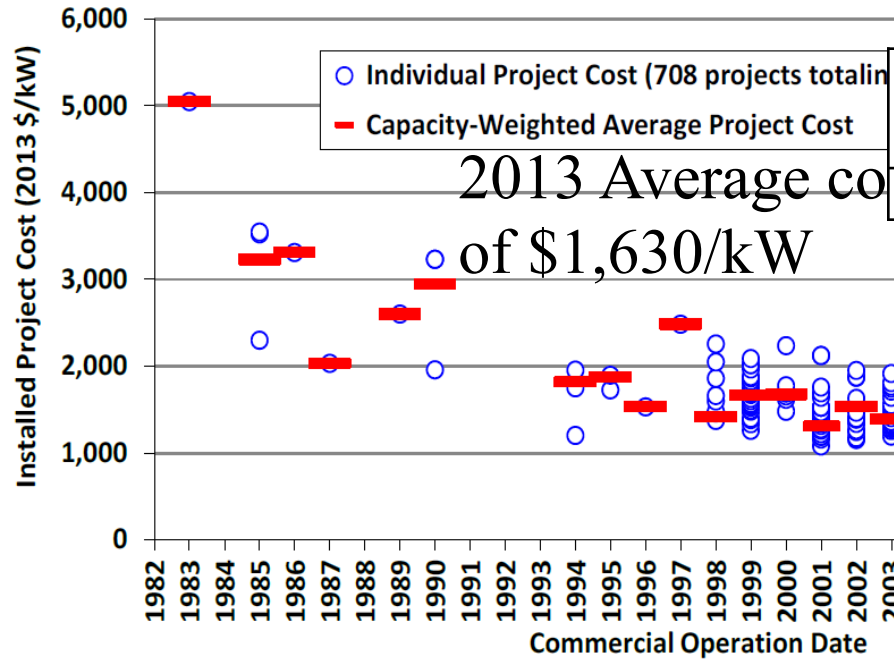
Length of Time of NO Power Production





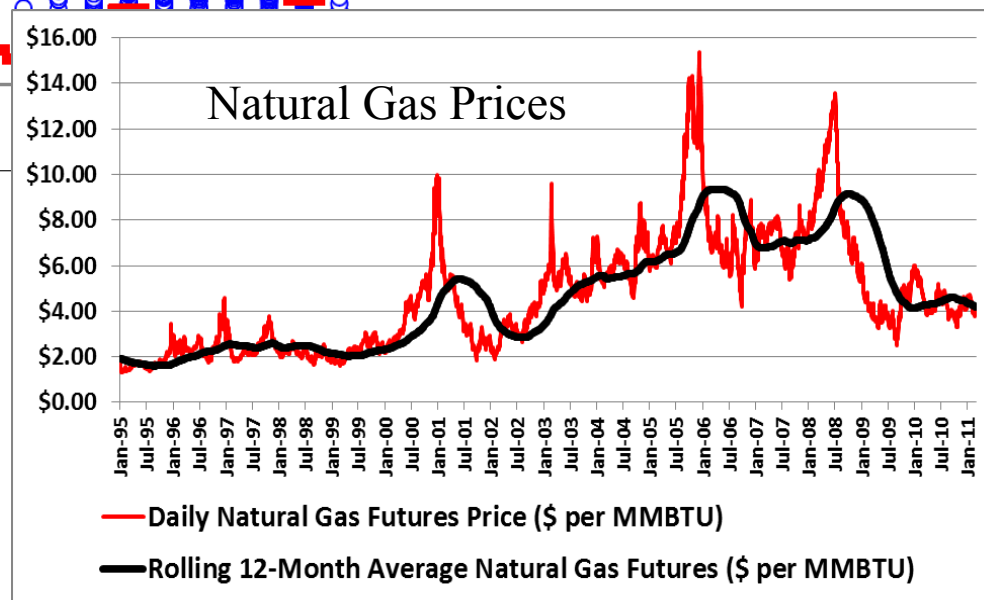
Economics

Reported Installed Project Costs Continued to Trend Lower in 2013



2009 Wind Technologies Market Report

1 Year	MWh Delivered	Capacity Factor	Estimated 2009 cost	Cost/Watt	One-year ICC/AEP
Wind	3,564	40.7%	\$2,120,000	\$ 2.12	\$ 0.60

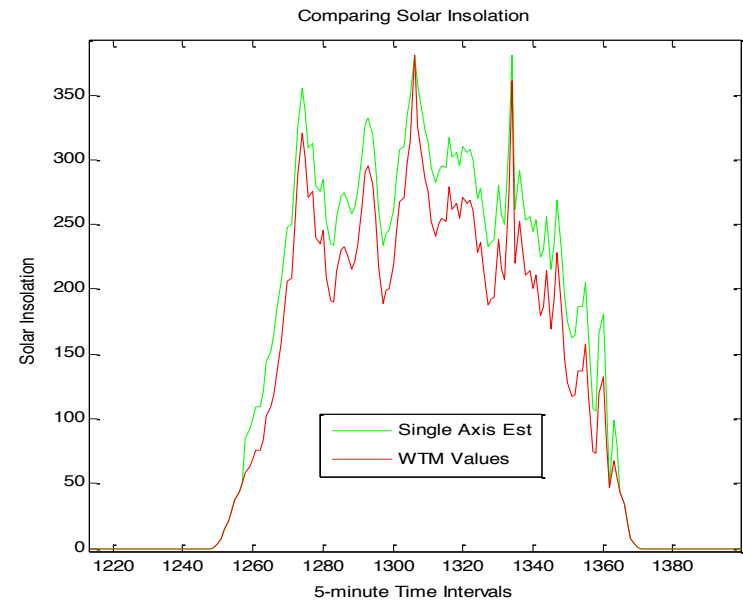
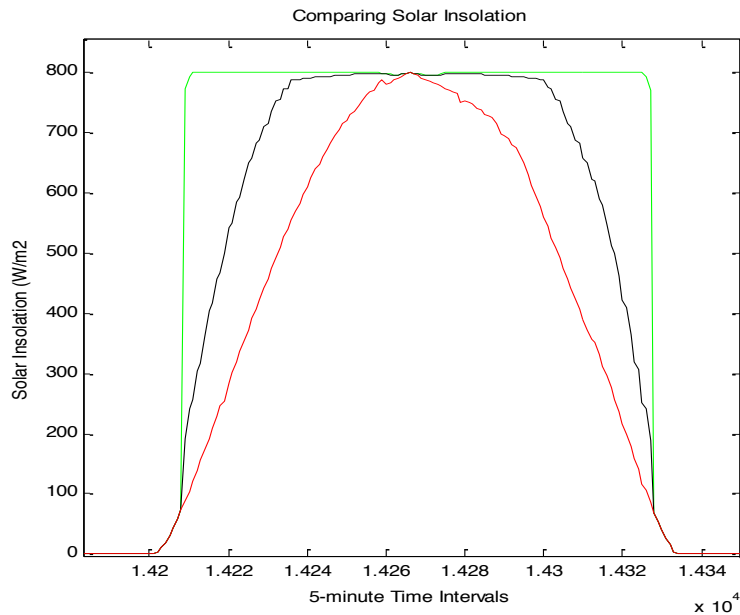
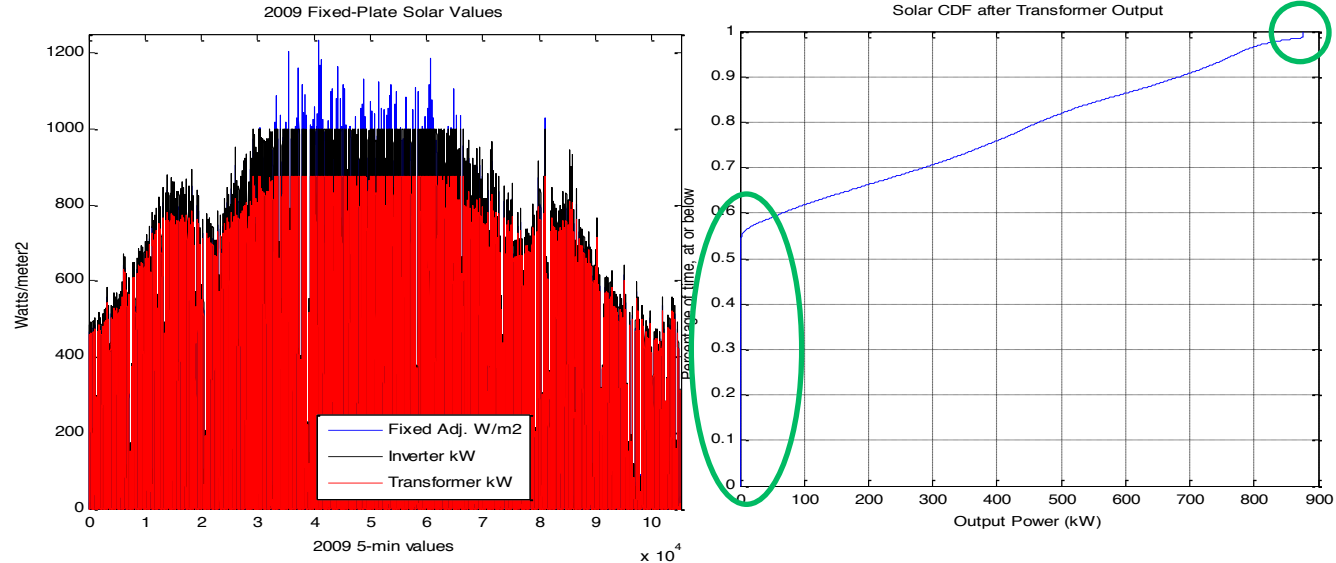


PPA vs. Merchant Plan
 Multi-year layout
 IRR/NPV graphs (Combined)



Solar Only

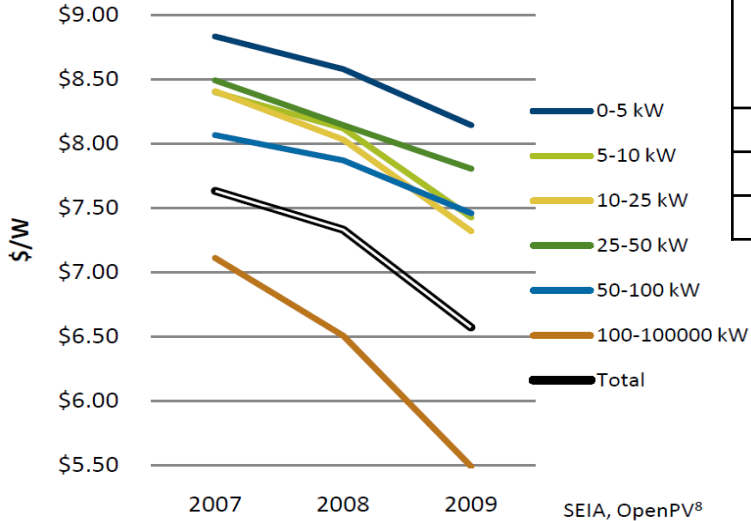
Fixed
Single-Axis
Dual-Axis





Economics

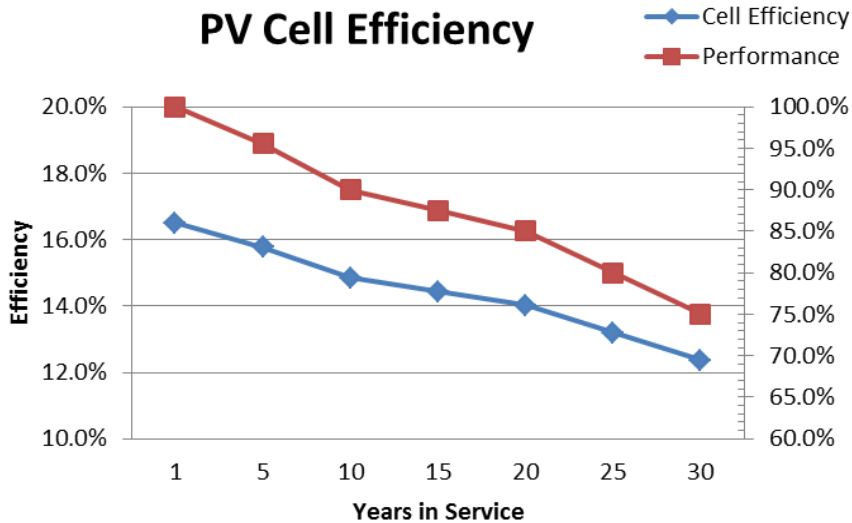
Average PV Installed Cost



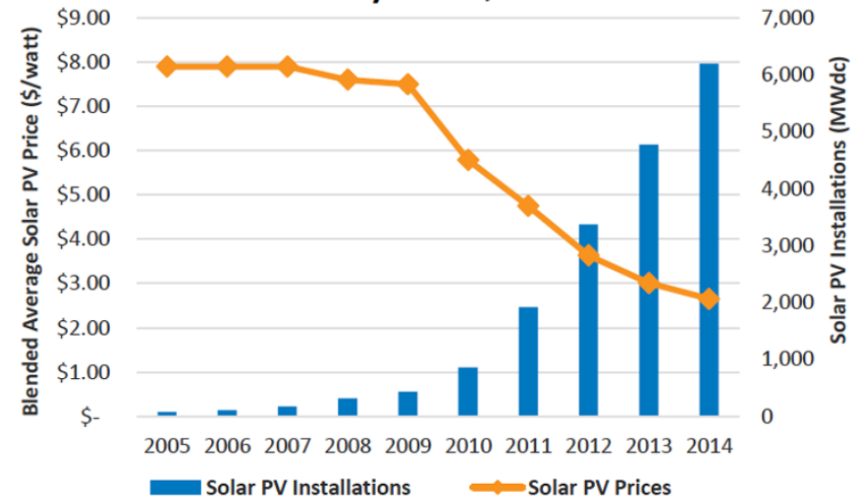
1 Year Compare	No. of Panels	MWh Produced	Net Cap Factor	% increase	Est. Cost w/o T-1603	cost/Watt AC w/o T-1603	One-year ICC/AEP
Fixed Solar	6570	1,687	19.3 %	-	\$5,303,715	\$ 5.15	\$ 3.14
Single-Axis	5900	2,235	25.5 %	32.5%	\$4,809,090	\$ 4.94	\$ 2.15
Dual-Axis	5600	2,341	26.7 %	38.8%	\$4,665,830	\$ 4.95	\$ 1.99

Modules: \$2.25 / Watt
 Labor: \$2.90 / Watt

PV Cell Efficiency



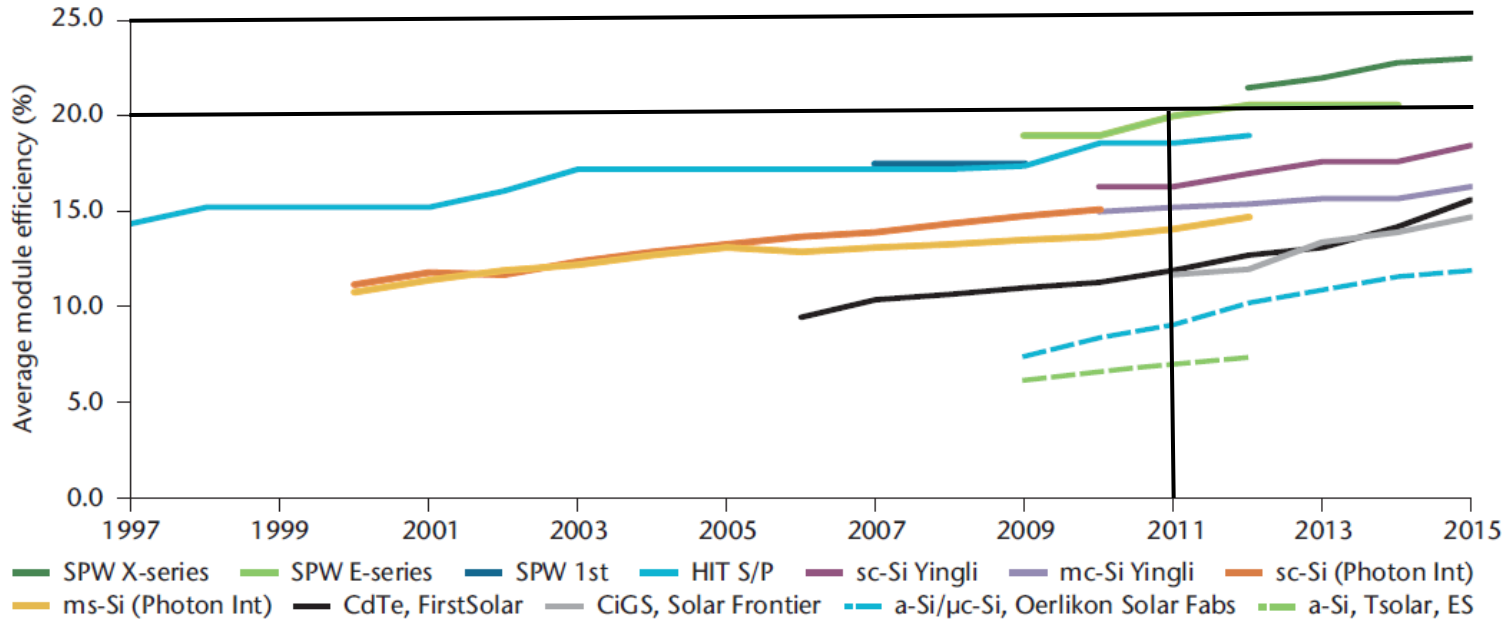
As Industry Scales, Prices Fall





Solar Efficiency Trends

Figure 13: Commercial 1-sun module efficiencies (actual and expected)

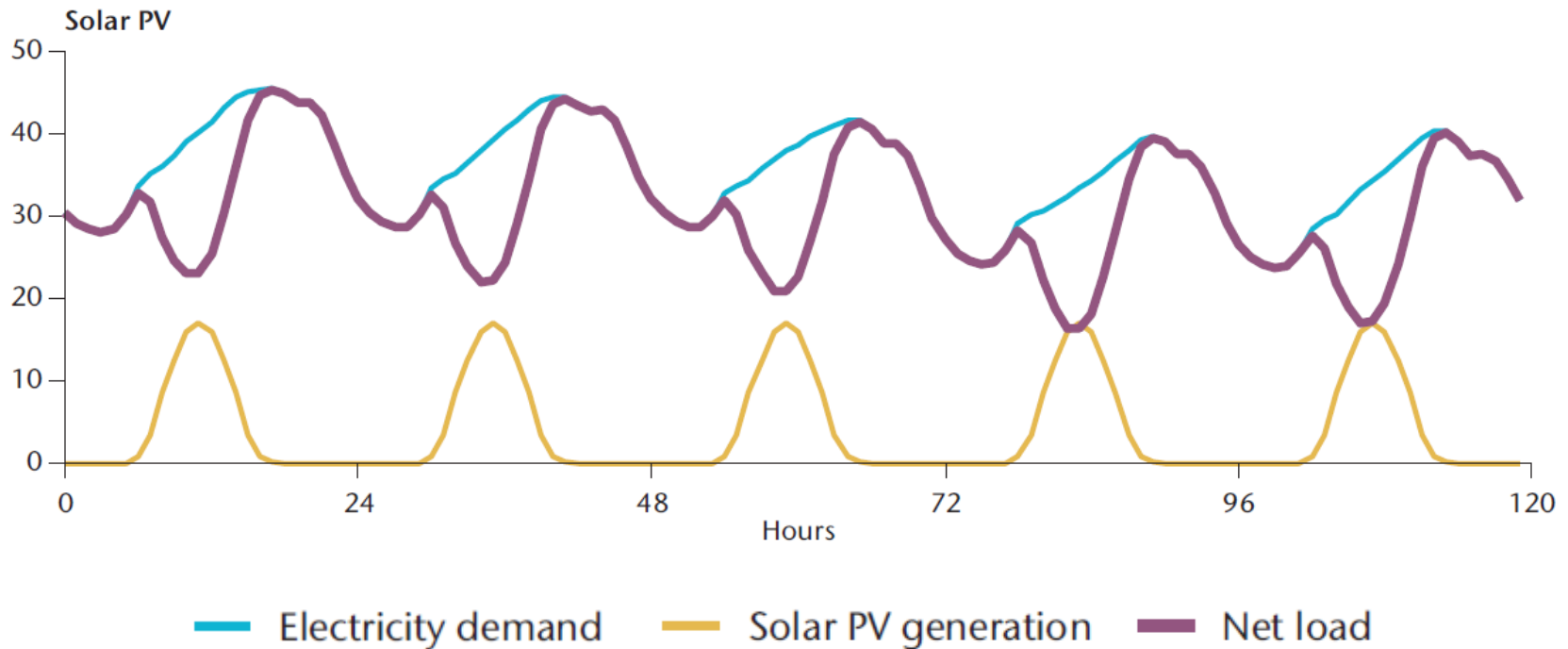


Note: SPW stands for SunPower, HIT S/P stands for Heterojunction Intrinsic Thin layer Sanyo/Panasonic.

Source: De Wild-Scholten, M. (2013), "Energy payback time and carbon footprint of commercial PV systems", *Solar Energy Materials & Solar Cells*, No. 119, pp. 296-305.

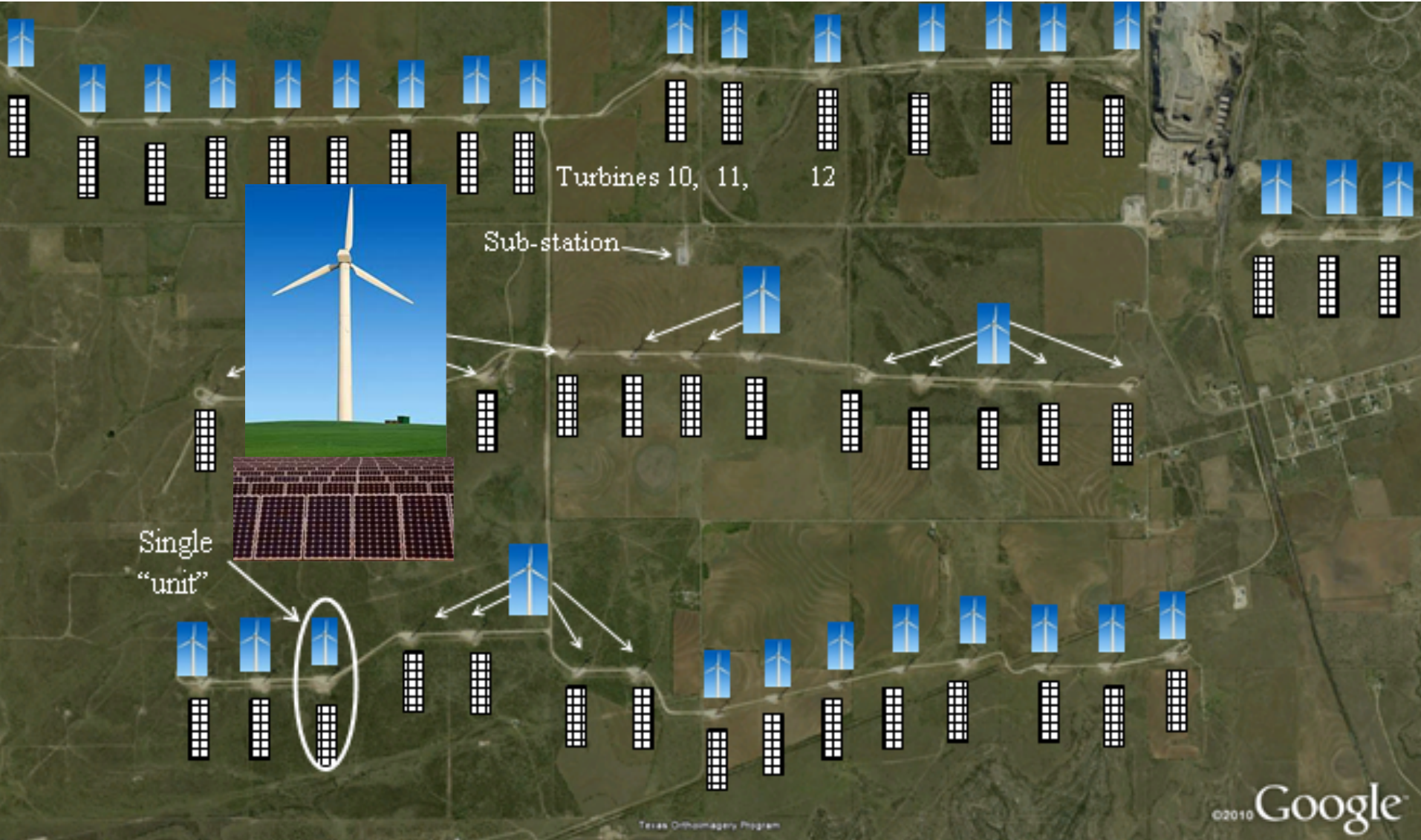


Ex: Solar's Affect on the Grid





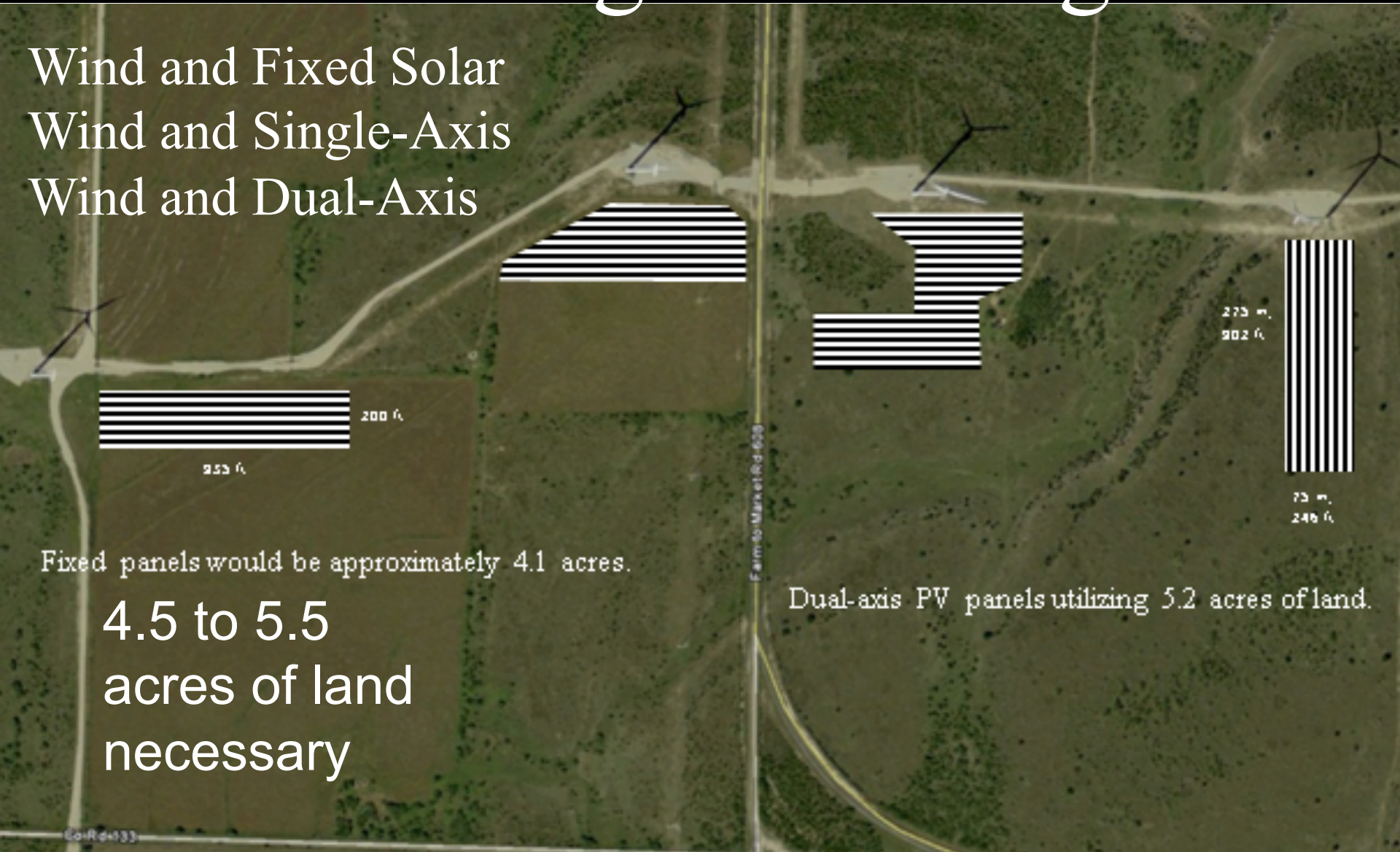
Combining Technologies





Combining Technologies

- Wind and Fixed Solar
- Wind and Single-Axis
- Wind and Dual-Axis



Fixed panels would be approximately 4.1 acres.

4.5 to 5.5
acres of land
necessary

Dual-axis PV panels utilizing 5.2 acres of land.



Design Options

Option 1: Add-On

Shared transformer

- Individual transformer, high-side bus
- Shared larger transformer

Collection system, under-designed

Internal curtailment

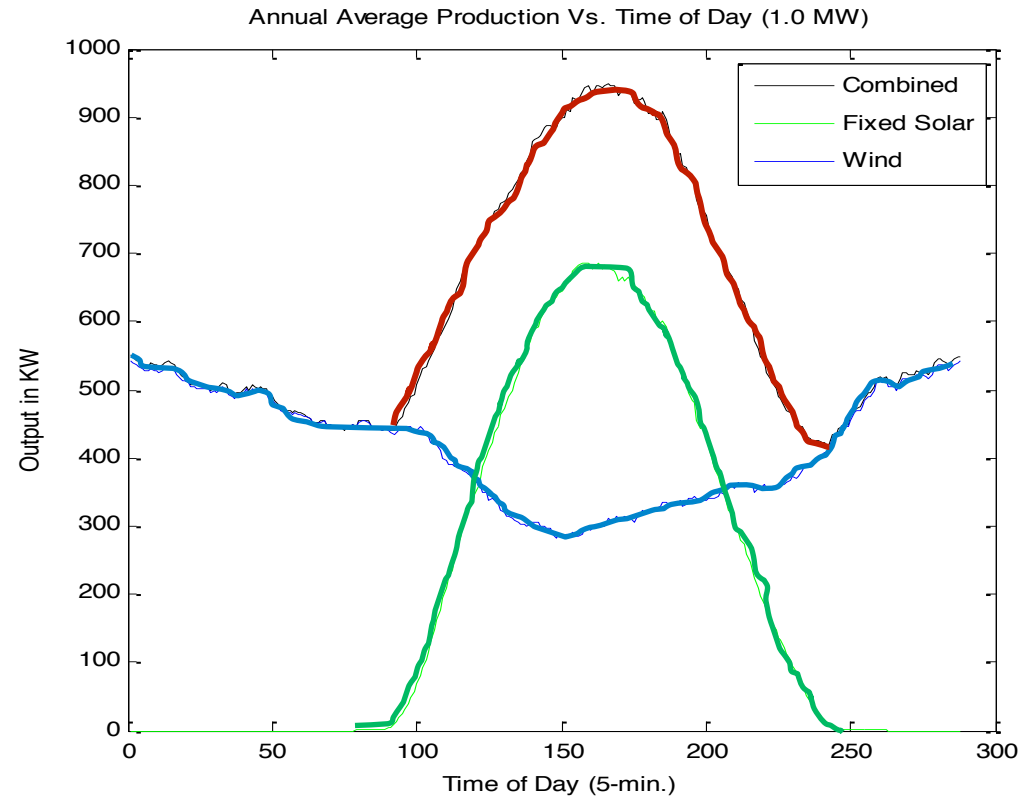
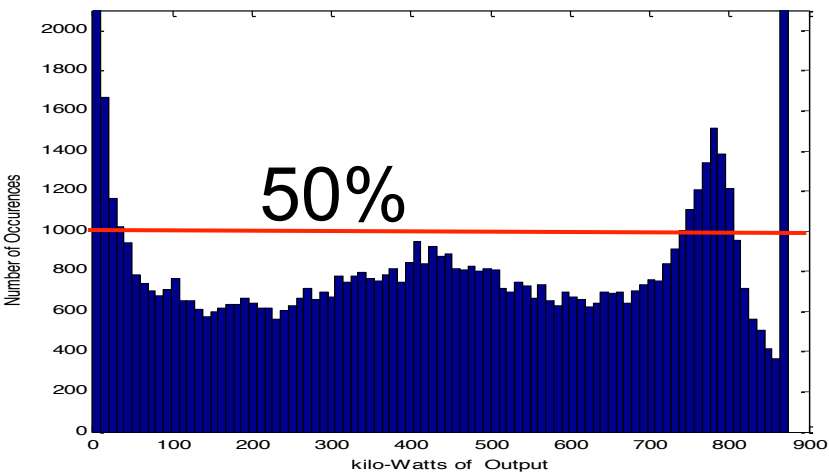
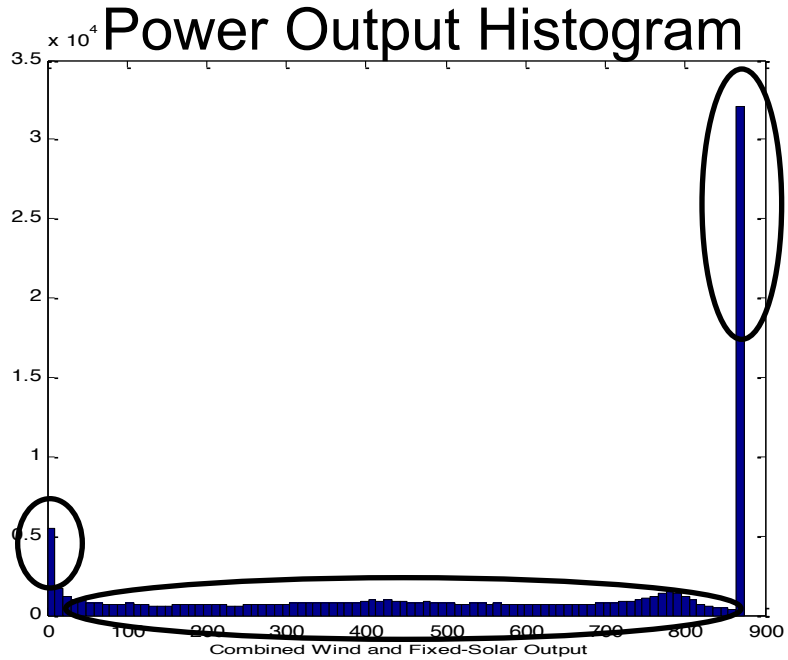
Option 2: Co-construction/design

Individual transformers, high-side bus

Shared larger transformer

Collection system, correctly designed

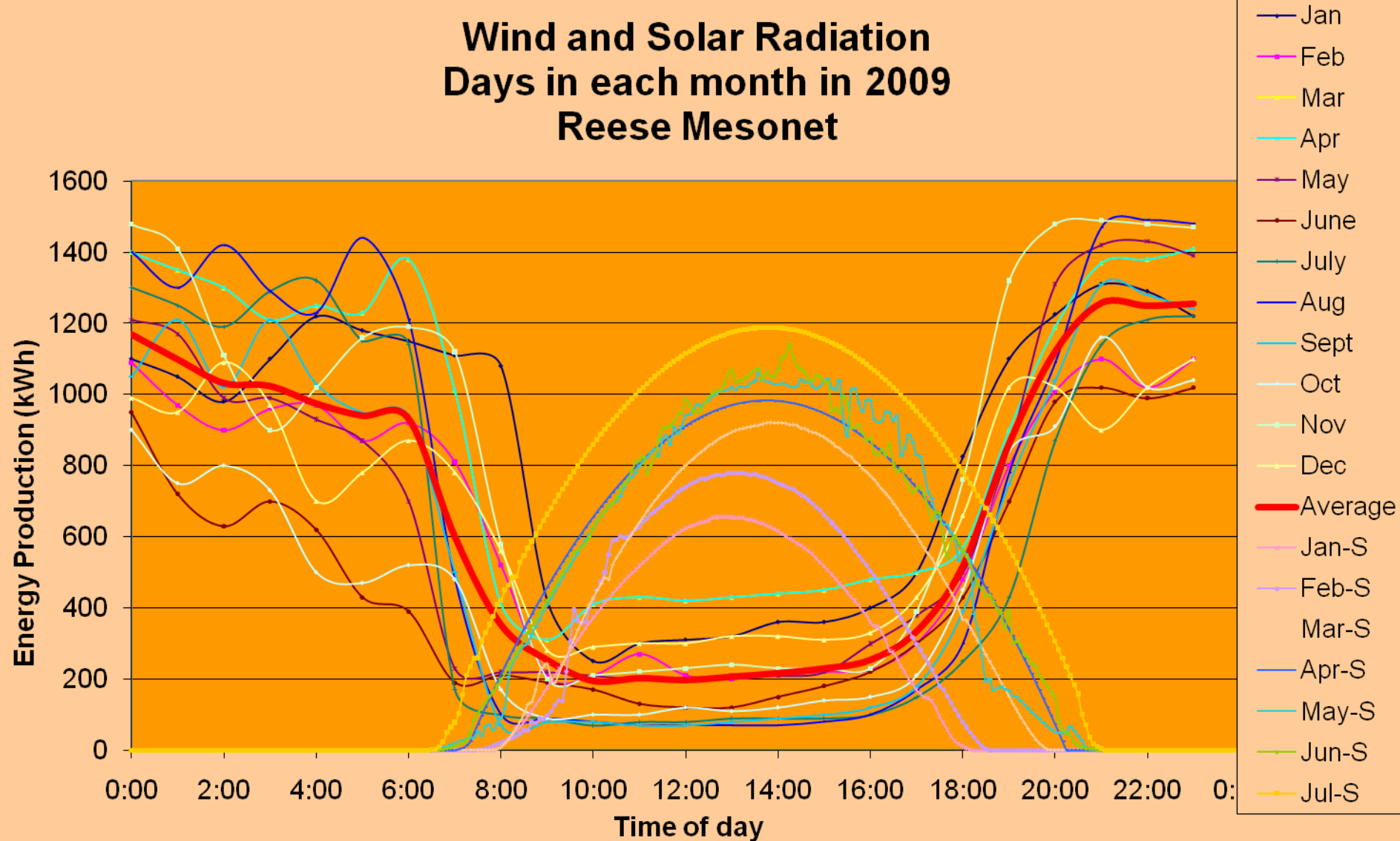
Combined Technologies



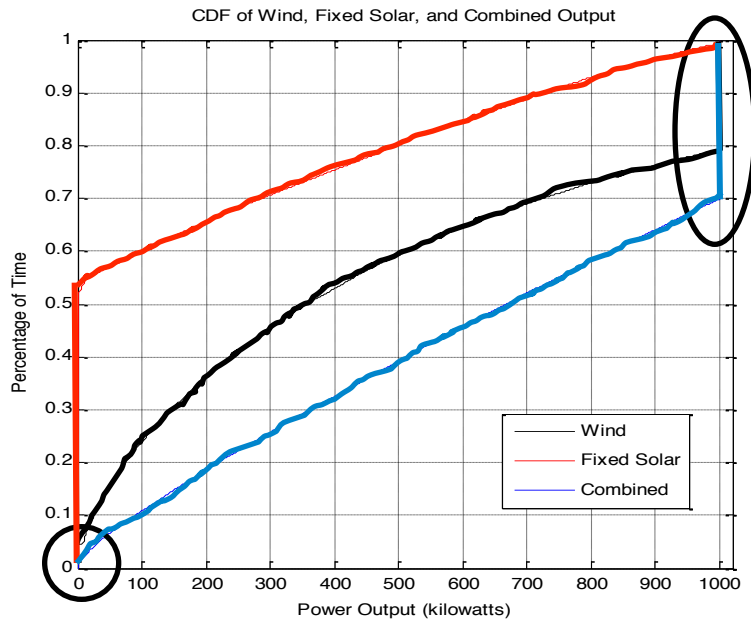
Combined Technologies



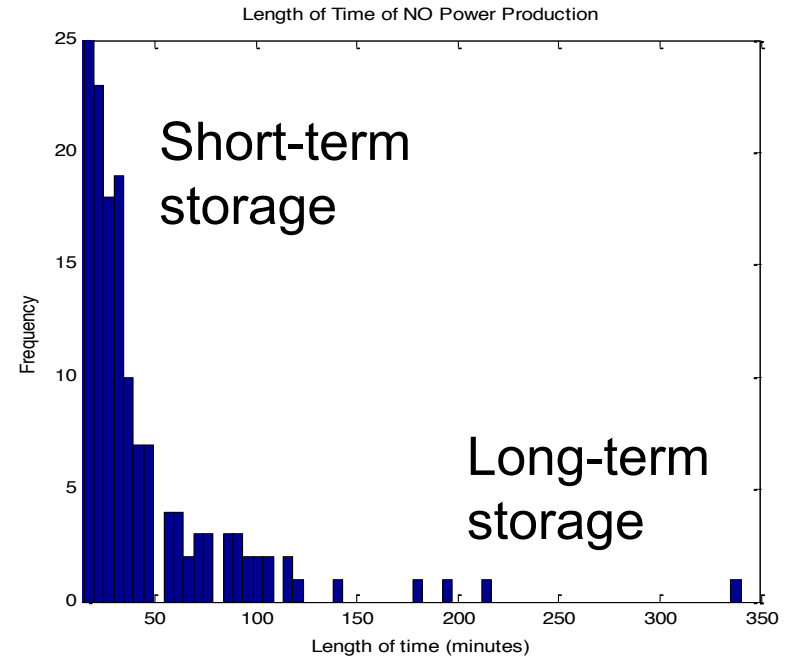
**Wind and Solar Radiation
Days in each month in 2009
Reese Mesonet**



Combined Technologies



Leads to storage

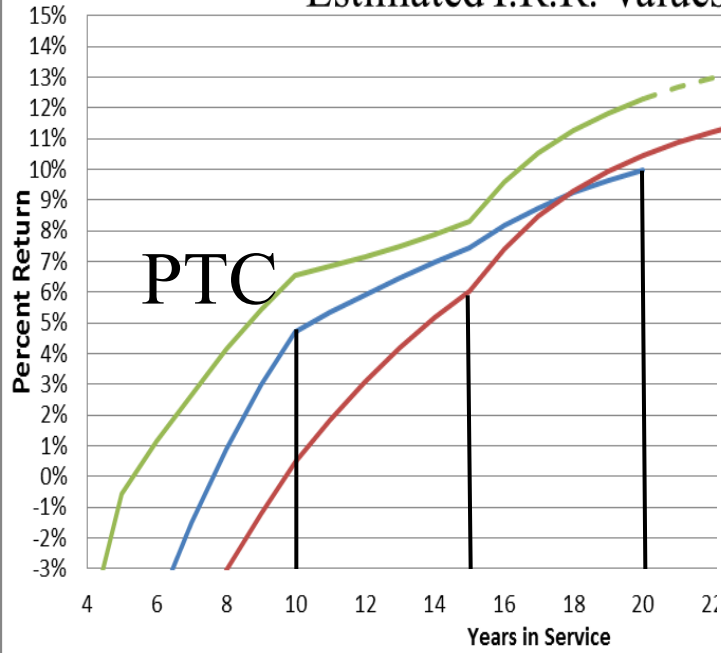




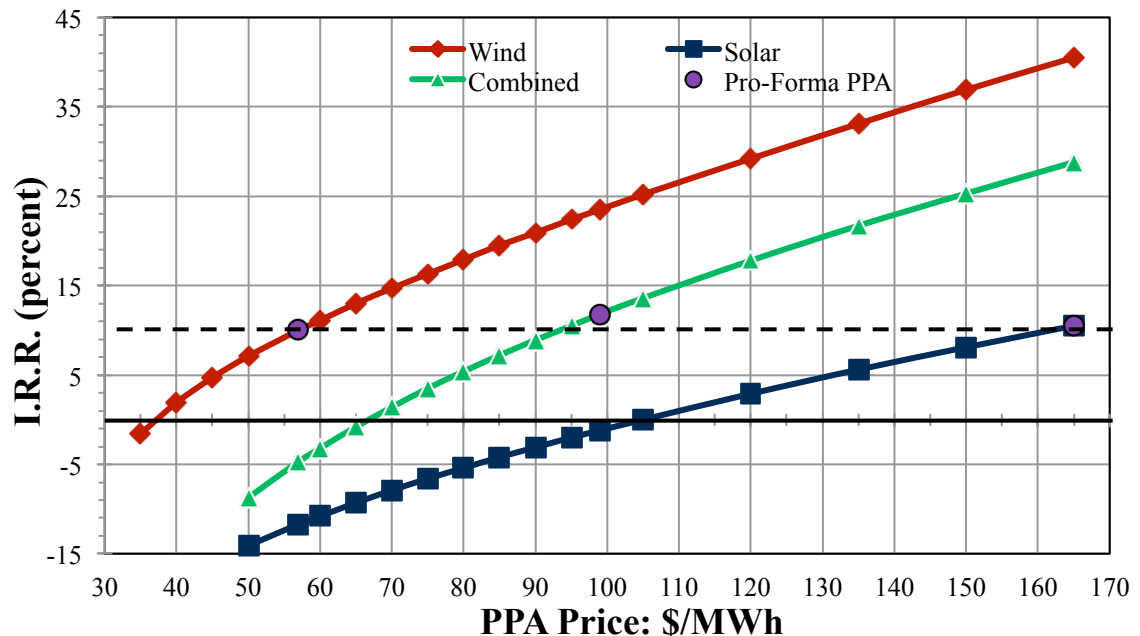
Econ Combined Technologies

Equal IRR's-10%
Wind PPA of \$56
Solar PPA of \$165
Combined \$95

Estimated I.R.R. Values



I.R.R. vs. \$/MWh (First year PPA)



NCF

Wind: 0.407

Solar: 0.19-0.27

Combined: 0.592



Storage

Persistence leads to storage

Options

Concentrated Solar Power (water)

Super-Capacitors (voltage control)

Hydrogen (tanks & water)

Pumped Hydro (large amount of water)

Compressed air (temperature & geography)

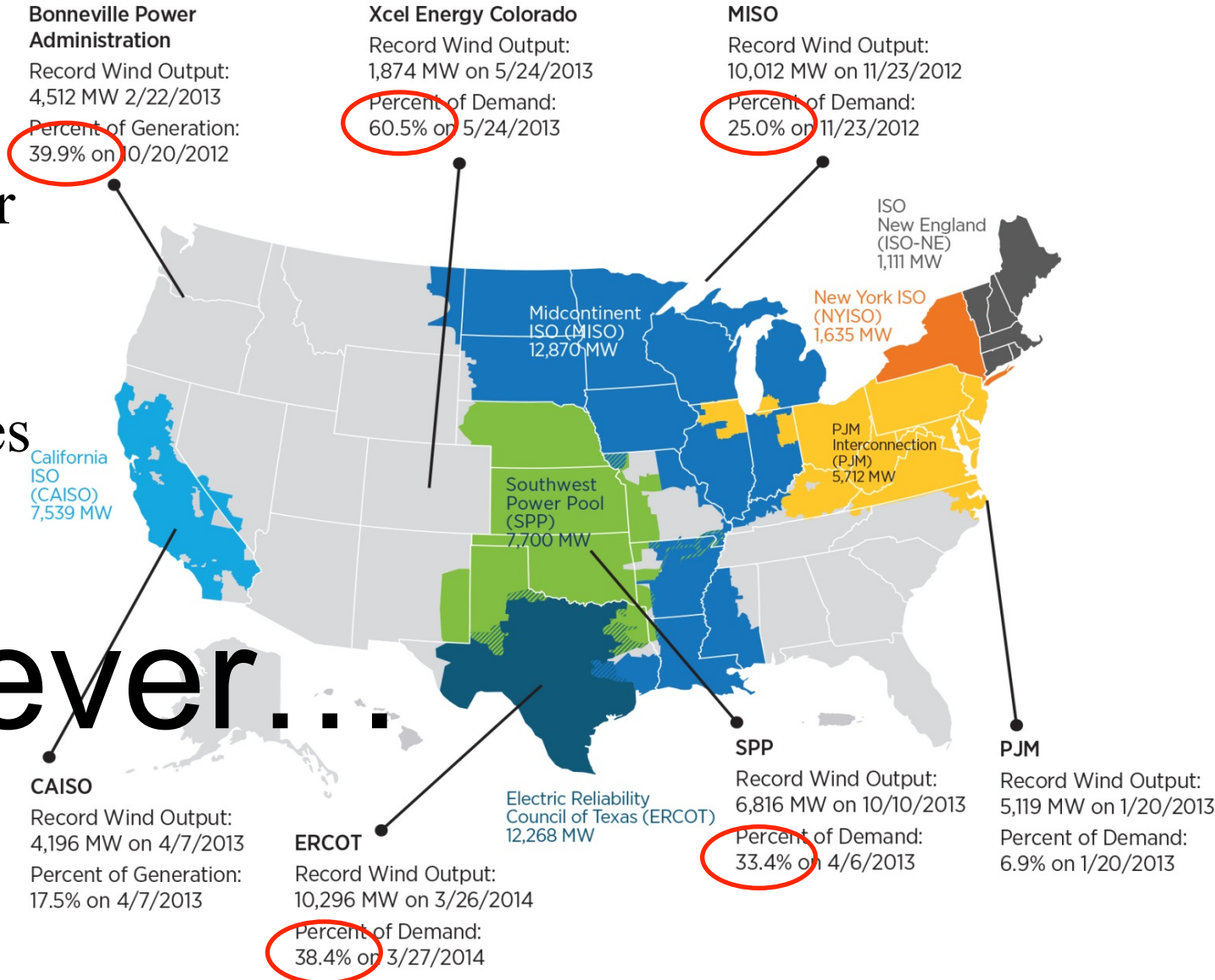
Fly wheels (short duration)

Batteries



Conclusion

More reliable power being delivered closer to the loads stabilizes the grid and reduces losses.



However...



The Washington Post

Health & Science

Arizona is imposing a monthly surcharge for net metering.

New Mexico is considering one.

Utilities wage campaign against rooftop solar

“If demand for solar continued to soar, traditional utilities could soon face serious problems, from ‘declining retail sales’ and a ‘loss of customers’ to ‘potential obsolescence,’ according to a presentation prepared for the group.”

“The warning... became a call to arms for the electricity providers in nearly every corner of the nation. ...The industry and it’s fossil-fuel supporters are waging a determined campaign to stop a solar insurgency that is rattling the boardrooms of the country’s government-regulated electric monopolies.”



TEXAS TECH UNIVERSITY

Wind Science and Engineering
Research Center

Thank
you!





TEXAS TECH UNIVERSITY

Wind Science and Engineering Research Center



TEXAS TECH UNIVERSITY™