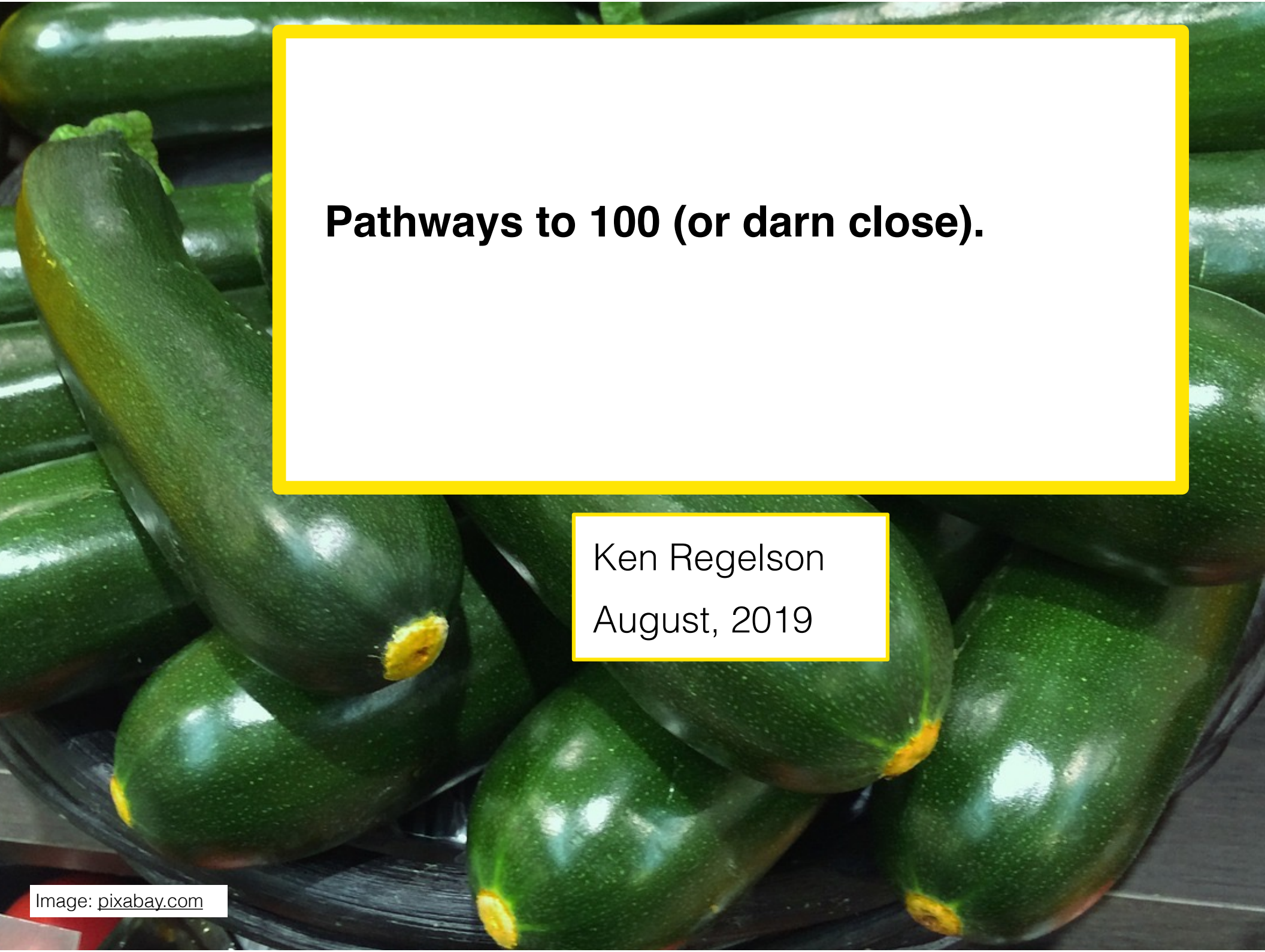

Pathways to 100 (or darn close).

Ken Regelson

August, 2019

Image: pixabay.com

Intro

Quite good with numbers & graphs.

When I speak to a general audience, I ask:

If the goal is

100% Renewables by 2030

how many would be satisfied with 95 or 98% by 2030?

My Daughter Bakes Really Great Cakes!

Like most bakers, she follows a recipe.

Colorado Energy Recipe

1 part 100% Renewable Electricity

1 part Electrify Everything Else

Just Colorado

	% of CO2	Cost (2016 Billions)	Increase in current electricity use to electrify all	Cost of electricity electrify all (based on 10 ¢ / kWh)
Electricity (all coal + gas used for electricity)	**40%**	**$5.5 B**	**-**	No Change **$5.5 B**
Oil (gasoline & diesel)	**35%**	**$6.5 B**	**40%**	**$2.3 B**
Natural Gas (gas NOT used for electricity)	**20%**	**$1.5 B**	**20%**	**$1.2 B**
Total		**$13.5 B**	**60%**	**$9 B**

$4.5 Billion Savings *per year!*

Notes: Most of data from 2016 EIA with analysis by EnergyShouldBe.org The electricity use to electrify transportation is conservative. 10 cents per kWh is the blended cost of Colorado electricity. Divide EIA Table 10 all Colorado revenue by MWh Sales,

The most speculative number is the electricity to electrify nat. gas use. This is based on using heat pumps with a COP of 3. Air source heat pumps are available now (2019) for Colorado at that COP.

Energy ShouldBe.org

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	% of CO2	Cost (2016 Billions)	Increase in current electricity use to electrify all	Cost of electricity electrify all (based on 10 ¢ / kWh)	Average Life of Fleet
Electricity (all coal + gas used for electricity)	**40%**	**$5.5 B**	**-**	No Change **$5.5 B**	
Oil (gasoline & diesel)	**35%**	**$6.5 B**	**40%**	**$2.3 B**	**~ 15 years**
Natural Gas (gas NOT used for electricity)	**20%**	**$1.5 B**	**20%**	**$1.2 B**	**50 - 100 years**
Total		**$13.5 B**	**60%**	**$9 B**	

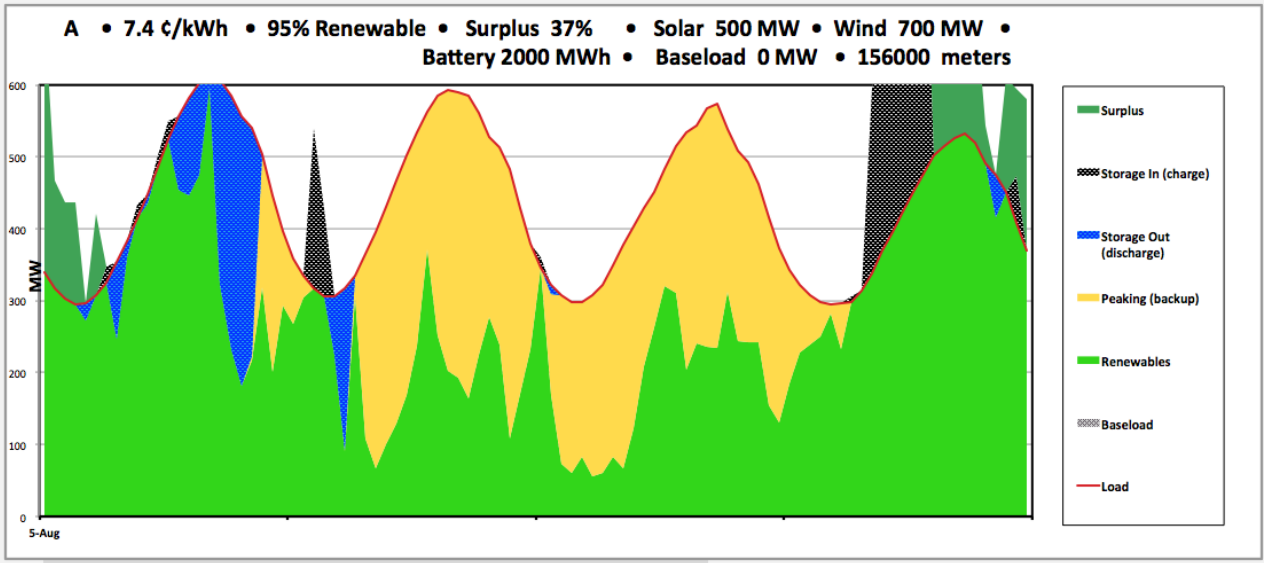
Notes: Most of data from 2016 EIA with analysis by EnergyShouldBe.org The electricity use to electrify transportation is conservative. 10 cents per kWh is the blended cost of Colorado electricity. Divide EIA Table 10 all Colorado revenue by MWh Sales,

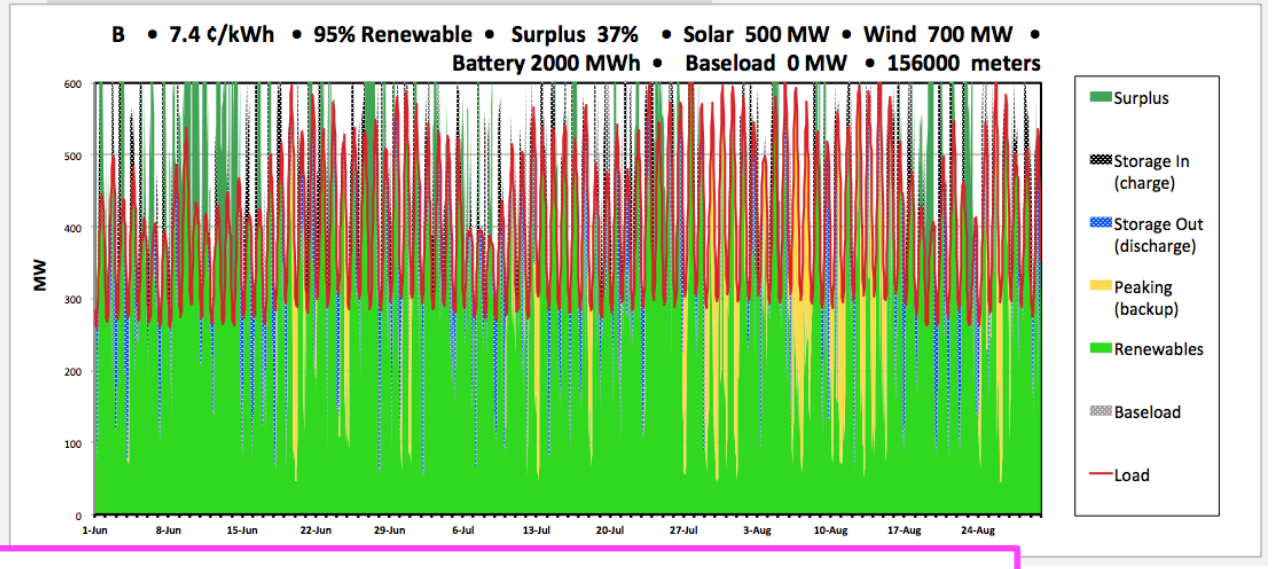
The most speculative number is the electricity to electrify nat. gas use. This is based on using heat pumps with a COP of 3. Air source heat pumps are available now (2019) for Colorado at that COP.

Energy ShouldBe.org

Modeling Electric Grids and Renewables

	A	B	C	D	F
1	*Use this model at your own risk.*	A	B		
2	Meters (use to adjust load up or down)	156,000	156,000	Meters	
4					colorado 2,600,000 meters
5	Battery	2,000	2,000	Storage MWh	17000 MW wind 10100 PV 4 hr 40,000 MWH
7	Hydro	90	90	Hydro MW	wind 1.9 ¢/kWh PV Stor 3.8 ¢/kWh
9	Solar	500	500	Solar MW	PRPA 2018 About
11	Wind	700	700	Wind MW	6.5 ¢/kWh
16		"normal" 500 90 500 700			
18	Annual LOAD	3,201,193	3,201,193	MWh	For A Chart
19	Annual RE GENERATED	4,200,473	4,200,473	MWh	starting day
20	*Renewables Used & Useful When Net Load > 0*				Title Calc 216
21	Annual RE USED	3,028,326	3,028,326	MWh	A • 7.4 ¢/l # of days
22	Annual RE USED	95%	95%		4
23	Annual RE OVER-GENERATED	1,172,147	1,172,147	MWh	
24	Annual RE OVER-GENERATED	37%	37%		PRPA peak avg min
25	Annual HOURS CURTAILED	3846	3846	Hours	630 370 270
26	Peak (max of load minus renewables)	449	449	MW	388 MW nat gas
27	Annual Backup Gen. (Peaker) Usage	202818	202818	MWh	Use of Peak Annual
28	Minimum (load minus renewables)	-906	-906	MW	PRPA about 6% of whole state
29	Energy Withdrawn From Storage	269,556	269,556	MWh	so 16 times PRPA
30	BASELOAD Generation	0	0	MW Baseload	135
31	Annual LOAD	3,201,193	3,201,193	MWh	storage utilization
32	Annual BASELOAD	0	0	MWh	
33	Net Annual LOAD - BASELOAD	3,201,193	3,201,193	MWh	
34	Annual RE GENERATED	4,200,473	4,200,473	MWh	
35	*Renewables Used & Useful When Net Load > baseload (assumes baseload is "must take")*				
36	Annual RE USED	3,028,326	3,028,326	MWh	For B Chart
37	Annual RE USED	95%	95%	%	If blank, default to above.
38	Annual RE OVER-GENERATED	1,172,147	1,172,147	MWh	starting day
39	Annual RE OVER-GENERATED	37%	37%	%	Title Calc 151
40	Annual HOURS CURTAILED	3846	3846	HOURS	B • 7.4 ¢/l # of days
41	Simple Cost Model				90
42	Hydro (wght avg of WAPA CRSP & LAP	$0.028	$0.028	$/kWh (PPA)	
43	Solar (from Xcel 2017 PPAs)	$0.023	$0.023	$/kWh (PPA)	
44	Wind (From Xcel 2017 PPAs)	$0.015	$0.015	$/kWh (PPA)	
45	Battery (upfront cost)	$0.125	$0.125	M$/MWh (upfront cost)	
46					
47	Interest Rate	3.5%	3.5%	%	
48	Term	20	20	years	
49	Sell Excess Overgeneration at	$0.010	$0.010	$/kWh	
50	Annual Operating Expense	$125	$125	M$	
51	Cost of baseload & peaking power	$0.015	$0.015	$/kWh	
52	Loans	$224	$224	M$	
53	Transmission (all kWh. Assumes no local generation)	$0.003	$0.003	$/kWh	
54	$/kWh blended (no separate rates residential, comn	$0.074	$0.074	$/kWh	





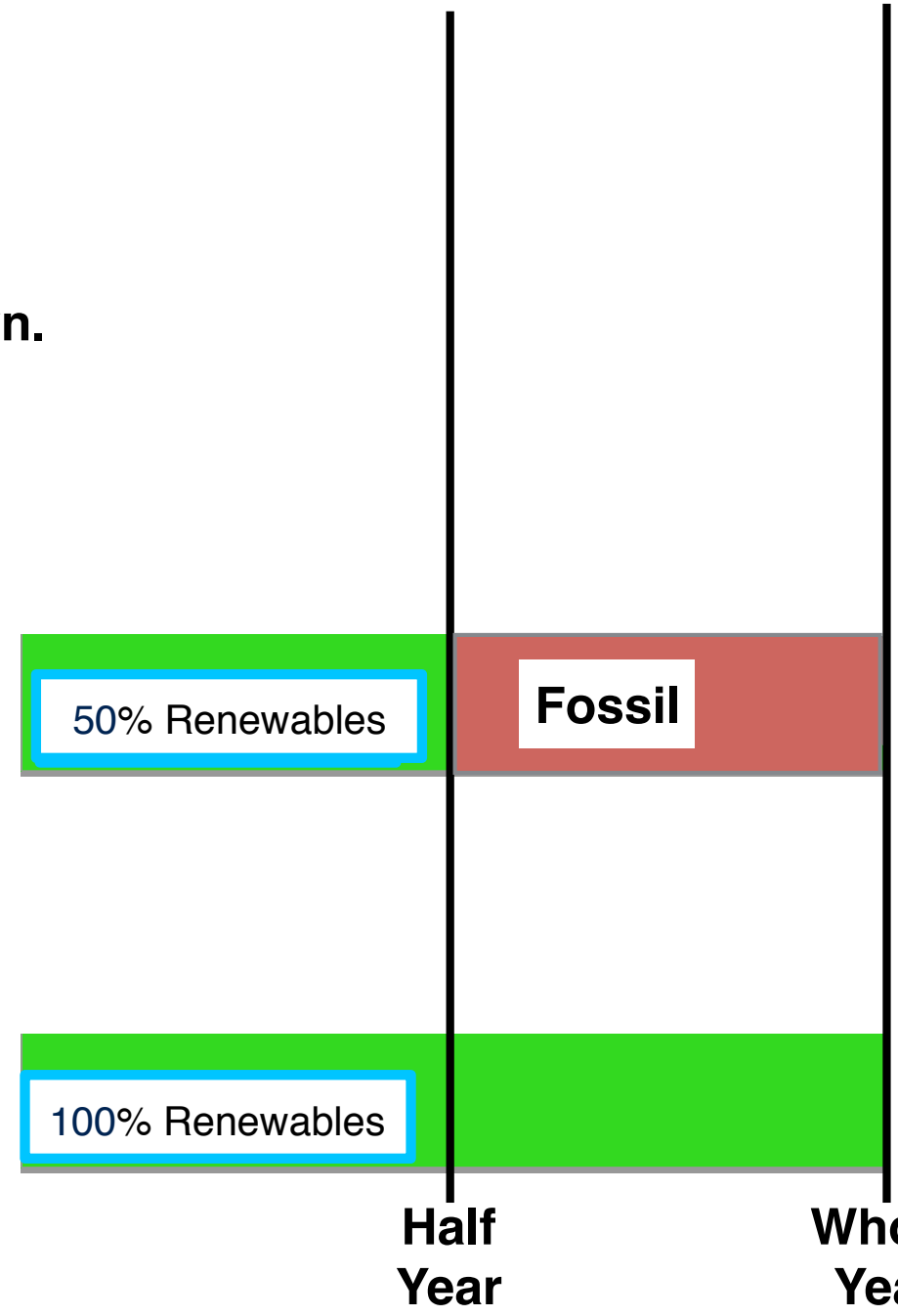
Models don't predict THE FUTURE.

They SUGGEST POSSIBLE FUTURES based on assumptions.

How Many Hours of Year Renewables Meet Load

Simplified view.

Every hour of the year is shown.



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The Cost, Use, and Generation Data Came From…

Xcel Colorado

Platte River Power Authority - PRPA

EIA (DOE)

Platte River Power Authority

Estes Park • Fort Collins • Longmont • Loveland

Compare For and Non-Profit Self-Generators. Colorado.

	Long Term Goal	50% Renewable	100%	% Colorado Served Retail	Blended Rate (cents/kWh)
PRPA non-profit	**100% non-carbon**	**2020**	**2030**	**6%**	**8.0**
Xcel for profit	**100% reduction in carbon dioxide**	**2023**	**2050**	**54%**	**9.5**
Tri-State non-profit	(none)	?		**15%**	**11.0**
Colorado Springs Muni non-profit	(none)	?		**9%**	**9.2**
IREA non-profit	(none)	?		**6%**	**12.4**
Black Hills for profit	(none)	?		**4%**	**12.8**

Lowest Rates in CO. Excellent Reliability.

If Xcel charged PRPA's rates we would save About

$400

Million per year on electricity.

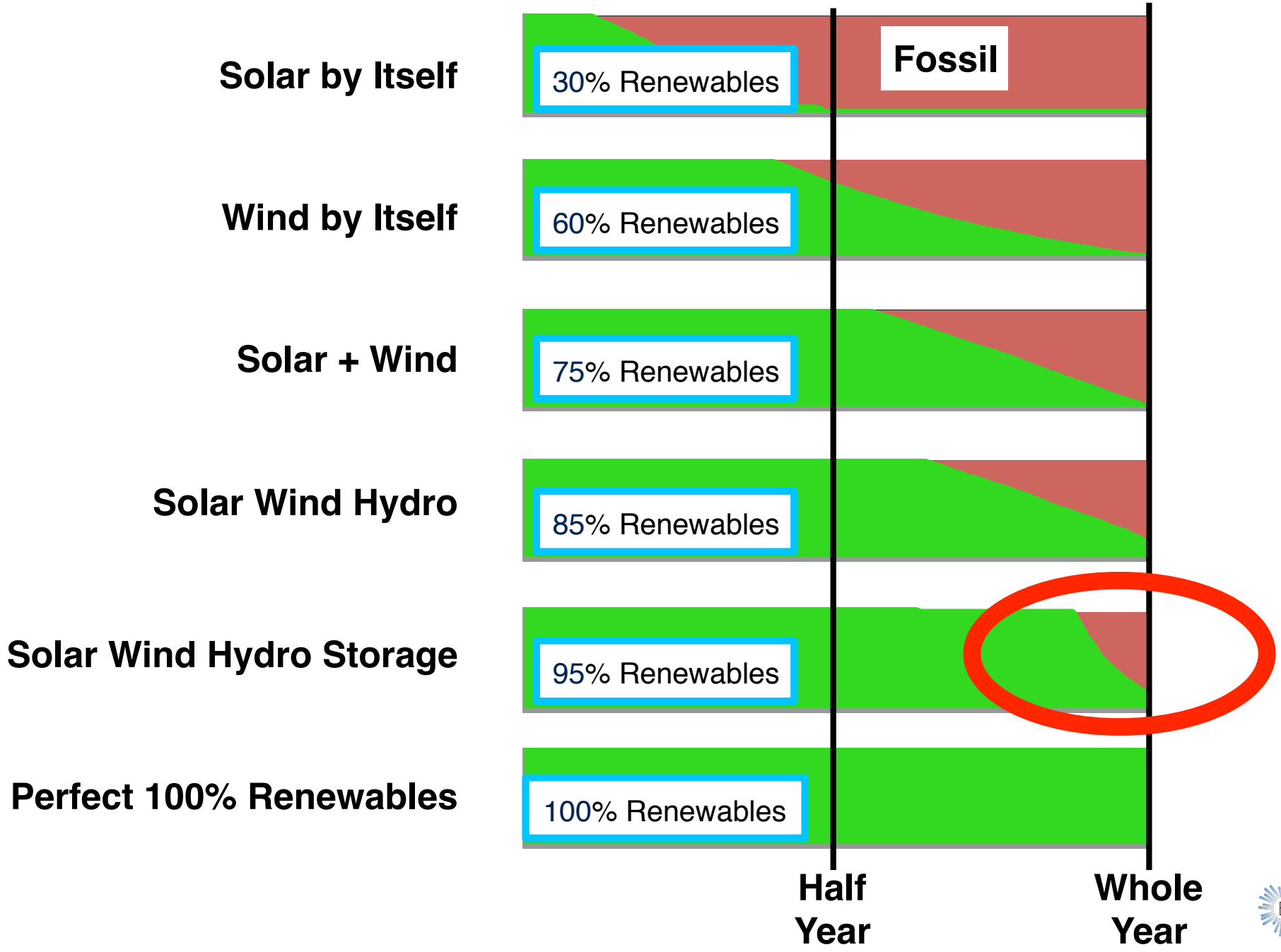
Bigger is not better.

Source: EIA Table 10 2015 retail sales by utility. Blended rate for Tri-State and PRPA are a weighted average for Colorado retail utilities by MWh sales. % Colorado served is by number of customers (meters). Number of customers turns out to track well with MWh sales. "?" means data not available.


Reliable,
Cheap,
100% Renewables by 2030
Image: pixabay.com

How Many Hours of Year Renewables Meet Load

Reliable Cheap
100%

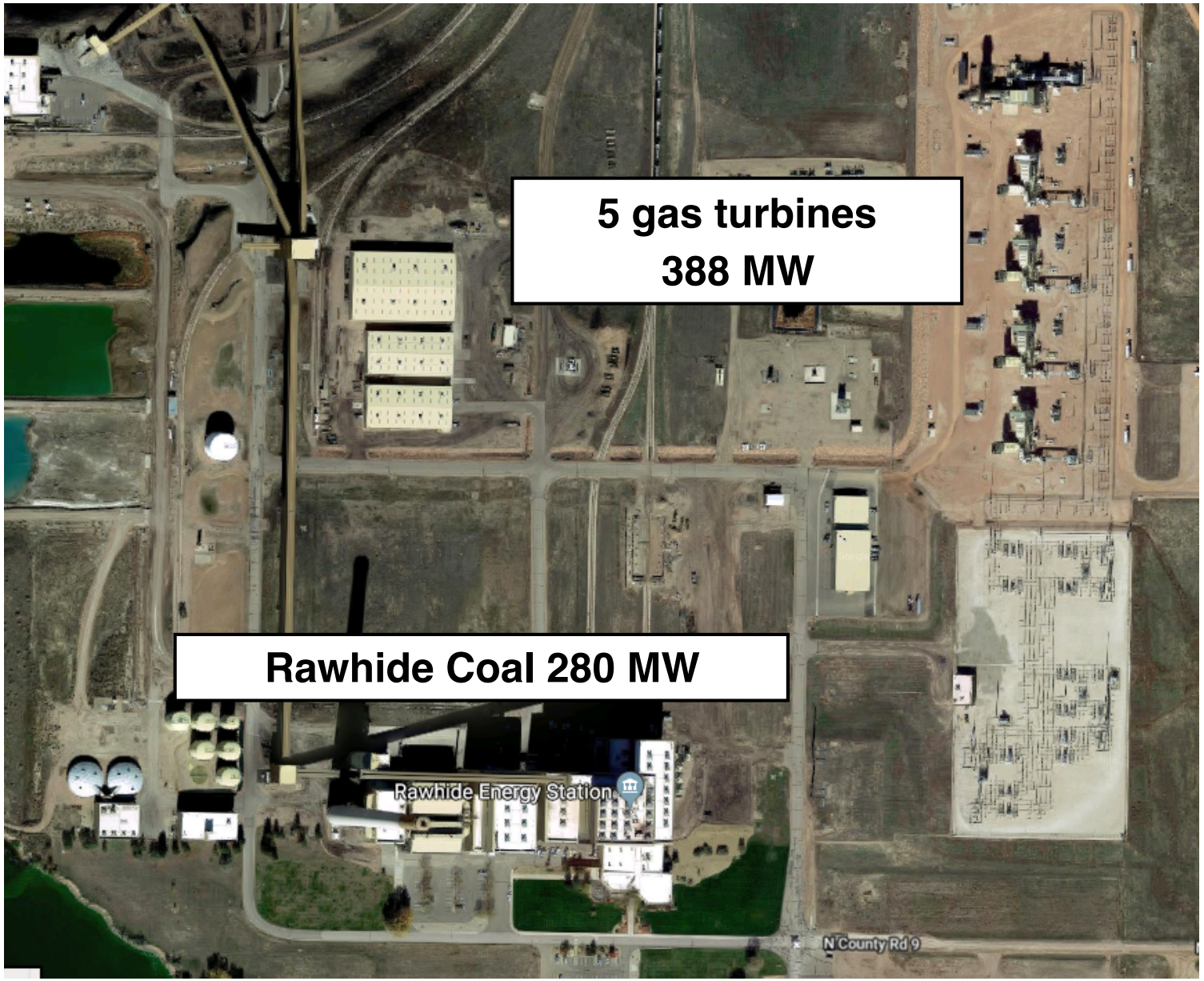


Energy ShouldBe.org

Filling in With Gas

95% Renewable Hourly.

PRPA's Rawhide Station

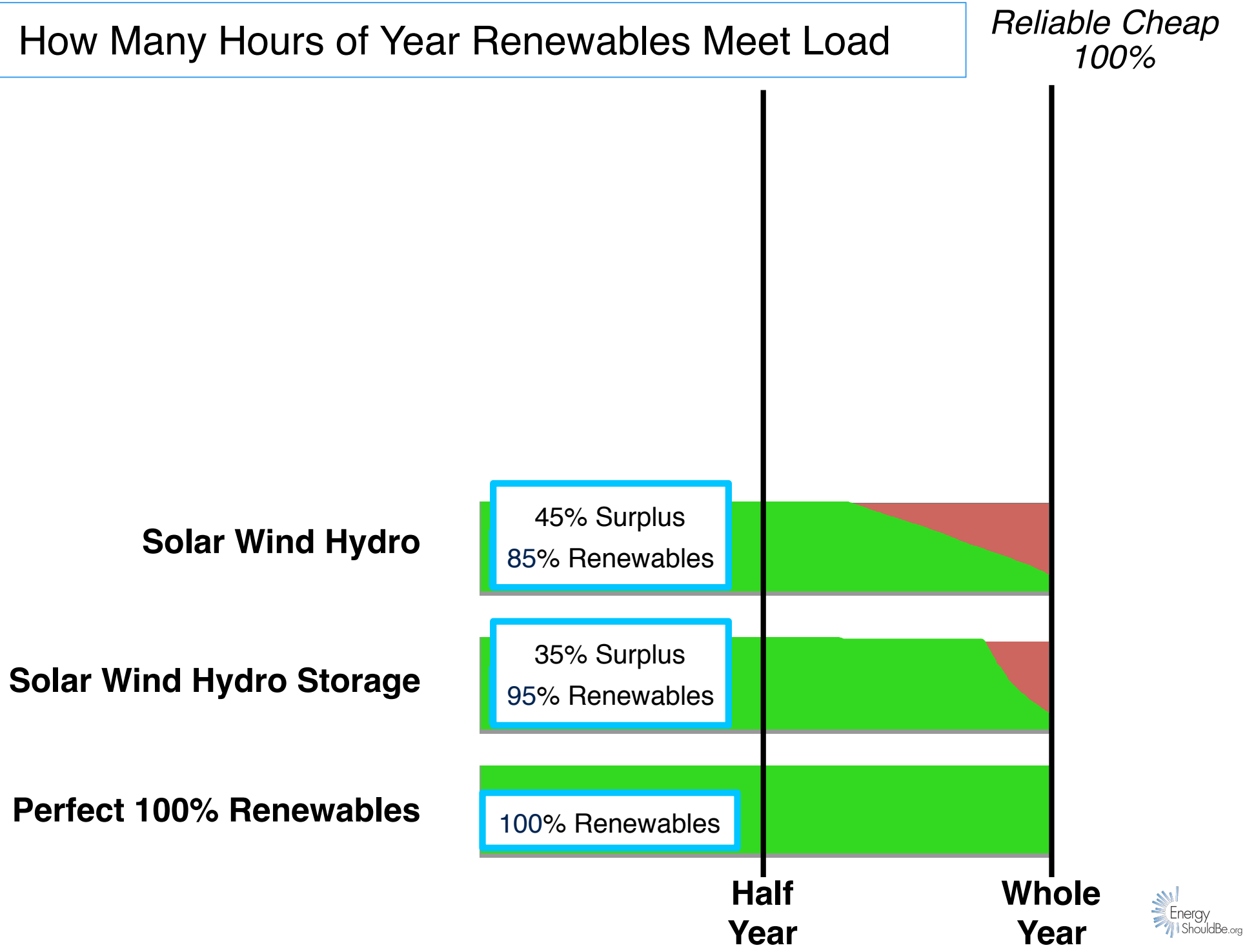


Craig
Coal 154 MW

Image: Google Satellite View

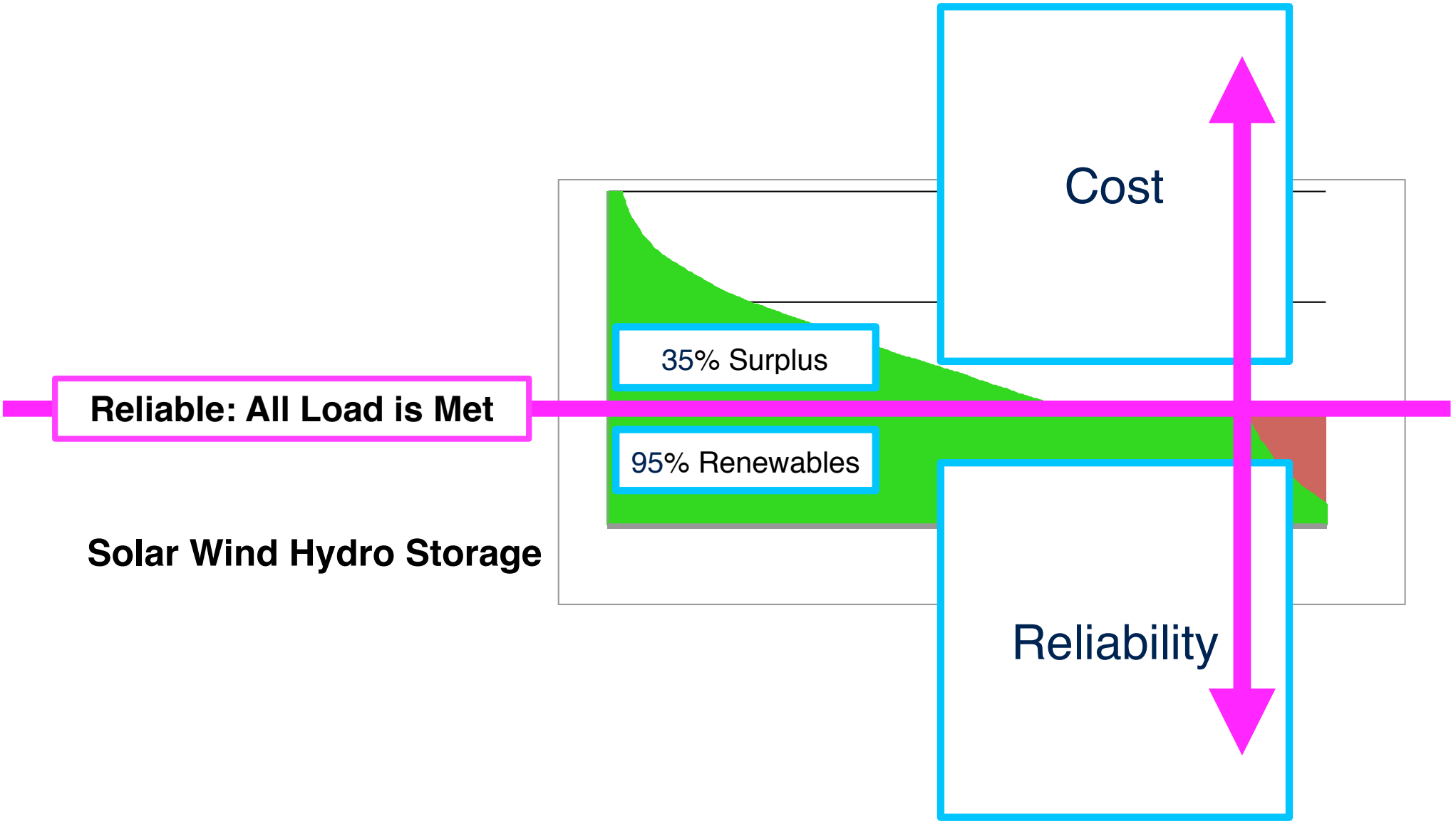
Image: pixabay.com

How Many Hours of Year Renewables Meet Load



How Many Hours of Year Renewables Meet Load

Reliable Cheap 100%

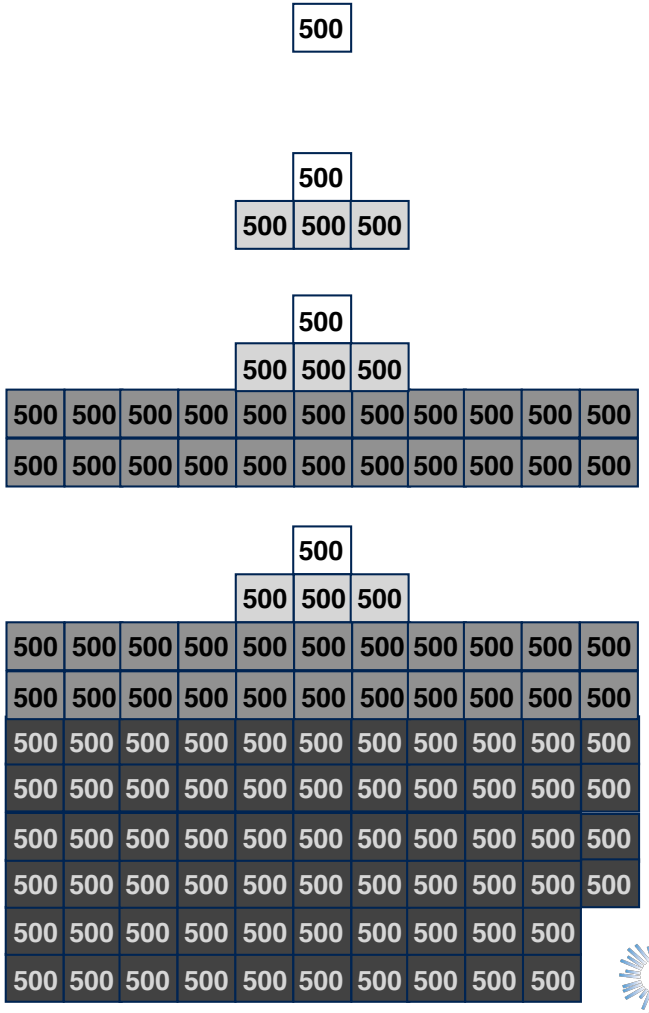


A modified load duration chart. Load is shown as a percentage.
The big horizontal purple line is 100%.
Note the long flat section of the curve is caused by use of storage.

Short Term Storage Utilization

Reliable Cheap 100%

	Renewable %	Surplus %	Storage (MWh)	Storage used (annual discharge / total storage) (times per year)
Solar Wind Hydro	**85%**	**45%**	**0**	**n/a**
Solar Wind Hydro Small Storage	**90%**	**40%**	**500**	**266**
Solar Wind Hydro Storage	**95%**	**35%**	**2,000**	**135**
Solar Wind Hydro Big Storage	**99%**	**31%**	**13,000**	**32**
Solar Wind Hydro Ginormous Storage	**100%**	**30%**	**47,000**	**10**



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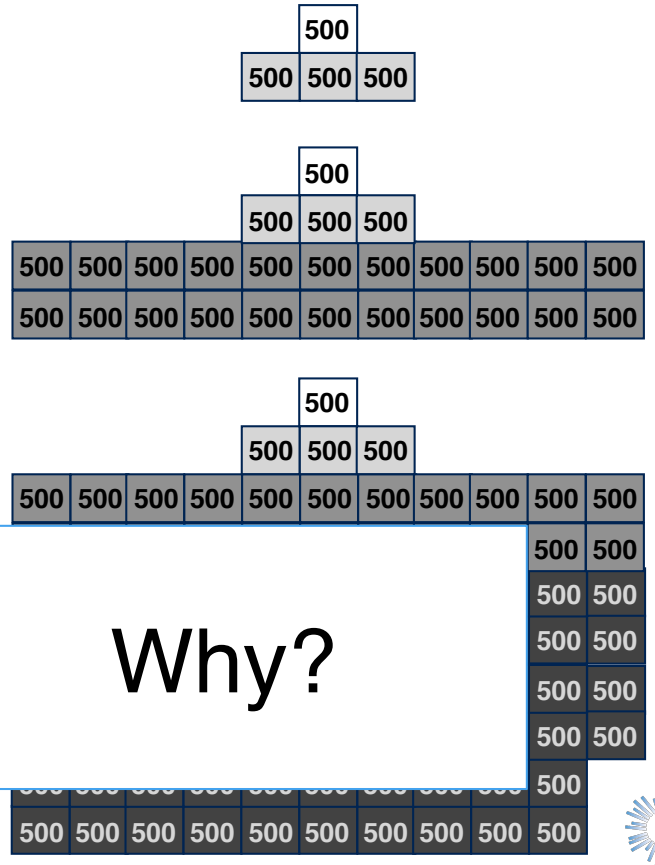
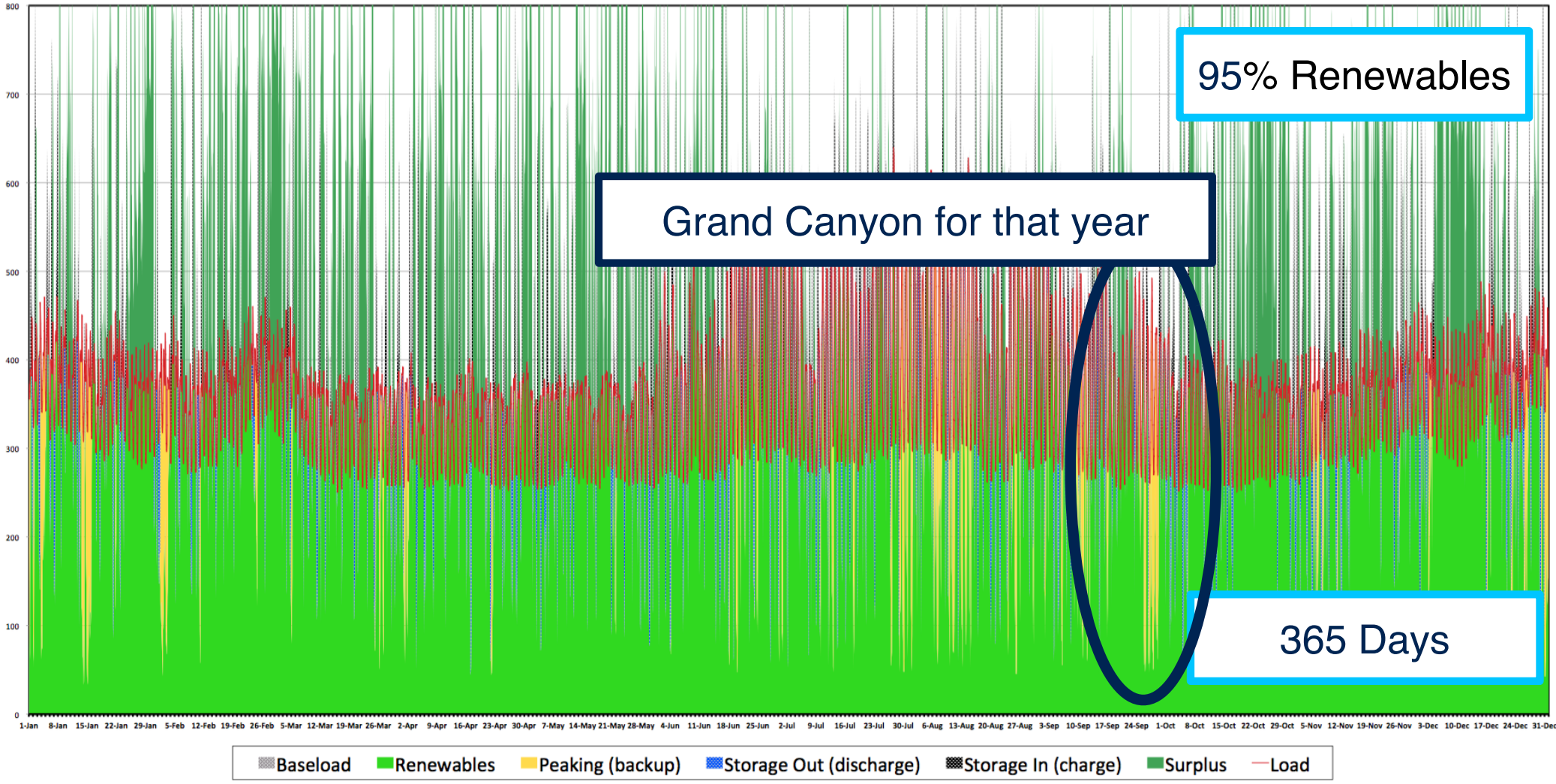


Why?

Solar Wind Hydro & Storage

Reliable Cheap
100%



Short Term Storage Utilization

Reliable Cheap 100%

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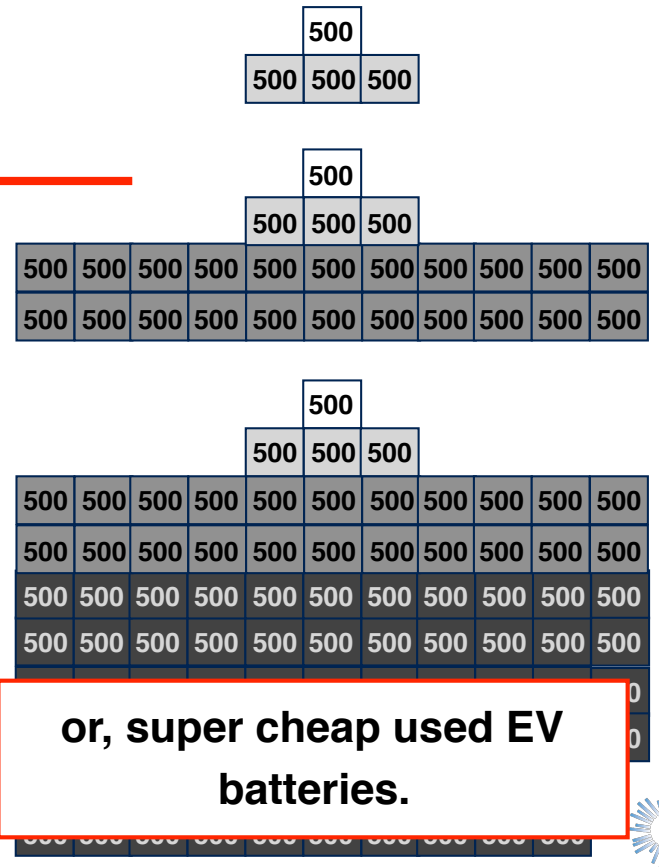
Sweet spot?



Long Term Storage?

Surplus Electricity to "natural" gas or liquid fuel?

or, super cheap used EV batteries.

Energy ShouldBe.org

Long Term Storage

Reliable Cheap
100%

Low capital

Use surplus

Make a Fuel?

PRPA's Rawhide Station

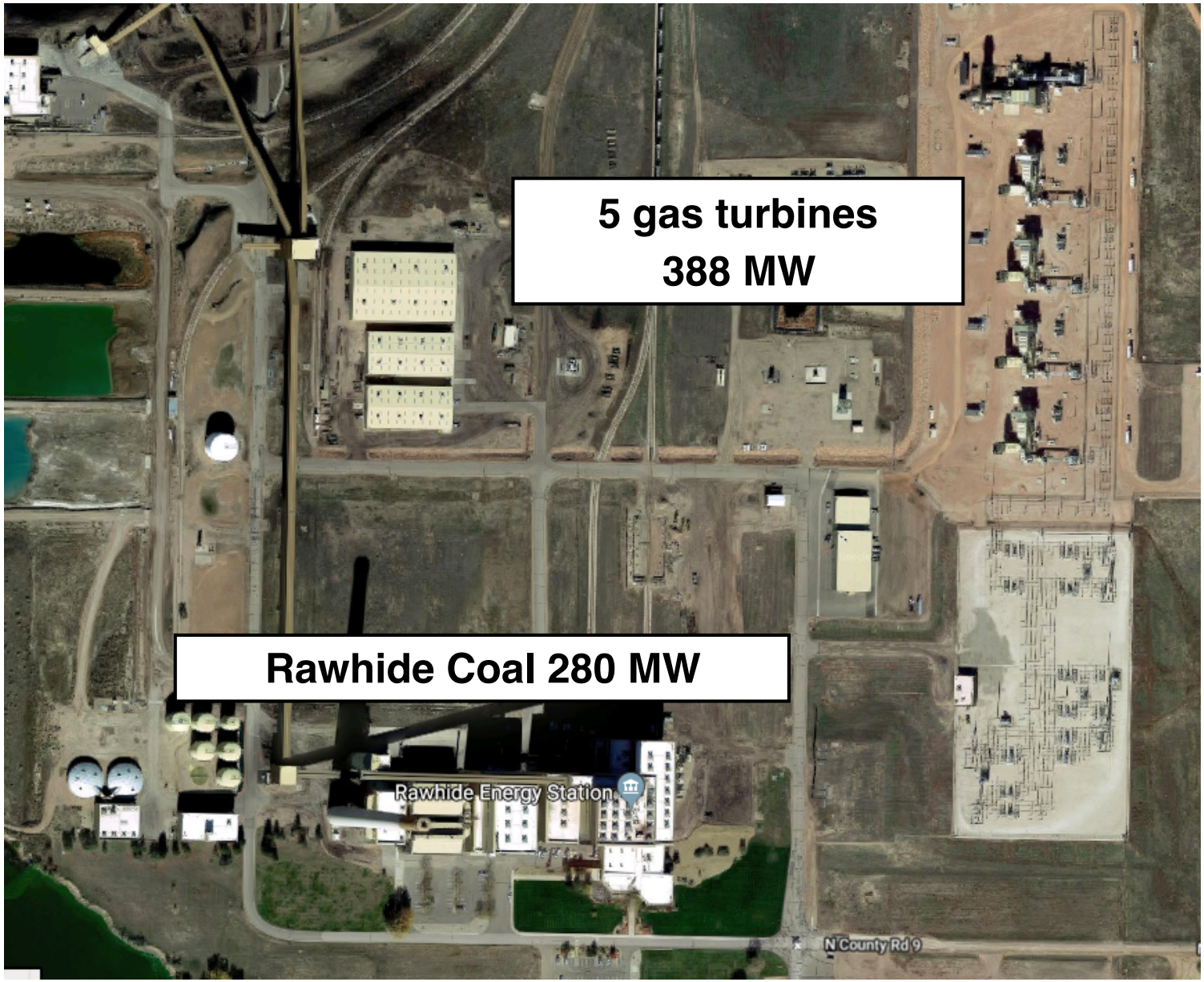


Image: Google Satellite View

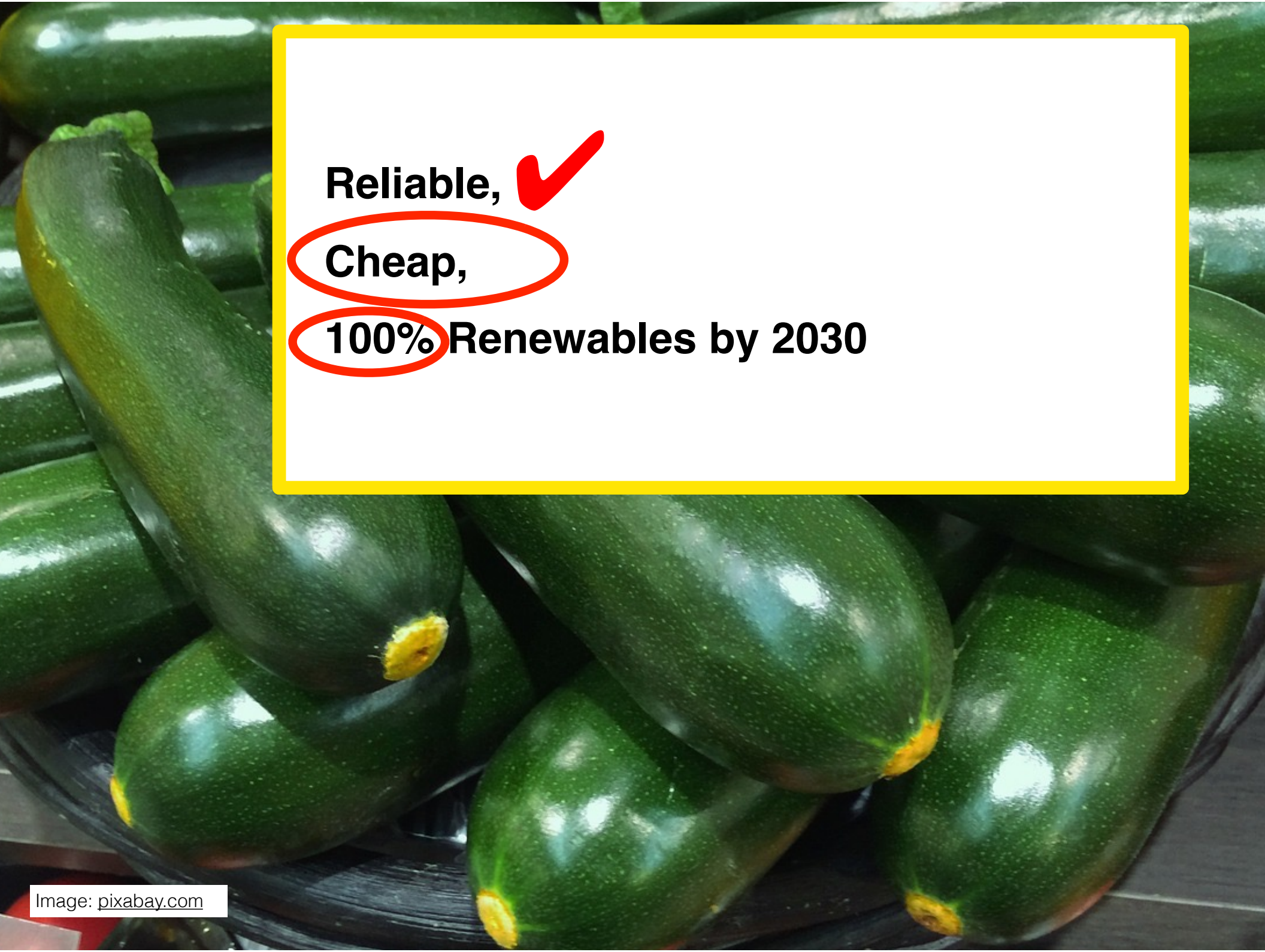


Image: pixabay.com

"The (plan) includes **unprecedented** low pricing across a range of generation technologies including wind at levelized pricing between $**11**-**18**/MWh, solar between $**23**-$**27**/MWh, solar with storage between $**30**-$**32**/MWh…"

- Xcel

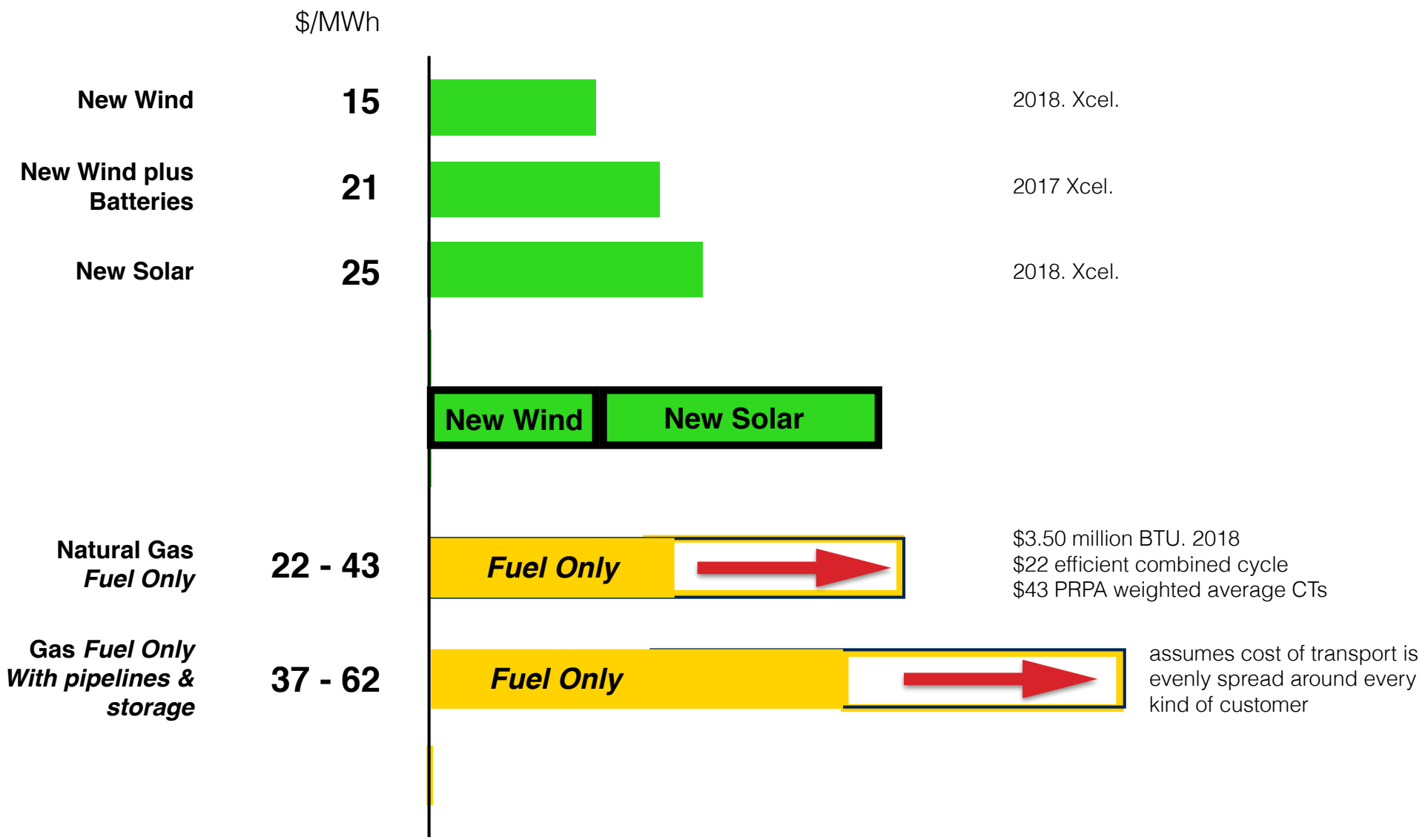
In 2022, Xcel Colorado 55% Renewables

Left 95% of bids on the table.

Xcel Energy (bottom P 51) https://www.documentcloud.org/documents/4546891-Xcel-Energy-Electric-Resource-Plan-120-Day-Report.html

What are the Cheapest Sources of Electricity in Colorado?

Reliable Cheap 100%



2019 Study: Replacing All Colorado coal plants with wind, solar & storage saves $2.5 Billion.
https://www.communityenergyinc.com/press

Guzman offers to buy and close Craig and Trapper mine, and replace with 70% renewables at lower costs.
https://energynews.us/2019/05/28/west/a-small-company-sees-opportunity-in-revolutionizing-colorados-energy-supply/

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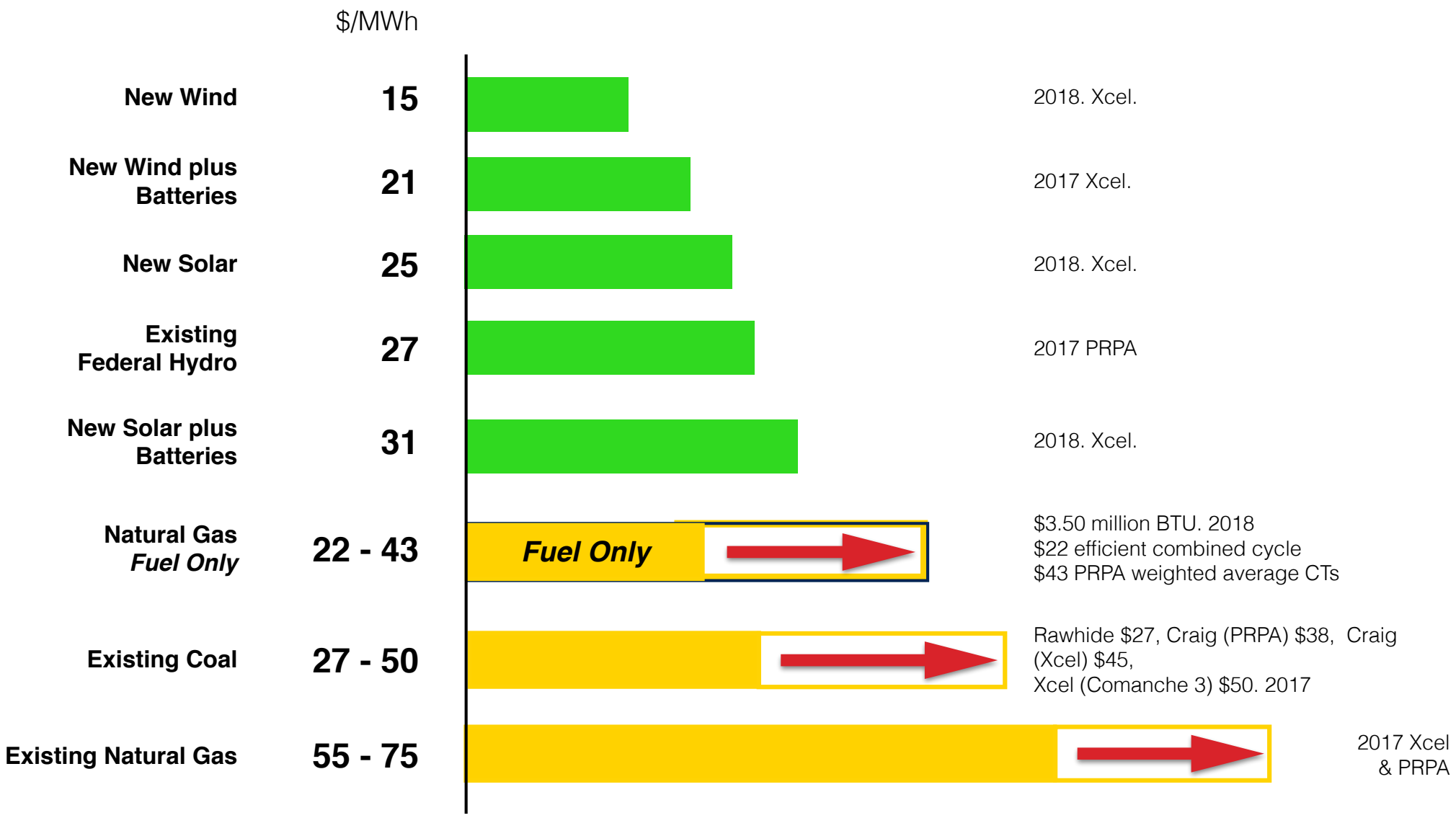

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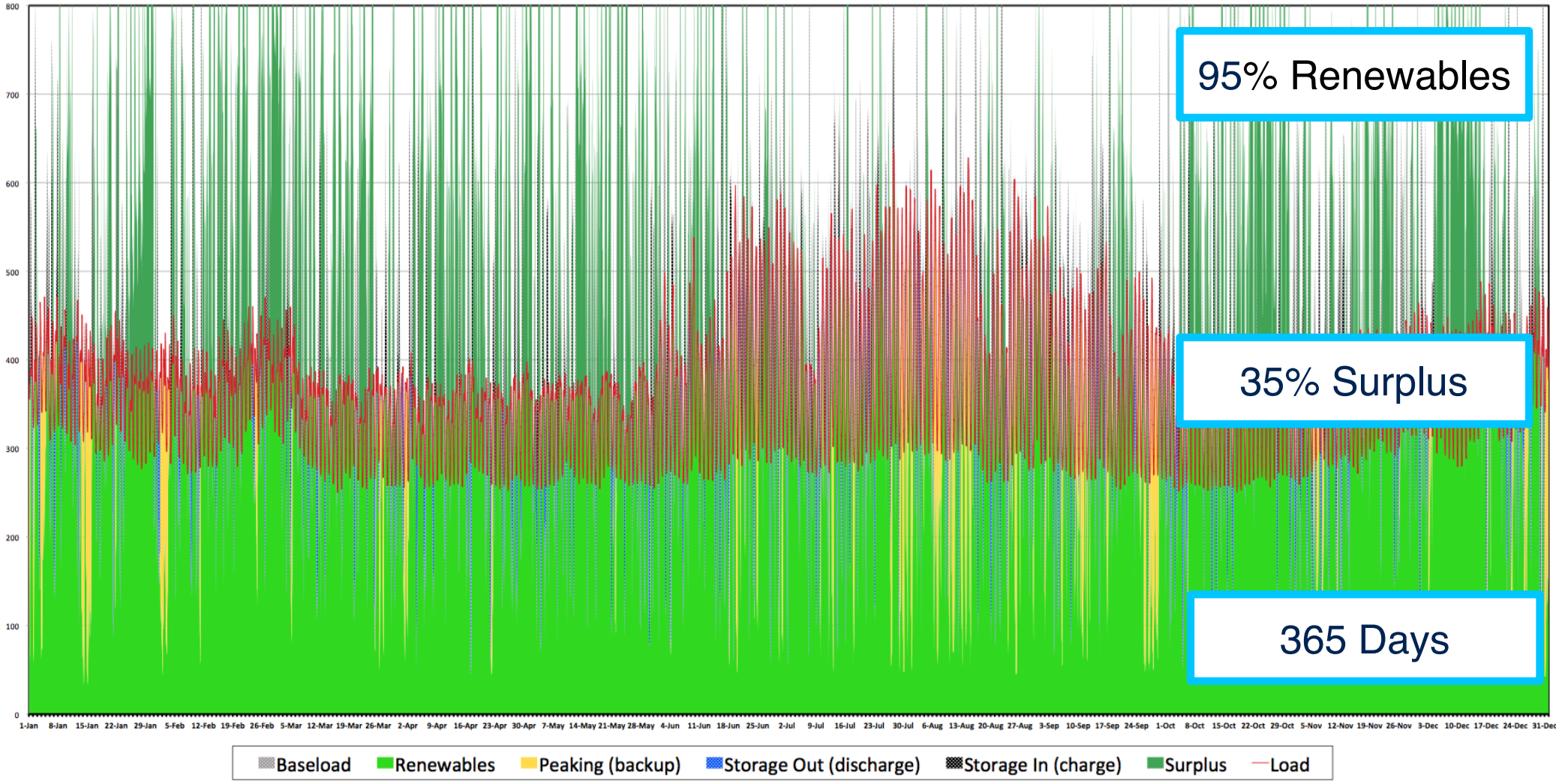
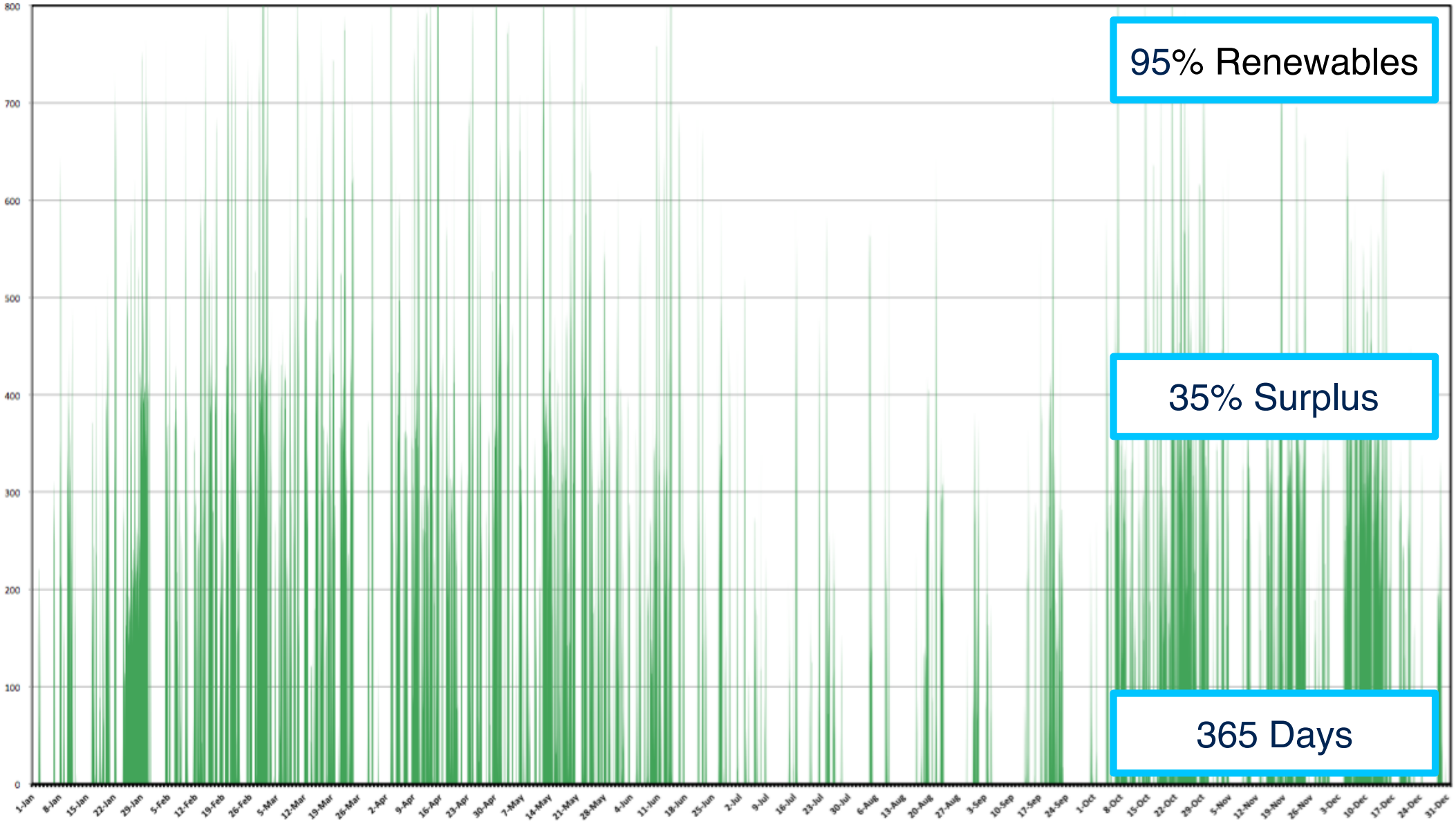
Solar Wind Hydro & Storage

Reliable Cheap
100%



Just the Surplus Electricity

Reliable Cheap
100%



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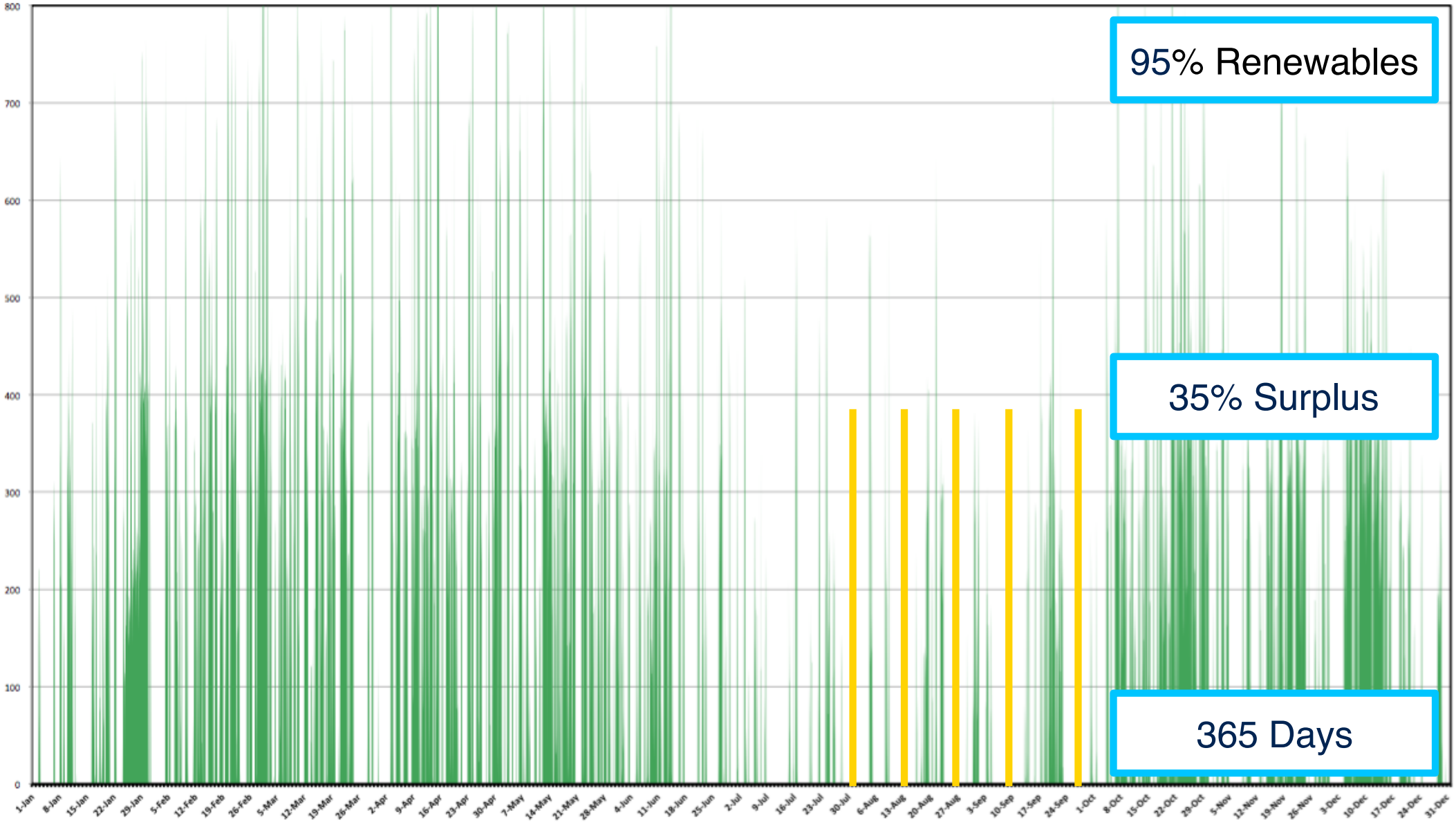
Using Natural Gas to Fill in a Small Amount Makes Selling Surplus Easier

Reliable *Cheap*
100%



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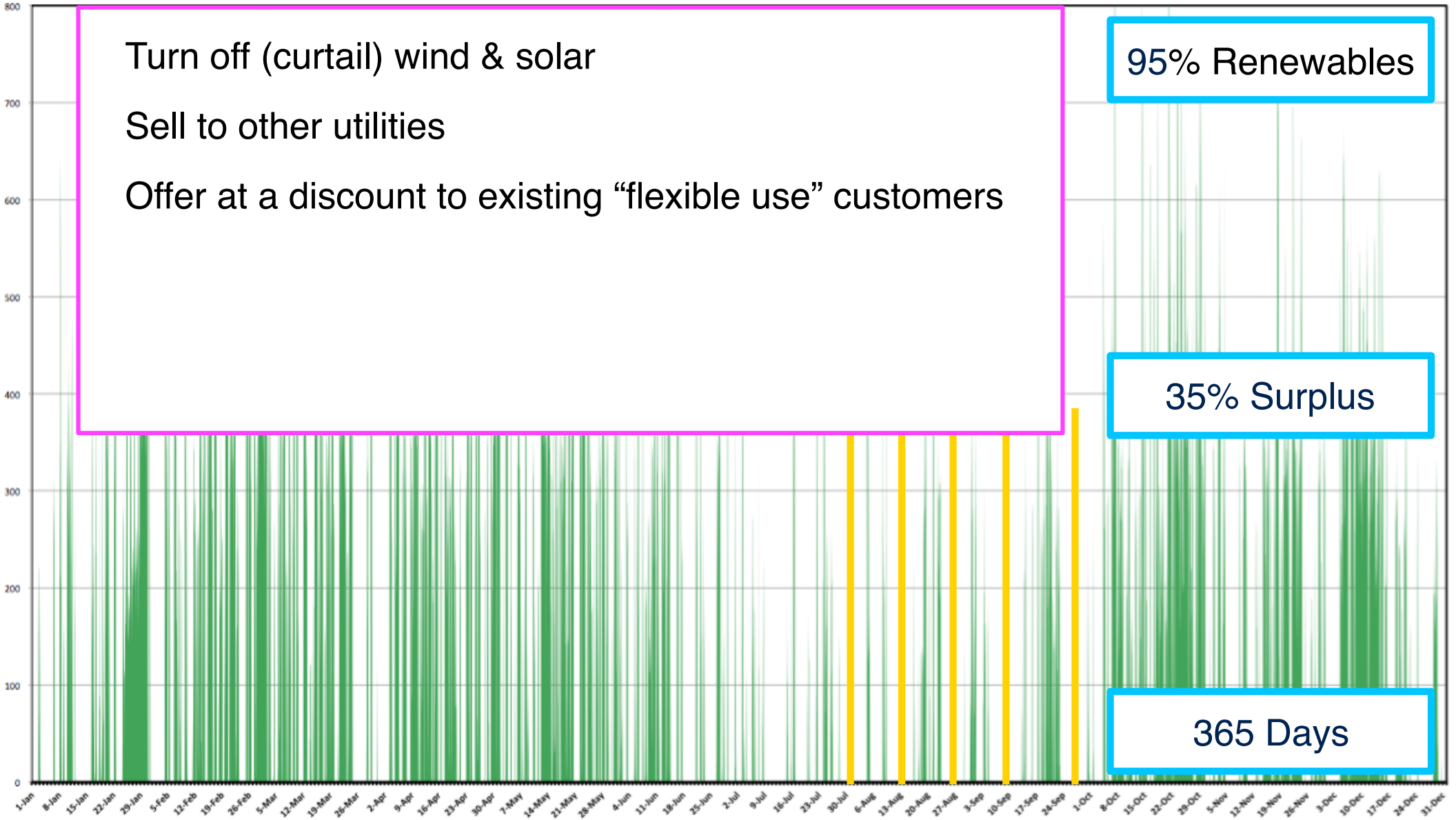
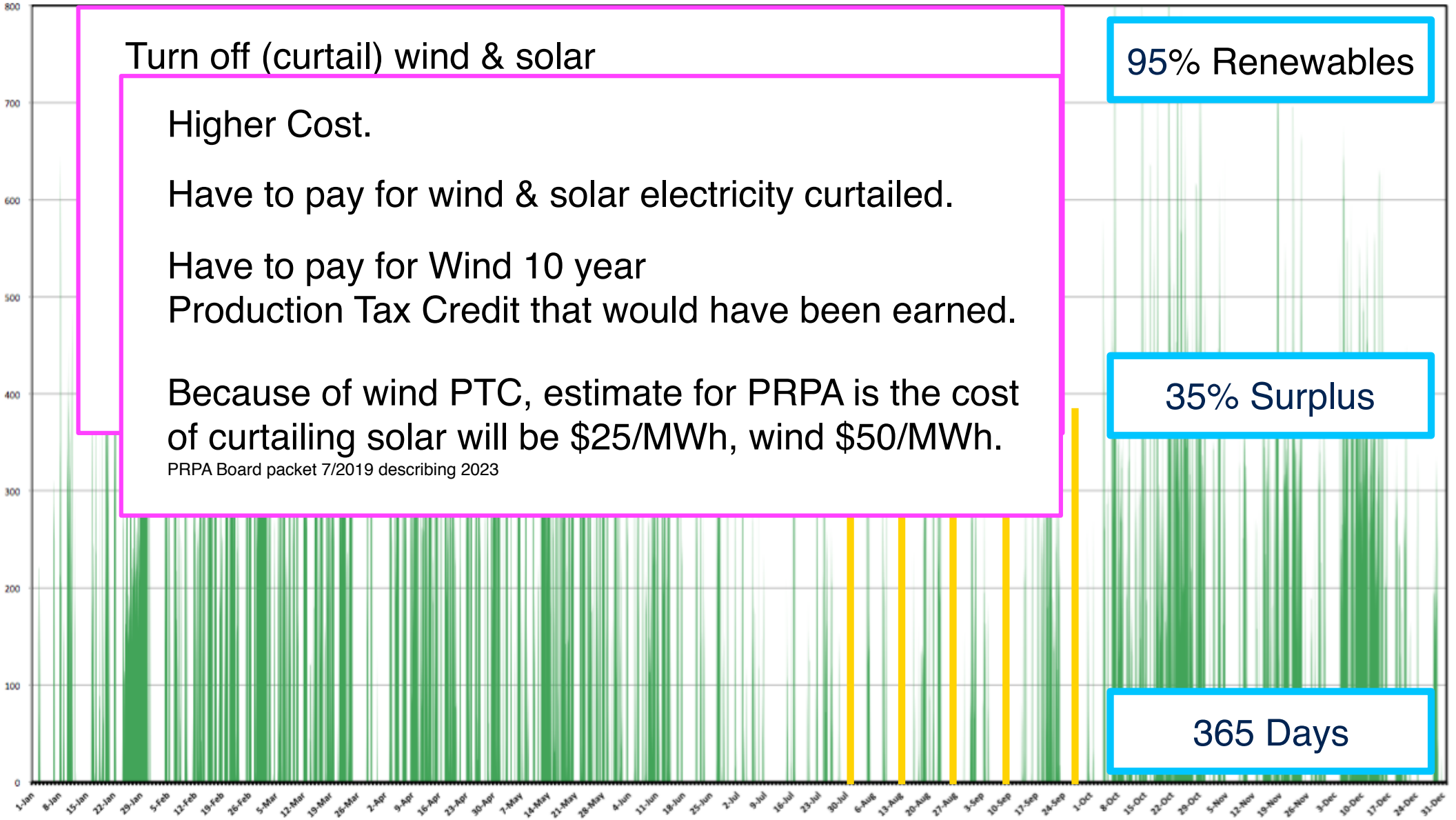
Just the Surplus

Reliable ***Cheap***
100%



Just the Surplus

Reliable Cheap
100%



Turn off (curtail) wind & solar

Higher Cost.

Have to pay for wind & solar electricity curtailed.

Have to pay for Wind 10 year
Production Tax Credit that would have been earned.

Because of wind PTC, estimate for PRPA is the cost of curtailing solar will be $25/MWh, wind $50/MWh.

PRPA Board packet 7/2019 describing 2023

95% Renewables

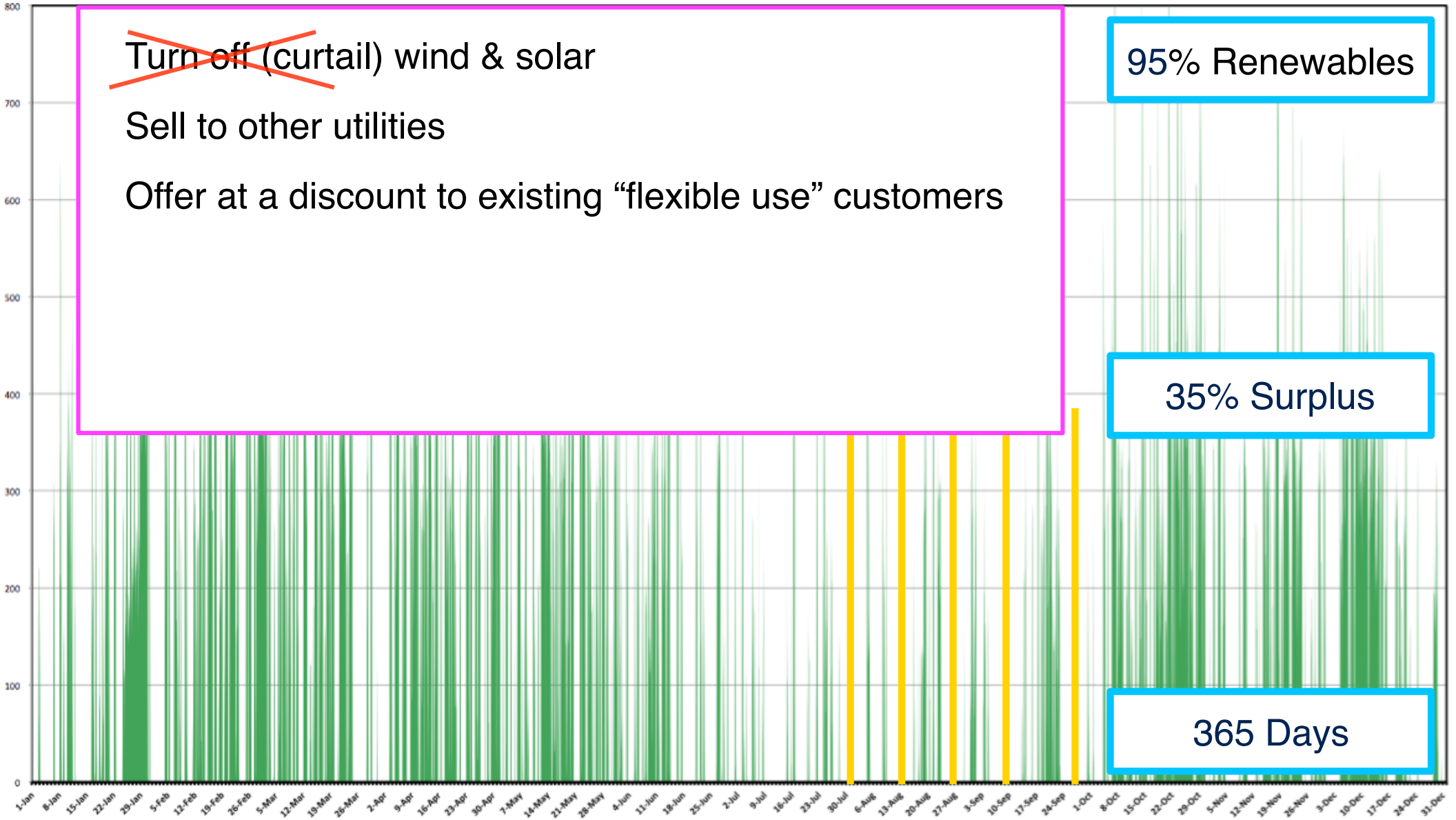
35% Surplus

365 Days

Energy ShouldBe.org

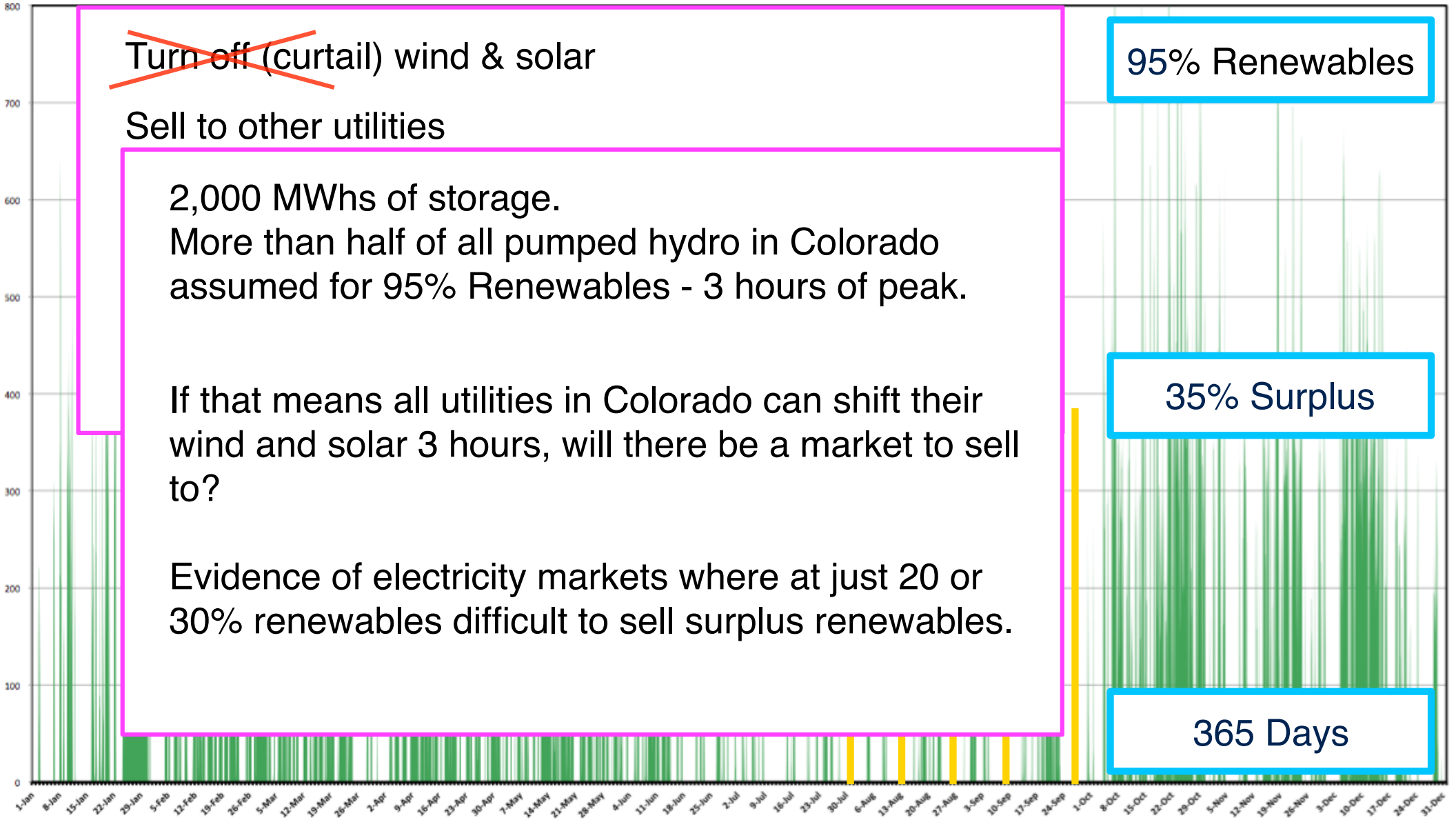
Just the Surplus

Reliable Cheap 100%



Just the Surplus

Reliable Cheap
100%



~~Turn off (curtail)~~ wind & solar

Sell to other utilities

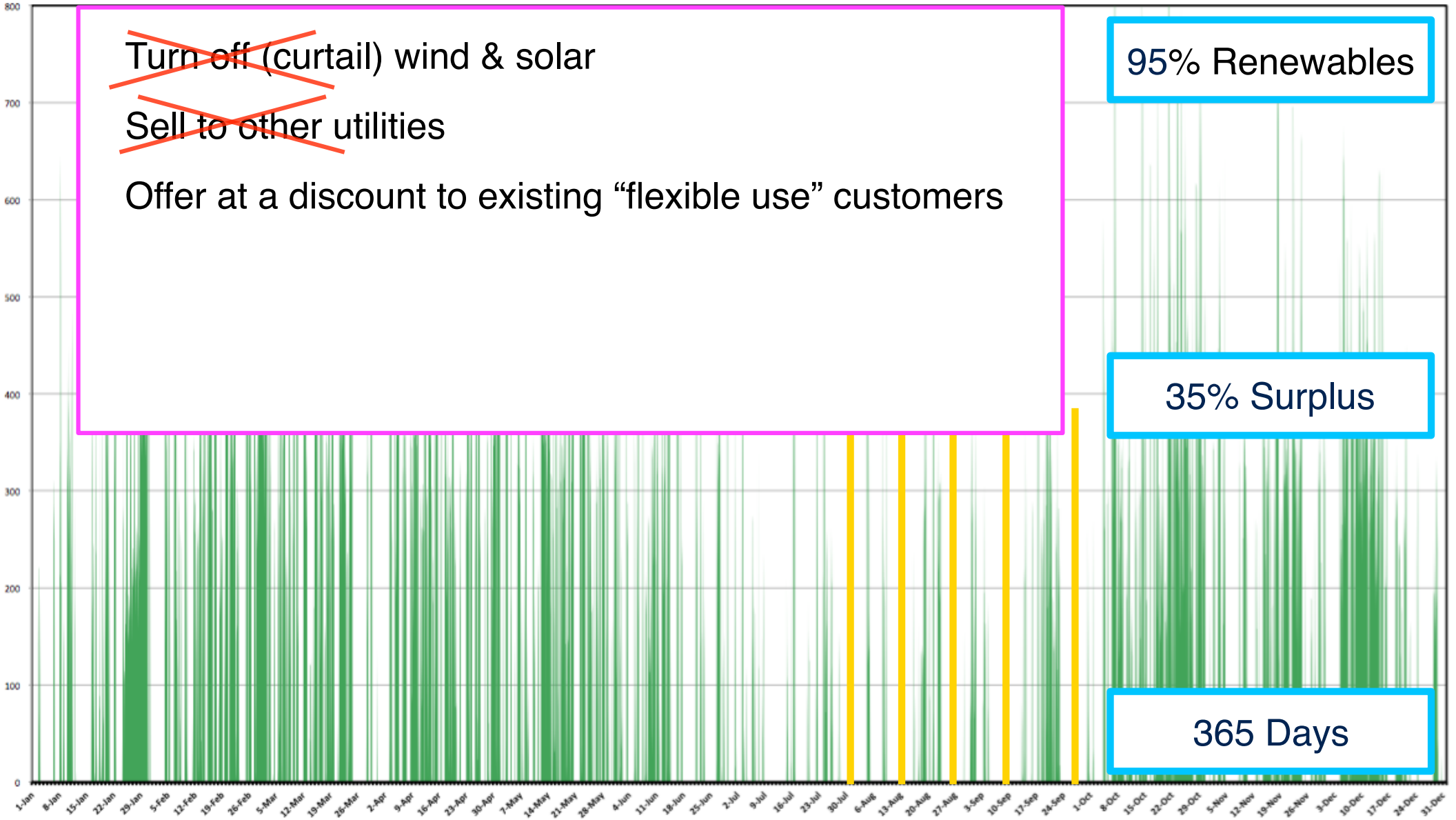
2,000 MWhs of storage.
More than half of all pumped hydro in Colorado assumed for 95% Renewables - 3 hours of peak.

If that means all utilities in Colorado can shift their wind and solar 3 hours, will there be a market to sell to?

Evidence of electricity markets where at just 20 or 30% renewables difficult to sell surplus renewables.

Just the Surplus

Reliable Cheap 100%



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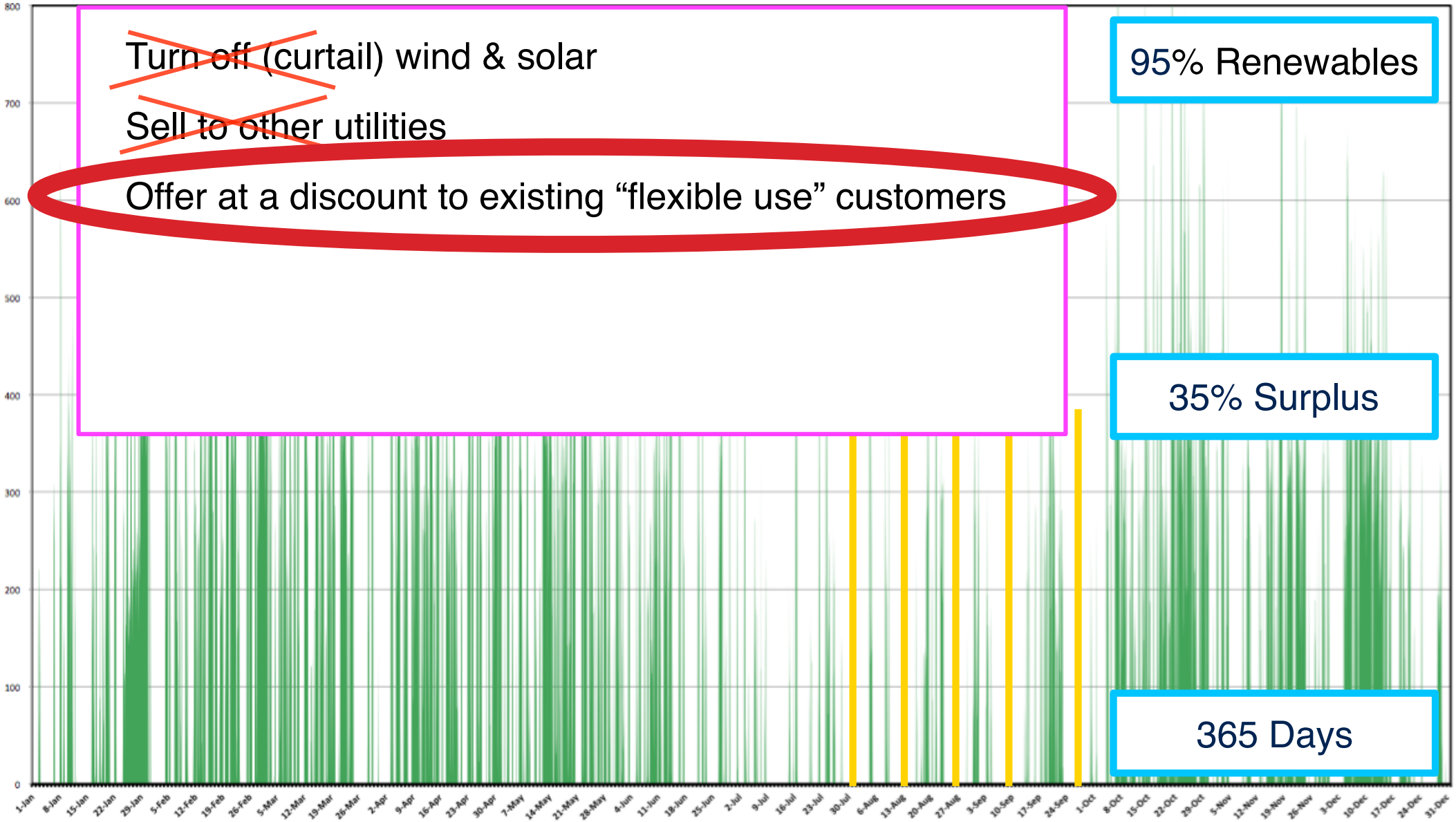


Show of hands

How much did you pay per gallon or equivalent?

- ☐ About $2.29
- ☑ $1.00
- ☐ $0.20

Show of hands

How much did you pay per gallon or equivalent?

- ☐ About $2.29
- ☑ $1.00
- ☑ $0.20

Offer really cheap electricity when there is surplus - the sun shining/wind blowing.

Show of hands

Do EV chargers exist today that allow charging when the sun is shining or wind blowing?


Yes

☐ No

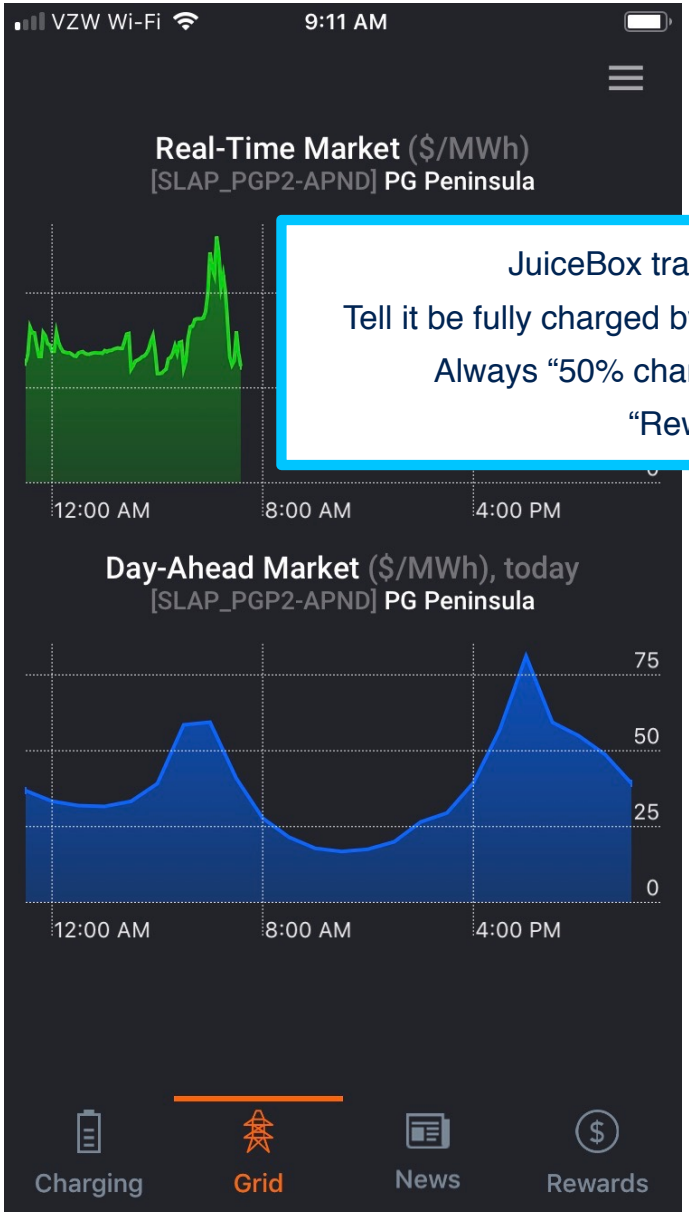
Ken's New Charger

Reliable *Cheap*
100%

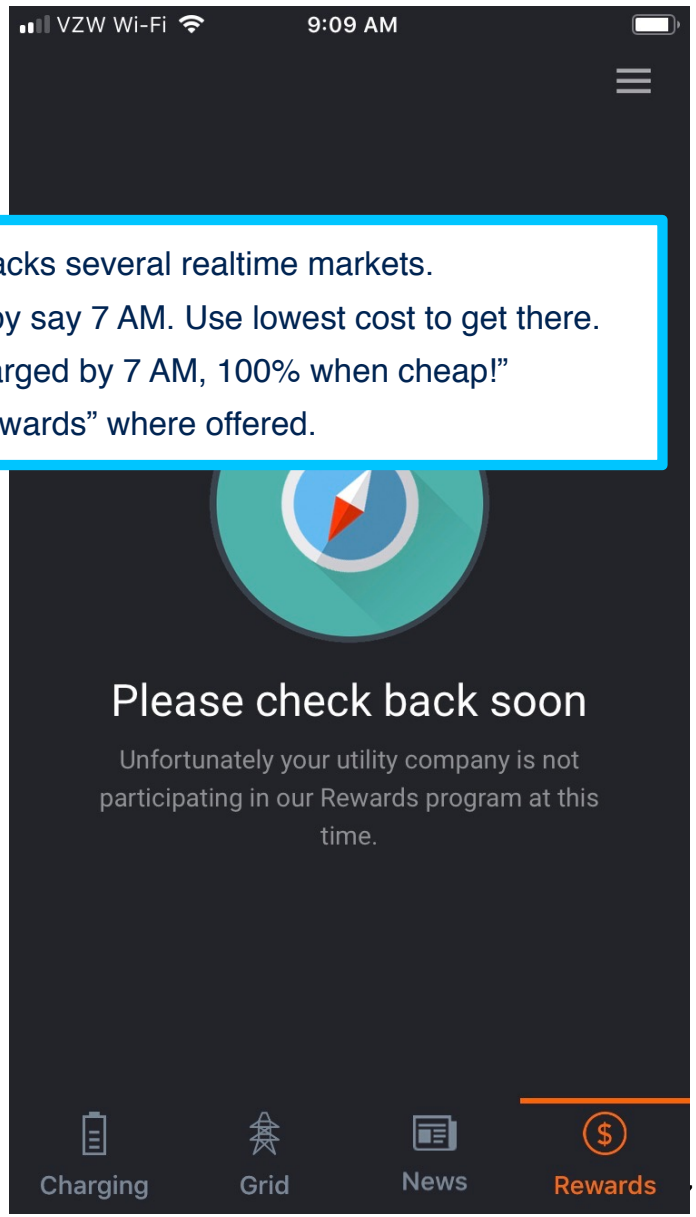
Ken's New Charger & App

Reliable *Cheap*
100%

Grid



Rewards



JuiceBox tracks several realtime markets.

Tell it be fully charged by say 7 AM. Use lowest cost to get there.

Always "50% charged by 7 AM, 100% when cheap!"

"Rewards" where offered.

PRPA EV Charger ***Rebates***

Reliable *Cheap*
100%

Platte River Power Authority

Estes Park • Fort Collins • Longmont • Loveland

Electric vehicle distributed charging study

Photo credit: eMotorWerks

Of the light-duty vehicles registered in Platte River's service territory, 0.4 percent are EVs, nearly twice the Colorado state average, according to the 2018 City of Fort Collins' EV Readiness Roadmap. Ultimately, EV energy usage could reach 60 GWh per year by 2026, and peak demand for EV charging may be as much as 99 MW (assuming all vehicles are charged simultaneously).[1]

Why are we conducting this study?

To better understand the effect of clustered EV adoption on the distribution system, Platte River is conducting an EV distributed charging study to evaluate vehicle energy consumption patterns and test smart charging technology. The study will be the first large-scale residential smart EV charging initiative in Colorado, serving Platte River's owner communities of Estes Park, Fort Collins, Longmont and Loveland. Data collection and analysis from up to 300 charging load monitoring and control devices will focus on:

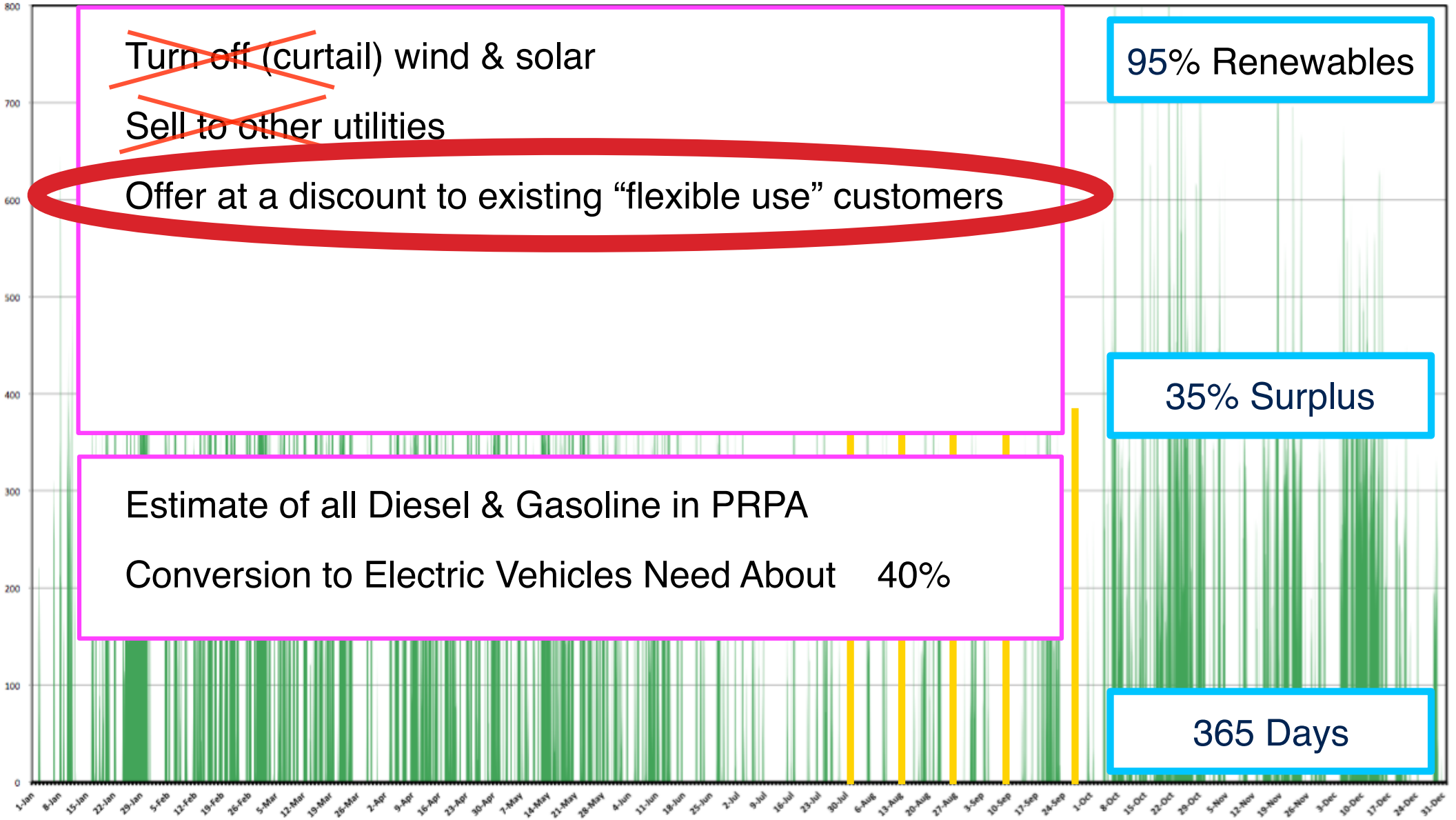
What's in it for study participants?

Platte River is offering a $200 rebate on smart Level 2 chargers through the Efficiency Works Store. The first 100 people to purchase a JuiceBox Pro 40 plug-in charging station will receive an additional $154 instant manufacturer's rebate, discounting the smart device by more than 60 percent.

https://www.prpa.org/ev-study/

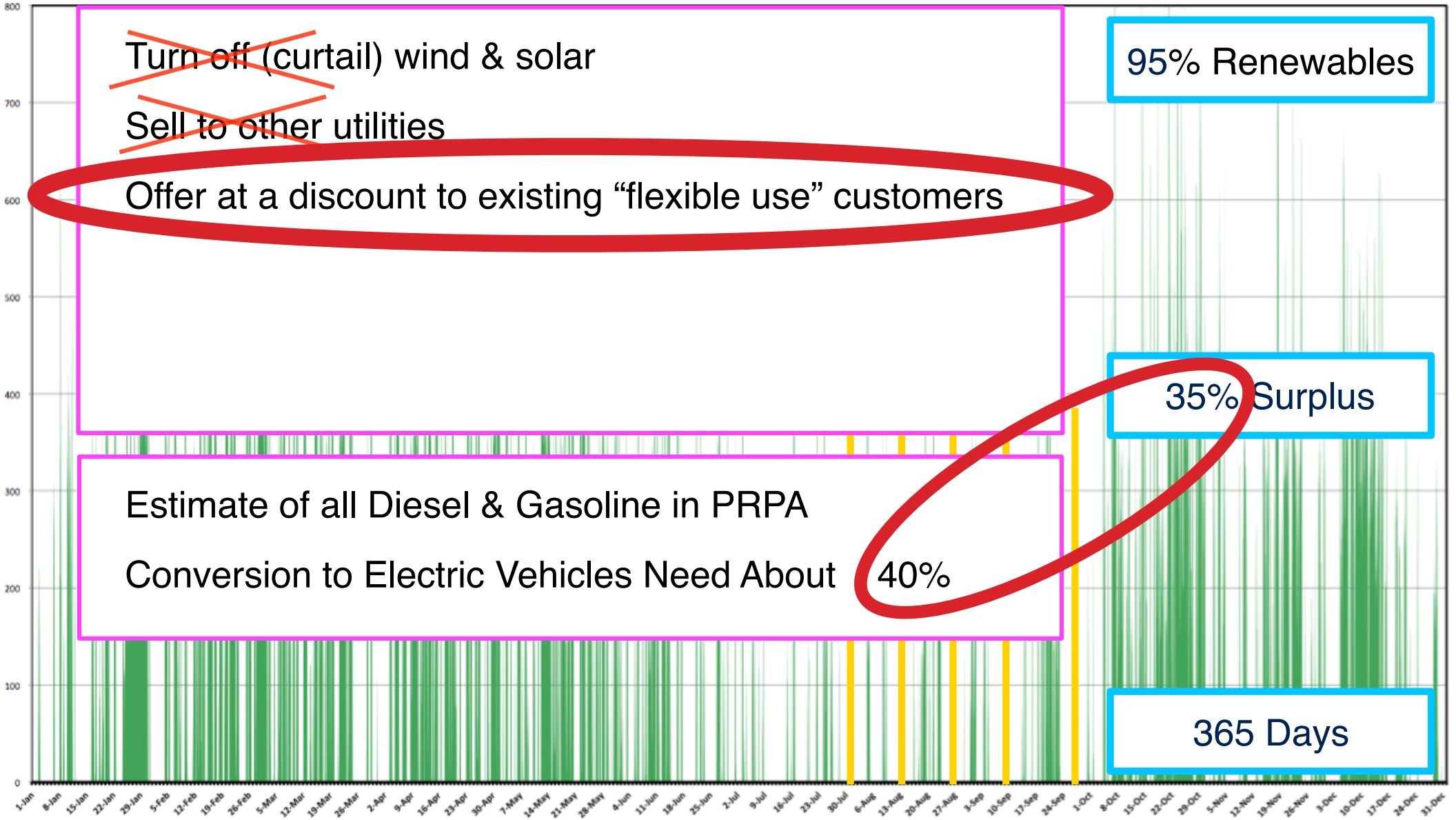
Just the Surplus

Reliable Cheap
100%



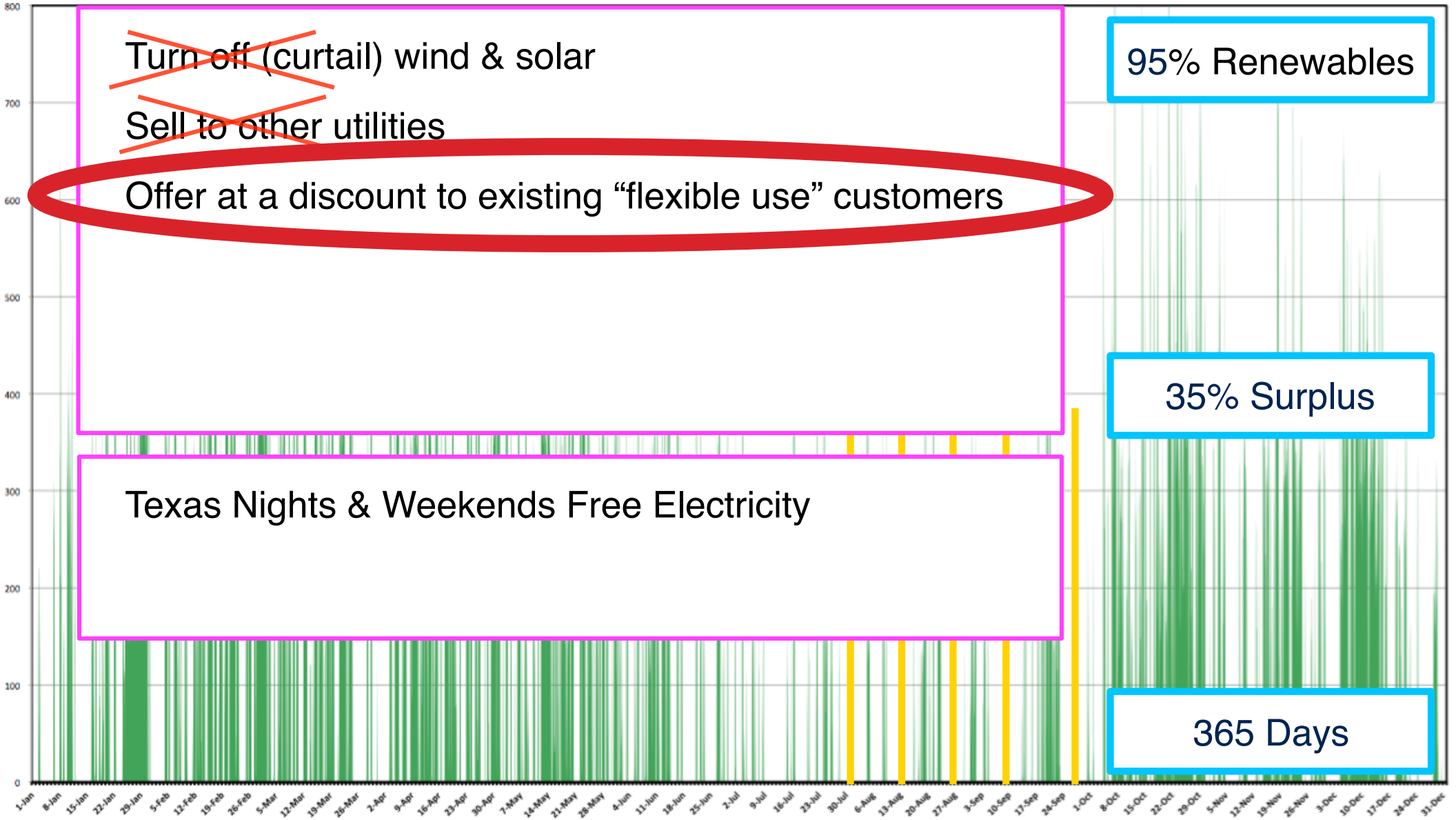
Just the Surplus

Reliable Cheap
100%



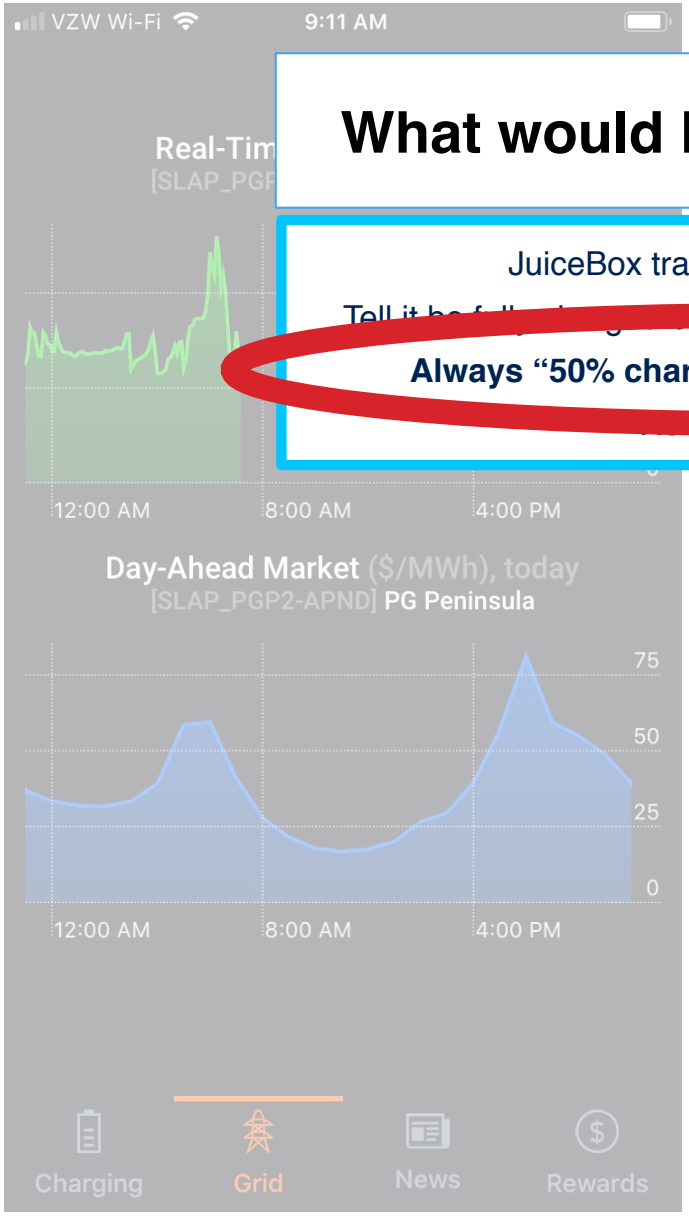
Just the Surplus

Reliable Cheap 100%



Ken's New Charger & App

Reliable *Cheap*
100%

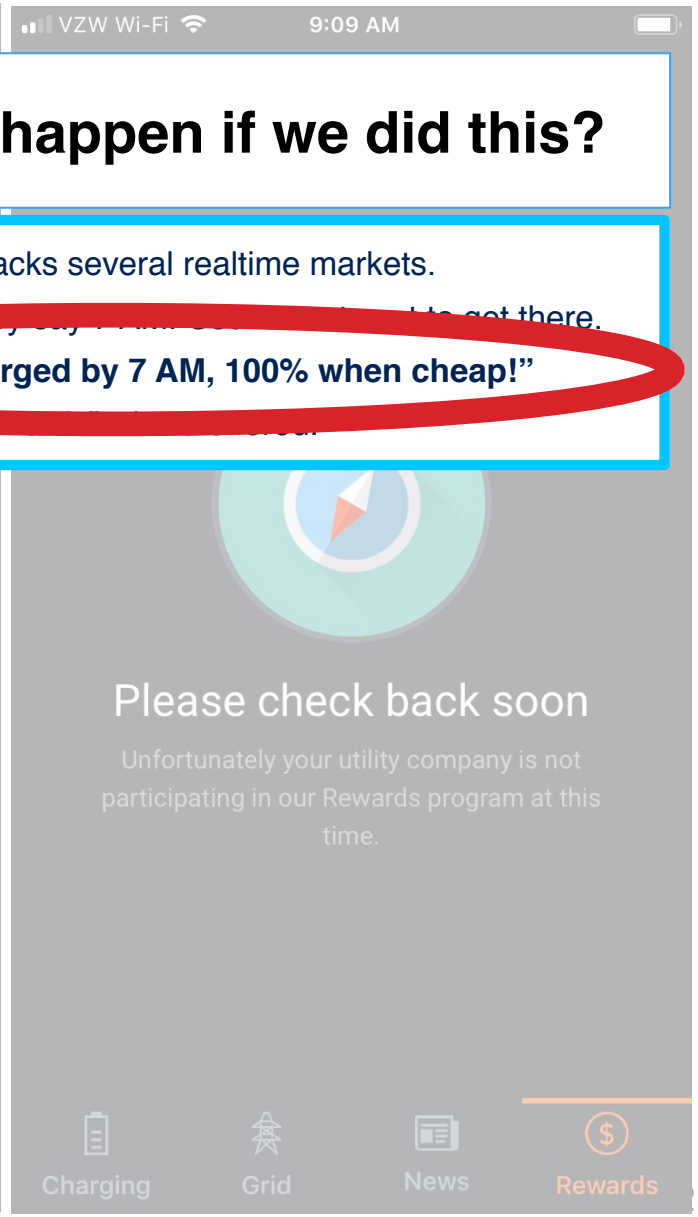


What would happen if we did this?

JuiceBox tracks several realtime markets.

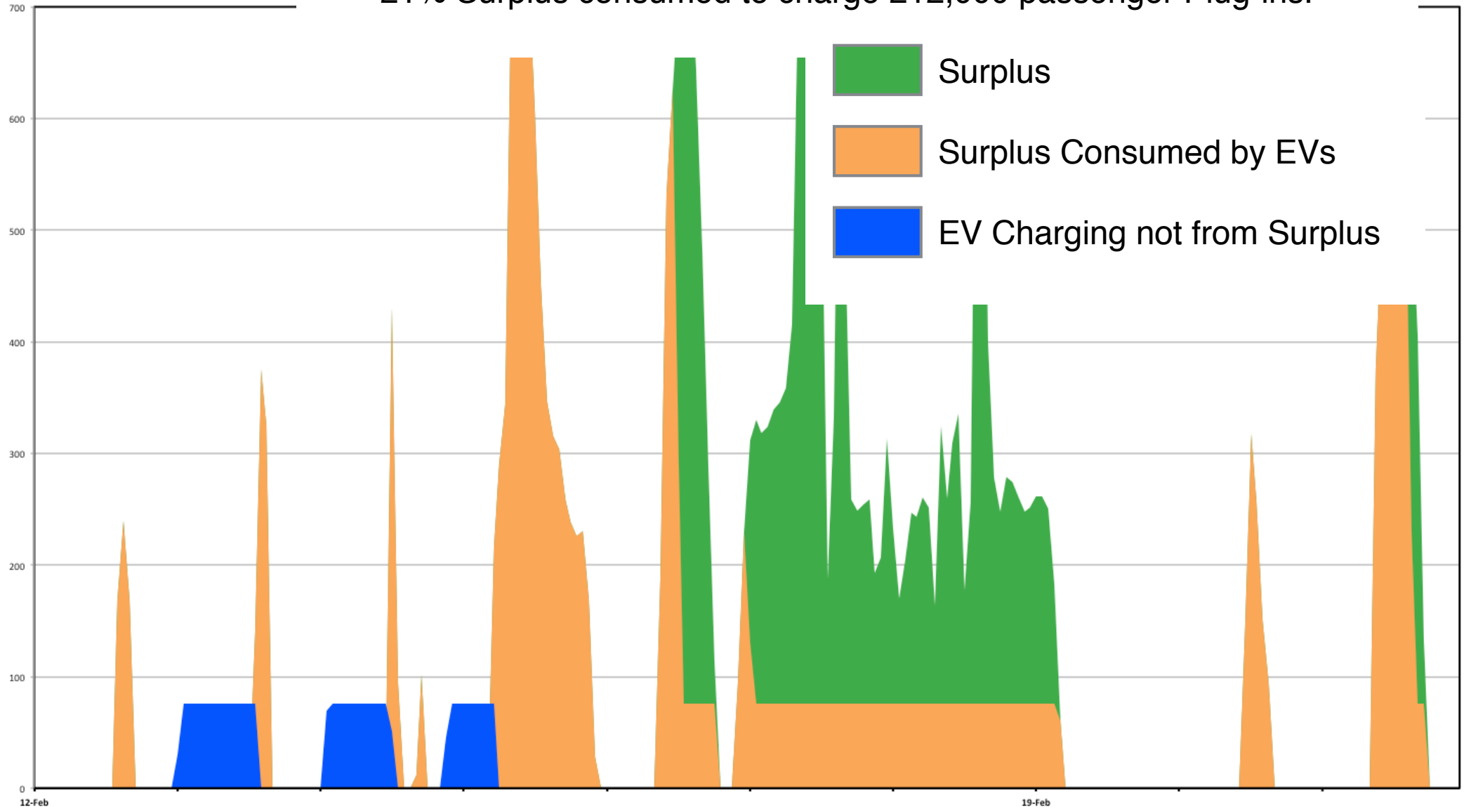
Tell it be full by 7 AM. Set to get there.

Always "50% charged by 7 AM, 100% when cheap!"



Rewarding Flexible Demand EV Charging on the Surplus.

10 days. 8760 hours. 95% Renewable, 14% Surplus,
21% Surplus consumed to charge 212,000 passenger Plug-ins.



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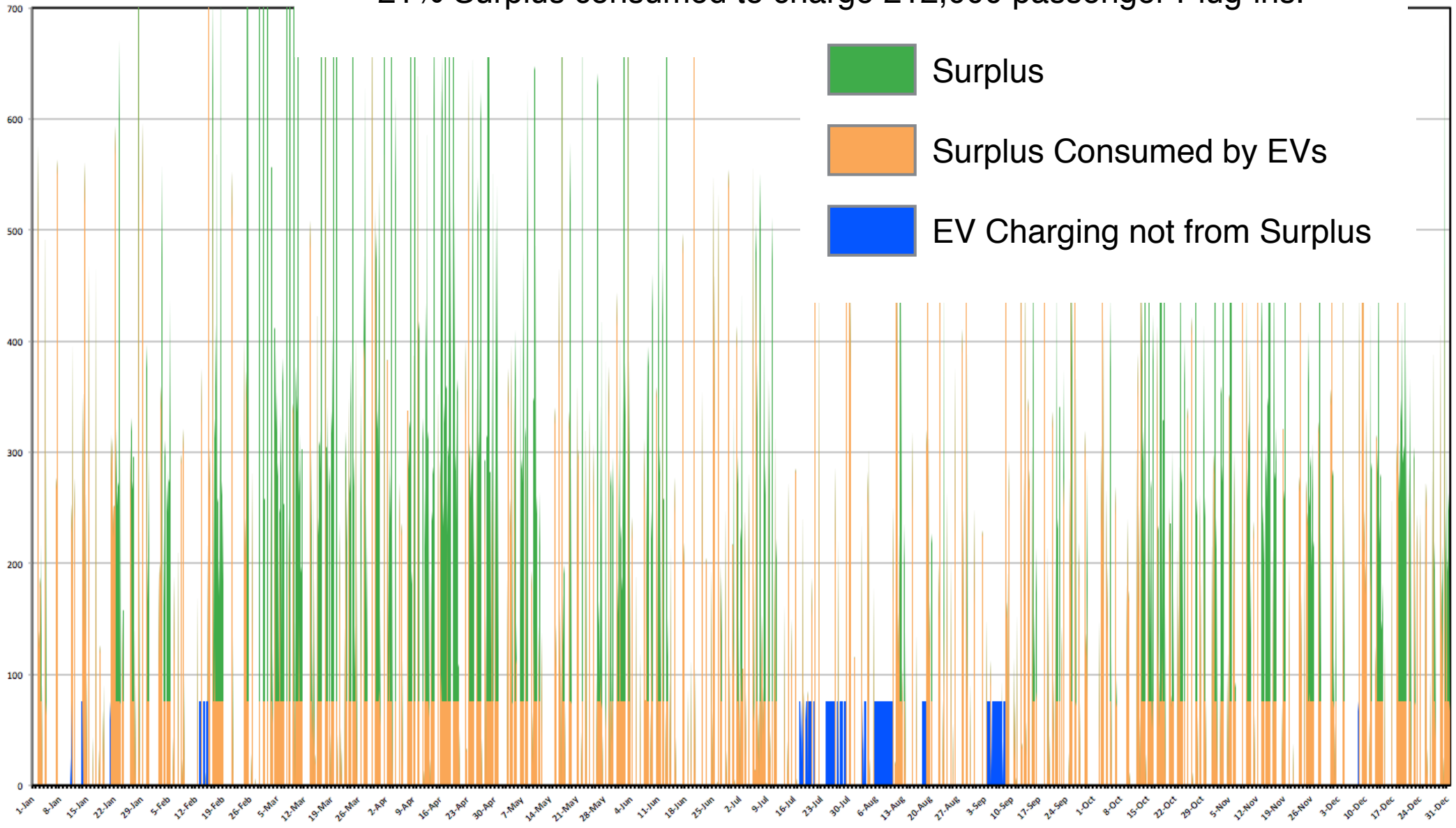


Rewarding Flexible Demand Beyond Charging Plug-ins.

A Reverse RFP - The Goal is Innovation

Bidders are offering to buy energy at a specific capacity. Reverse - high bids win.

Perhaps in 5 MW blocks of capacity.

Only when there is surplus.

New load so there is minimal cannibalization of existing load.

They must use power when directed to (with penalties?)

They must be located where there is adequate transmission & distribution.

Even with 10,000 Plug-Ins at 50% renewables, 1250 hours of surplus (14% of the year)

Examples:

Fixing nitrogen. Instead of using natural gas, make ammonia/fertilizer with surplus electricity.

Conversion of gas appliances to electric heat pumps.

Creation of green natural gas. Electricity to methane, inserted into existing nat gas distribution & storage system.

Image: pixabay.com

A few short items:

Reliable,

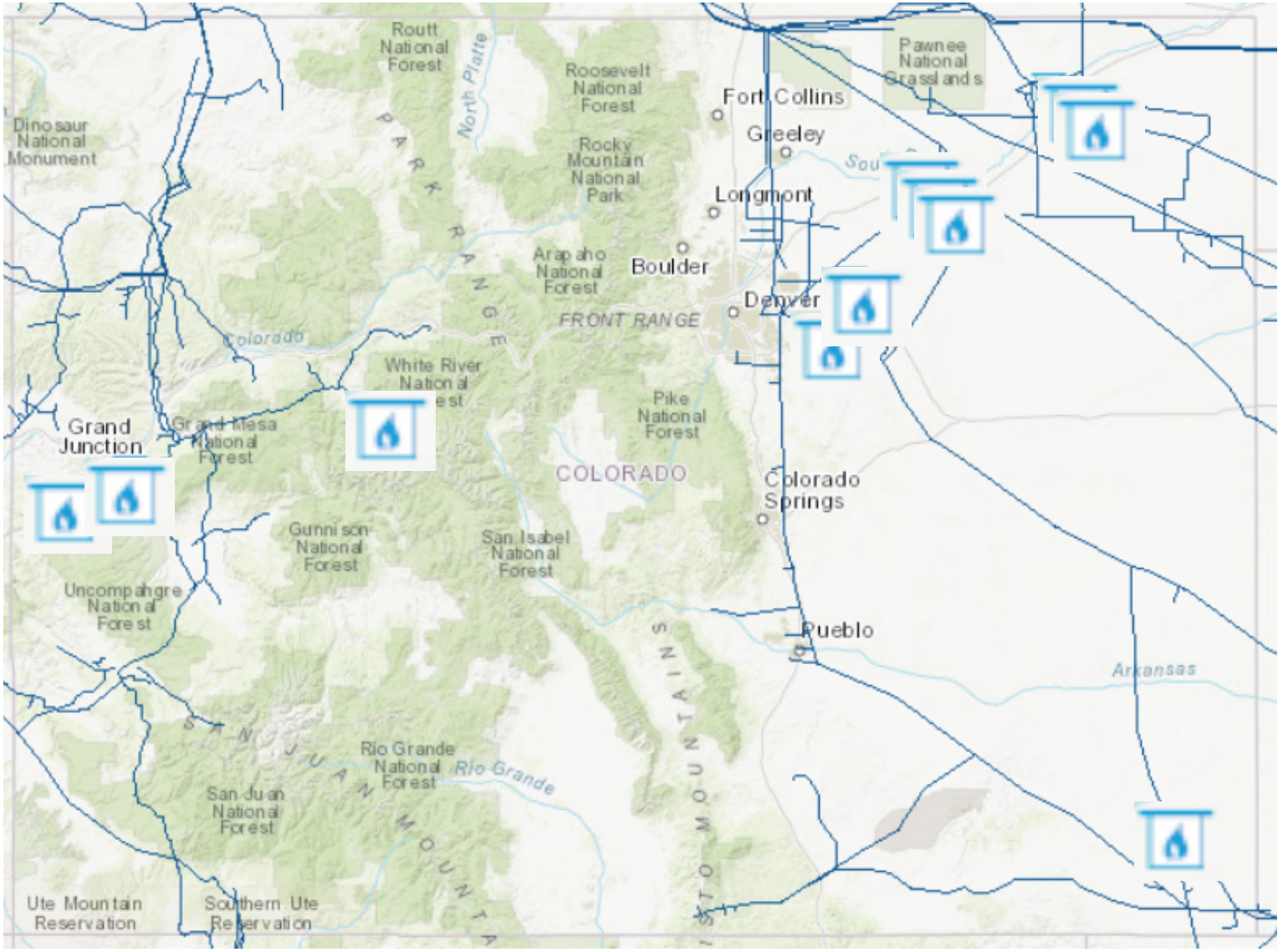
Cheap,

100% Renewables by 2030

Image: pixabay.com

As we use less and less…

What happen$ to natural ga$ pipeline$ and $torage?



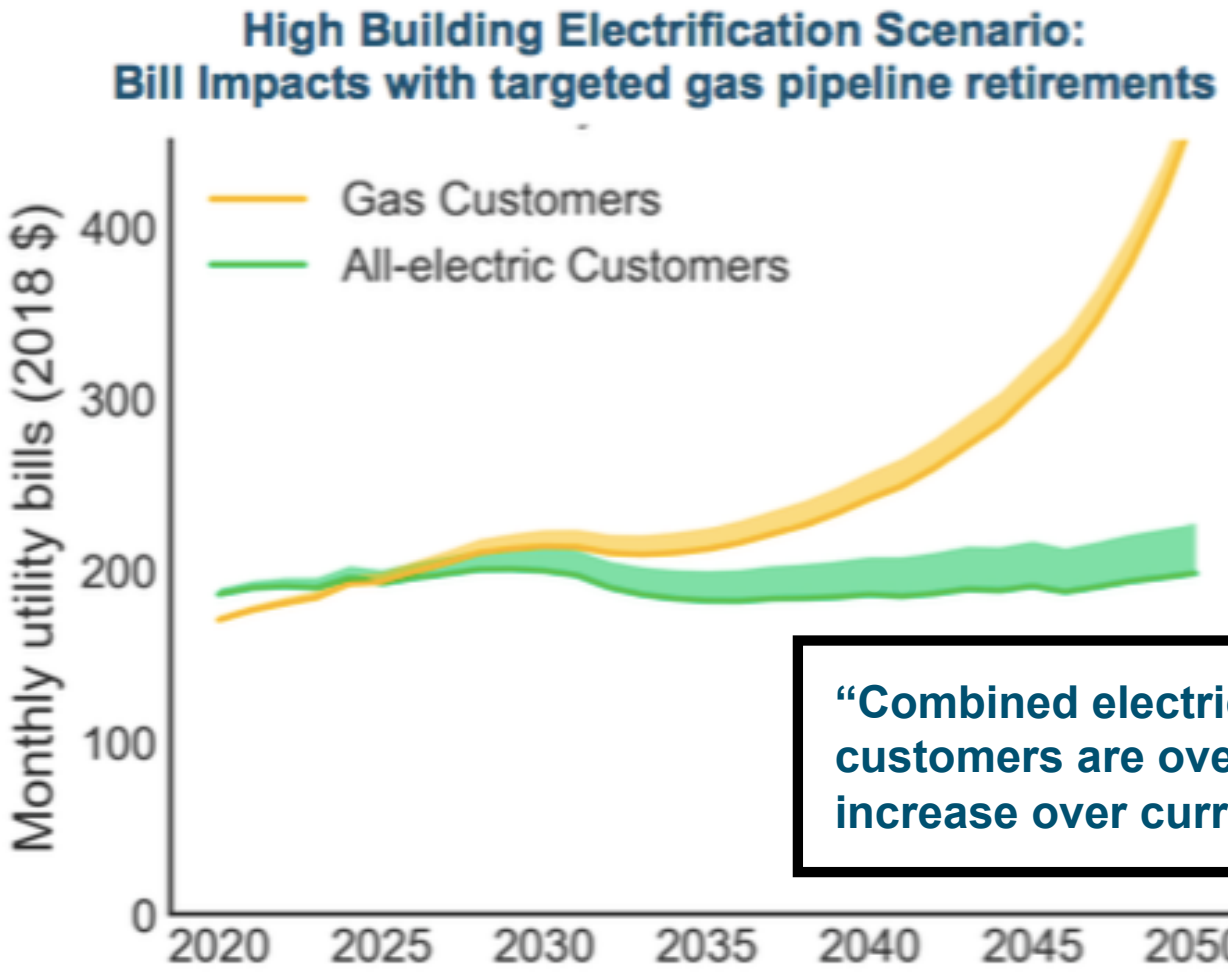
Source: EIA map https://www.eia.gov/state/maps.php?v=Natural%20Gas

Recently Released California Gas Future Study

Reliable Cheap 100%

Energy+Environmental Economics

Draft Results: Future of Natural Gas Distribution in California



"Combined electric and gas bills for remaining gas customers are over $490/month in 2050, a 2.5X increase over current bills "

Energy ShouldBe.org

For ALL Colorado: Is There Enough Renewables?

PUBLIC VERSION Updated Attachment A

RFP Responses by Technology

Generation Technology	# of Bids	Bid MW	# of Projects	Project MW	Median Bid Price or Equivalent	Pricing Units
Combustion Turbine/IC Engines	29	6,365	19	4,436	$ 5.08	$/kW-mo
Combustion Turbine with Battery Storage	7	804	3	476	6.21	$/kW-mo
Gas-Fired Combined Cycles	3	873	3	873	[redacted]	$/kW-mo
Stand-alone Battery Storage	28	2,144	24	1,945	10.53	$/kW-mo
Compressed Air Energy Storage	1	317	1	317	[redacted]	$/kW-mo
Wind	96	41,915	42	16,949	$ 19.30	$/MWh
Wind and Solar	5	2,601	4	2,151	19.96	$/MWh
Wind with Battery Storage	11	5,700	5	2,700	20.63	$/MWh
Solar (PV)	148	28,382	78	14,085	30.96	$/MWh
Wind and Solar and Battery Storage	7	4,048	7	4,048	30.41	$/MWh
Solar (PV) with Battery Storage	79	14,980	57	10,098	38.30	$/MWh

Use Only "Wind" & "PV + storage" —> All Colorado: 95% Renewable. 60% Surplus.

Xcel Energy (bottom P 51) https://www.documentcloud.org/documents/4546891-Xcel-Energy-Electric-Resource-Plan-120-Day-Report.html

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Questions & Policy 1

20 to 25% of natural gas in the US is “associated” - produced from oil extraction. Suppose EVs do take a big whack out of oil sales. What happens to natural gas prices?

Big new investments in

- CCS,
- Combined cycle natural gas generation,
- nuclear,
- transmission,
- or distribution

may be doomed to being stranded and cause needless high costs to consumers as we rapidly change to renewables. And cheap storage is a threat to all of these as well. This is because the utilization rates will probably be much lower than optimistic projections.

Our dependence on the electric system will be increasing rapidly with extreme heat. At the same time, the grid will become more difficult to make resilient in the face of extreme storms. Perhaps new transmission, and over time, old transmission needs to be buried to increase resiliency as well as make siting transmission easier. Our species is clever at reducing costs when forced to. Perhaps mandate a portion of transmission be underground.

100s of cities have taken the 100% pledge and yet have no practical way to get there because they have little control over their monopoly IOUs. Are there ways to make CCE - Community Choice Energy (AKA CCA) easier to accomplish?

Questions & Policy 2

CARPA - like DARPA but for fighting catastrophic climate change.

- a replacement for SF6 - Sulfur Hexa-Flouride. 50,000 x CO2
- atmospheric methane reduction. Catalyst on blades of wind turbines, or outdoor fans.

The amount of space needed to sequester the billions of tons of CO2 being discussed may be wildly above the amount of storage space available in depleted natural gas reservoirs - CO2 may prove to be much tougher to store than the much smaller methane molecules. In addition, our history of burying our wastes has been checkered at best. And CO2 needs to be sequestered for as much as a 1000 years. Making a renewable liquid like oil and sequestering that may be much more practical.

A few comments on testimony.

All 3 - Great on the whole. In some cases, not thinking through the practicalities and costs of recommendations on nuclear, transmission, other giant new capital projects.

Cohen. Clean Air Task Force. Some ways the most interesting and controversial. Firm energy. Several data points pretty far out of date.
Limited actionable policy recommendations.

Hausker. World Resources Institute. Clearest presentation. Thoughtful and interesting.
Limited actionable policy recommendations.

Cleats. Union of Concerned Scientists. The most policy recommendations, but in something of a jumble.

If it would truly be useful, I'm willing to go through them point by point.

I skate to where the puck is going to be, not where it has been.

- Wayne Gretzky

Q: How much rooftop high yield solar in the city of Boulder?

A: 630 MW. About 65% of Boulder's Total Annual Electricity Use.

Boulder is 4% of Colorado's population.
By population - **16 GW** rooftop solar statewide.

mapdwell.com

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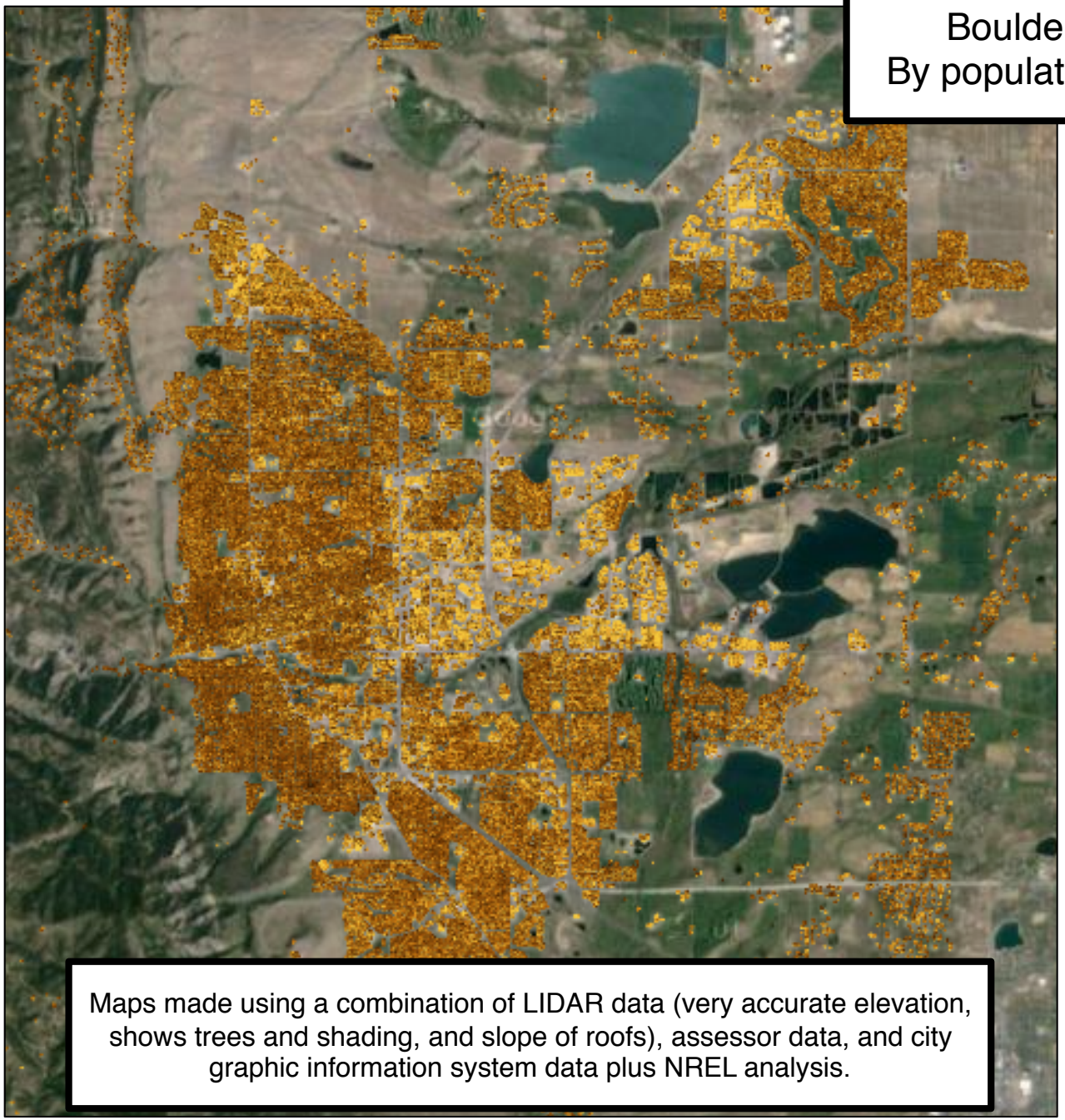

Maps made using a combination of LIDAR data (very accurate elevation, shows trees and shading, and slope of roofs), assessor data, and city graphic information system data plus NREL analysis.

Barriers to 100% Clean Energy.
Does Colorado Need Electricity Competition?

"Don't Believe Everything You Think!"

This idea needs to be researched.

EnergyShouldBe.org
abundant secure for all forever

Ken Regelson

January 10, 2017

Image: NASA

EnergyFreedomCO.org - Research & Education on Electricity Competition

Working to bring electricity competition to Colorado.

A bunch of white papers.

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abundant secure for all forever

Ken Regelson

January 10, 2017

Image: NASA

EnergyFreedomCO.org

Beginners, start here

- The U.S. electricity system
- Energy Freedom basics
- Why restructure monopolies?
- ***Terms and definitions***

Intermediate level

- Retail choice in Colorado
- Wholesale markets in Colorado
- Massachusetts CEO restructuring story
- Figures – Energy costs & trends

Advanced topics

- The case to study retail electricity choice
- Electricity prices - monopoly vs choice
- Stranded assets & securitization
- RTO / ISO governance

Example Choice States: Illinois | Texas | Massachusetts

EnergyFreedomCO.org

GREENING THE GRID through COMMUNITY CHOICE AGGREGATION

Shawn Marshall, LEAN Energy

Community Choice Aggregation is a local energy model and a shared-service model with investor-owned utilities that enables cities and counties to combine their electric load, offer customers lower rates and a choice of electricity provider, and lower greenhouse gas emissions.

LEAN Energy (Local Energy Aggregation Network) is devoted to accelerating the expansion and competitive success of the CCA model nationwide. **LeanEnergyUS.org**

EnergyFreedomCO.org

"Cheaper and cleaner electricity through competition and consumer choice"

LEAN ENERGY US
Local Energy Aggregation Network
Harnessing the Power of Communities

Boulder, Colorado, March 4, 2019. Introduction by **Dan Greenberg**, Research Analyst.
Produced pro bono by Martin Voelker for Energy Freedom Colorado & the Colorado Renewable Energy Society **cres-energy.org**

Just Announced…

First Regular Session | 72nd General Assembly

Colorado General Assembly

INTERIM COMMITTEE INTERIM COMMITTEE

Investor-owned Utility Review Interim Study Committee

(last bullet point)

- the role of community aggregated choice in the consumer price of energy.