Solar Energy in Texas:
Pumped Storage Issues & Opportunities

Presented to:
The North Texas Renewable Energy Group
Dallas, Texas

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The $64,000 Question:

Are renewables viable, technically and economically?
Why it matters

Higher energy use correlates with:

• Economic growth
• Prosperity
• Longer life span
• Better diet
• Higher IQ
• Cleaner environment

Martin Wolf
Financial Times
Energy poverty correlates with:

- Disease
- Malnutrition
- Educational poverty
- Lower IQ
- Social Instability
- Conflict

High energy prices discriminate against the poor
Are renewables viable, technically and economically?

My answer:

• Renewables are generally economically viable
• Renewables can actually be good for the grid
• Developments in energy storage will be a ‘major disruptor’
• Renewables are environmentally friendly
Renewable electric generation from wind and solar will see impressive growth:

Electrical sector - Renewables

Energy Information Administration
Wind and solar are seeing impressive capacity additions:

EIA’s long-term power plant projections
March 6, 2020 report
The public likes renewable energy:

A study of 2,000 Americans found 42% of those surveyed also said they want to see dedication to 100 percent renewable energy in their lifetime.

March 2020
Renewable electric capacity from wind and solar are seeing impressive growth – Texas:

ERCOT: Texas solar growth projections!

Wow!
Record power use in Texas forecast this summer!

2010 - 2019 period:

Average annual summer peak demand growth rate was 1.4%

Forecast to set record this summer by 1.5%!
Texas will need additional power

Last fall:

- Conservation appeal is in effect today from 2 to 7 p.m. Please safely reduce your electric use during this time to help lighten the load on the grid.

- Operating reserves show a tight condition with 3.669 MW available.
In Texas energy is Supreme - we are:

• #1 in crude oil production
• #1 in natural gas production
• #1 in natural gas liquids production
• #1 in electrical generation
• #1 in refining capacity
• #1 in pipeline throughput
• #1 in refined product exports
• #1 in wind power
• And will be #2 in solar within 24 months!

Oklahoma is #46 in solar. Why?
The U.S. has **three** electrical grids

Interconnections and Reliability Regions

1. Eastern and Quebec Interconnection
2. Western Interconnection
3. ERCOT Interconnection

Source: NEIC
And Texas has its own electrical grid!

**INTRASTATE ELECTRIC SALES**

VS

**INTERSTATE ELECTRIC SALES**

**INTERSTATE** FEDERALLY REGULATED – ACROSS STATE LINES

**TEXAS INTRASTATE** – STATE REGULATED ONLY (ERCOT)

*Don’t connect across state lines:*

*The famous Oklahoma ‘Midnight Connection’*
Implications: Texas is an island!

For $20, where does the Davis, Oklahoma Arbuckle Wind Farm sell their green renewable power?
Texas is an island!

For $20, where does the Davis, Oklahoma Arbuckle Wind Farm sell their green renewable power?

Answer: Lincoln, Nebraska!

Question: Do you think the electrons make it to Nebraska?
Five Lessons:

1. Electrons generated in Texas ERCOT generally stay in Texas!

2. The business and regulatory rules that impact the transmission and the sale of electrical energy are Texas based!

3. State (ERCOT) policy drives the energy mix and the use of renewables!
Texas is an island!

However:

4. Texas needs to meet demand with Texas generation – and needs to keep the grid stable.

5. In times of peak demand we don’t have neighbors to easily ‘borrow’ electrons from.
Texas is unique in that it has a market driven regulatory scheme!

Goal is to have 13.75% reserve margin in Texas ERCOT
Last summer we only had 9% reserve margin
Texas is unique in that it has a market driven regulatory scheme!

Texas has no “capacity market” for back up power
This is unique! And impacts storage projects
The rest of the country pays for backup capacity
‘Spinning reserve’ charges
Texas is unique in that it has a market driven regulatory scheme!

Texas uses price signals to address supply and demand

Currently a $9,000 MWh ERCOT ‘cap’ on prices
Up from $5,000 MWh cap in 2014
Texas is unique in that it has a market driven regulatory scheme!

Monthly and annual range of wholesale electricity prices for selected regional trading hubs, December 2019

Can you say ‘volatility’?
Finance theory:
Higher volatility = Higher risk
Why Texas for solar installations?

- Solar resources
- ERCOT/State policies
- State economy
- Regulatory environment
Texas power demand curve

Note peak demand on the grid is generally from 1 pm to 7 pm - especially in the summer
Solar generation has a “positive covariance to the load”

Note peak solar generation to the grid is generally from 1 pm to 6 pm
Texas power is cheap: Impacts project economics

Residential rates per KwHr:

- Keweenaw Energy Transition Lab - $0.24
- TXU Oncor (Dallas) - $0.13
- TXU Houston - $0.14
Landowner’s Right to Solar

Welcome to Miami Beach, Florida!
Enjoy the sun and the ocean

Inter-coastal Waterway
Plaintiff hotel
Pool area
Defendant hotel
Atlantic Ocean

‘Doctrine of ancient lights’ does not apply in the United States
Can use the sunlight, but not an enforceable property right

Fontainbleau Hotel v. 45 25 Inc., 114 So. 2d 357 (1959)
Why Texas for wind turbine installations?

- Wind resources
- ERCOT/State policies
- State economy
- Regulatory environment

Wind ‘fairway’
Keweenaw Energy Transition Lab Investigation: Offshore Lake Superior?

Power generated is function of the cube of the wind speed -

Twice the wind speed will generate 8 times more power!!

Wind ‘fairway’

"Cherry"
Wind generation can have a negative “covariance to the load” except for near shore facilities.
Wind Power ‘Issues’: Excess Power When Not Needed

Peter Thiel-Backed Startup Says Texas Is The Best Place To Mine Bitcoin

Sat, 02/29/2020 - 14:35

Author by Samuel Haig via CoinTelegraph.com,

Alex Liegl, CEO of Layer1 Technologies, a US-based Bitcoin (BTC) mining company that recently announced its intention to repatriate 30% of Bitcoin’s hash power by 2022, has described Texas as offering miners the “cheapest power in the world, at scale.”

Texas: #1 in Bitcoin! (?)

How Texas's wind boom has spawned a Bitcoin mining rush

Texas's wind-powered digital gold rush might redraw the global map of the Bitcoin mining network.

by Mike Orcutt  February 27, 2020

Is Texas the new promised land for Bitcoin miners? The backers of several big-money projects are betting yes, thanks to the state's cheap electricity and
Wind generation automatically ‘cuts out’ at high wind speeds – destabilizing the grid

Storage can assist in addressing this issue
Wind generation spikes with approaching storms
Solar Power ‘Issues’

Intermittency
Non-dispatchable power
Demand = Supply

Instantaneously across the grid!

<table>
<thead>
<tr>
<th>Generation Type</th>
<th>2009 Capacity Factor</th>
<th>2015 Capacity Factor</th>
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<tbody>
<tr>
<td>Nuclear</td>
<td>90.3</td>
<td>92.8</td>
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<td>Coal</td>
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<td>Natural Gas—Combined Cycle</td>
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<td>55.9</td>
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<td>Solar PV</td>
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<tr>
<td>Petroleum</td>
<td>7.8</td>
<td>13.3</td>
</tr>
</tbody>
</table>


Two nuclear facilities in Texas ‘anchor to the grid’
solar

Energy Law & Policy, 2nd Edition
Davies, Klass, Osofsky
The ‘Physics’ of Electricity

Keep in mind:

- Electricity travels near the speed of light
- Electrons ‘dumped’ into the system in Tulsa can end up in New York City almost instantaneously
- Electrical SUPPLY has to always equal DEMAND instantaneously
- Demand for electricity can change dramatically in a short period of time
Demand = Supply

Stupid professor joke:
Solar and wind are not always “Reddy”!
Another Renewable Power ‘Issue’

Generation hotspot

Moving the ‘product’ to market
Angry US landowners are killing off renewable energy projects

March 7, 2020 | 10:30pm

Wind-energy projects like the Groton Wind Farm in New Hampshire require huge amounts of land — and rural communities are not all happy about it.

There’s an old saw in the trash business that says, “everybody wants their trash picked up but nobody wants it put down.”

That’s not a perfect analogy for what’s happening with renewable-energy projects in New York and New England but the sentiment behind it is familiar. A recent Gallup poll found that 73 percent of Americans favor increased use of wind and solar energy. But in New York and the Northeast, adding large increments of new renewable capacity is getting increasingly difficult due to growing local opposition. Land-use conflicts are also hindering high-voltage transmission projects.

Moving the ‘product’ to market
What is the largest threat to the U.S. electrical grid?

A. Thunderstorms and Lightning
B. Tornados
C. Hurricanes
D. Wind gusts
E. Hail
F. Power spikes
G. Transformer failures
H. Capacitor discharges
I. Terrorists
J. Trees and brush
Transmission lines can cause fires, especially if overloaded

Answer: J. Trees and brush

Transmission is a major issue:
- Fire liability (PG&E - California)
- Moving power to market (Project ‘Windcatcher’ failure)

Generation hotspot

Dallas

Houston

Est. transmission power loss to Dallas: <10%

Transport and ‘traffic jam’

Bitcoin use of stranded energy
Where does ‘pumped storage’ fit?

- 97% of large volume energy storage is pumped storage (not batteries)
- Technology been around for decades
- Roughly 80% efficient
- Water has a high energy density
- Changes intermittent power into dispatchable power
- Can assist in stabilizing the grid
- Great for “black starting the system
- Can follow the load
Ludington Pumped Storage Facility

Isolated electric market due to lakes

110 feet deep
2.5 miles long
363 foot drop
Ludington Pumped Storage Facility

Six 312 MW hydro turbines

Equal to 900 wind turbines

Ludington, Michigan pumped storage

Lake Michigan
High energy density, less land impacted

Need approximately 250 square miles of land for the wind turbines – energy density comes into play

900 wind turbines = Pumped storage output

Ludington Pumped Storage
Pumped storage requirements

Need two things:
1. Stored water
2. Elevation change

Niagara Falls, New York
Pumped Storage Reservoir

Hydro Generators
Keweenaw Energy Transition Lab
Pumped storage investigation
A “battery” – Deep shaft mine

“Turning a liability into an asset”
Professor Roman Sidortsov
Michigan Technological University
Pumped storage application
Pumped storage application

Power delivered to mine when operating

Power can be transported from mine if abandoned

Massive mine workings underground

6,200 feet deep

Quincy #6

3D modeling & testing

Michigan Copper District
Hancock, Michigan
Keweenaw Energy Transition Lab
Offshore Wind Investigation: Lake Superior

Power = Cube of wind speed

Offshore wind farm in Lake Superior?
Super high electricity rates
Power from Pumped Mine Storage:

Bill Muston, VP Engineering, Oncor: "Energy Storage will be a disruptor"
Texas A&M Law 11th Annual Energy Seminar (March 2020)

Available instantaneously across the grid

- Load following
- Voltage stabilizing
- Frequency control
- Spinning reserve
- Black start capability
- Longer duration needs

![Figure 3-1 Representative Weekly Pumped Storage Operating Cycle](image-url)
Pumped Storage is Not a New Concept

Pumped storage can be used for arbitrage, generation ‘time shifting’, load management and grid stability

Prof. Dan Richer, Exec. Director Energy Center, Stanford University:

“Pumped storage has a strong potential to add to the renewable game”

Texas A&M Law 11th Annual Energy Seminar (March 2020)
Battery storage is more recent –
But on a much smaller scale

Utility scale battery installations are more recent additions to the grid, but are not to the scale of pumped storage

“Lithium is an element with an attitude”
Battery scientist
Texas Pumped Storage Application?

Need abandoned:

- Deep shaft mines
- Mining Pits

Abandoned Mines!
Cultural Heritage of Industrial and Mining Communities to Preserve

Mariscal District
Big Bend National Park

Four mining periods on Mariscal Mountain:
1900-1910; Lindsay Mine
1917-1919; Ellis Mine
1919-1923; Mariscal Mine
1941-1943; Vivauna Mine

Copper Harbor, Michigan

Cliff Mine
Eagle River, Michigan

Cliff Mine Stamp Mill

Terlingua Ghost Town

Terlingua District

Quincy Mine educational tour
Hancock, Michigan
Need water to store power

Need water for hydro storage

‘Produced’ Water
Fasken Ranch
Midland, Texas
'Produced water' is saline: But lots of it in the Permian!
Produced water: Environmental hazards

Need water for hydro storage

‘Produced’ Water
Fasken Ranch, West Texas

Fiberglass storage tanks

Stainless steel fittings

Underground injection disposal well
Renewables and pumped storage in Texas?

It might make sense!
But more research is needed

Evaporation reduced in underground facilities

Deep shaft mines
Keweenaw Energy Transition Lab

Upcoming renewables, pumped storage, and industrial archeology research:

- 3D modelling of potential pumped storage facilities
- Records search for abandoned locations
- Historical search for impact of cultural preservation on project perception
- Legal impediments to pumped storage and environmental concerns
- Renewable regulations in applicable jurisdictions
- Discussing alliances with academic institutions
- Examining alliances with industry and professional associations
Keweenaw Energy Transition Lab

Using technology to shape the future – while preserving our industrial and cultural history

Interested in our projects?

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