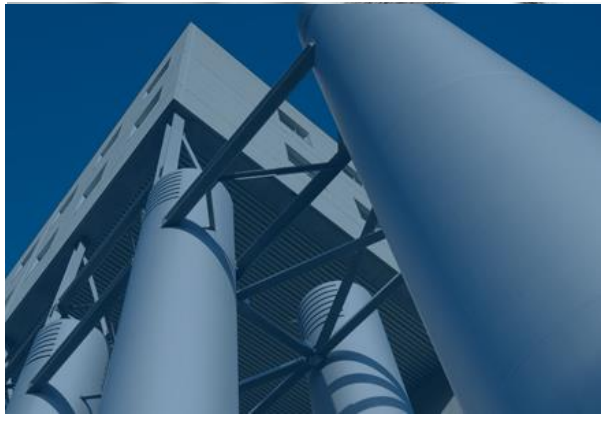
4th AIEE Symposium on Current and Future Challenges to Energy Security

Bitcoin mining to reduce solar curtailment

A case study of CAISO



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North American “Crypto Rush” dilemma

Cryptocurrencies issues from various point of view

Financial point of view:

- “Revolution”, “Just a dream”, Bitcoin, Ethereum, XRP, EOS, Litecoin, Binance Coin, Bitcoin SV, Tether, Stellar, Cardano, Tron, … etc. https://coinmarketcap.com/all/views/all/

Technical point of view:

- “blockchain”, “decentralized public ledger ”, “blocks”, “chaining”, “unique crypted code”, “hash”, Antminer S9s, PH/s, … etc. https://www.buybitcoinworldwide.com/mining/profitability/

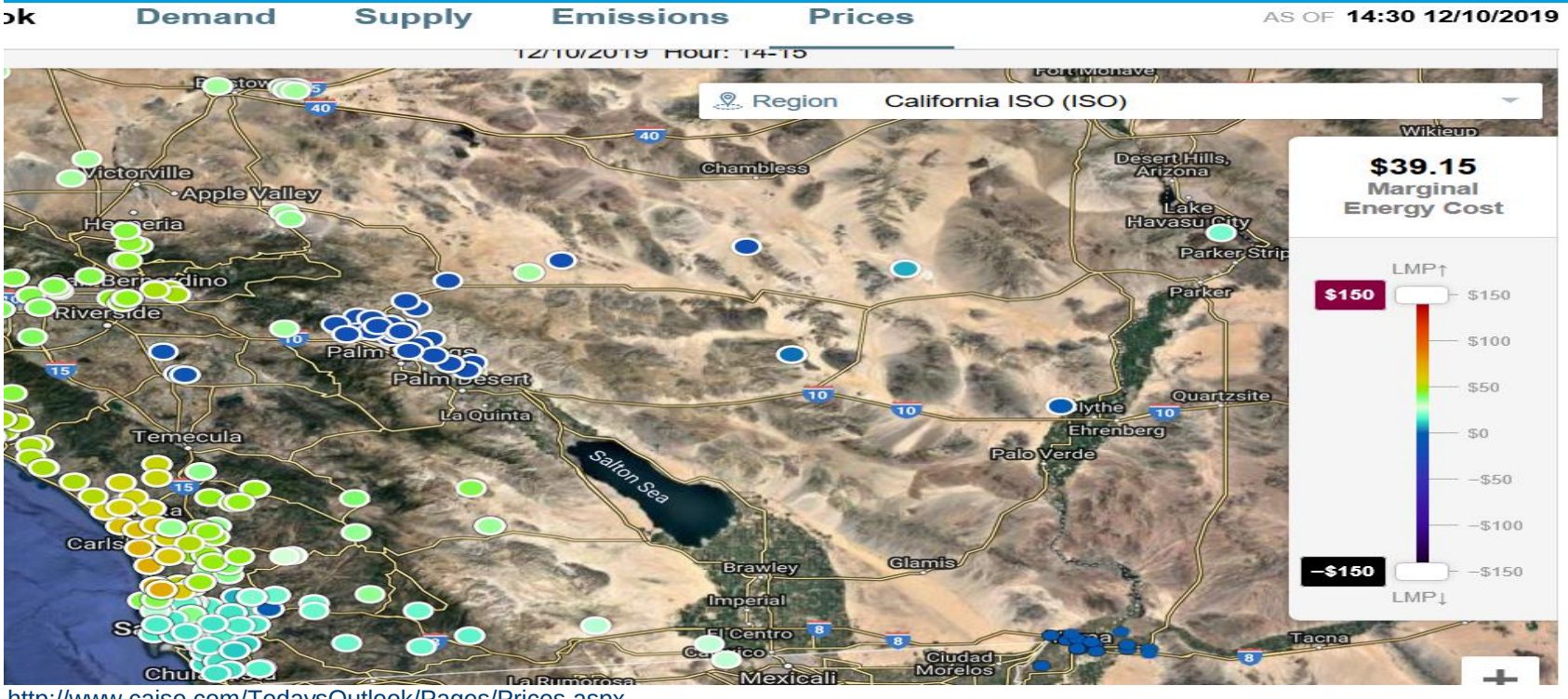
Energy sector point of view:

- Supply-Demand, MW, $/KWh, public service, utilities, rate, banning …

Low carbon economy point of view:

- High hashrate (TH/S) usage is problem or solution to promote renewable?

Background 1a – Curtailment of renewable



http://www.caiso.com/TodaysOutlook/Pages/Prices.aspx

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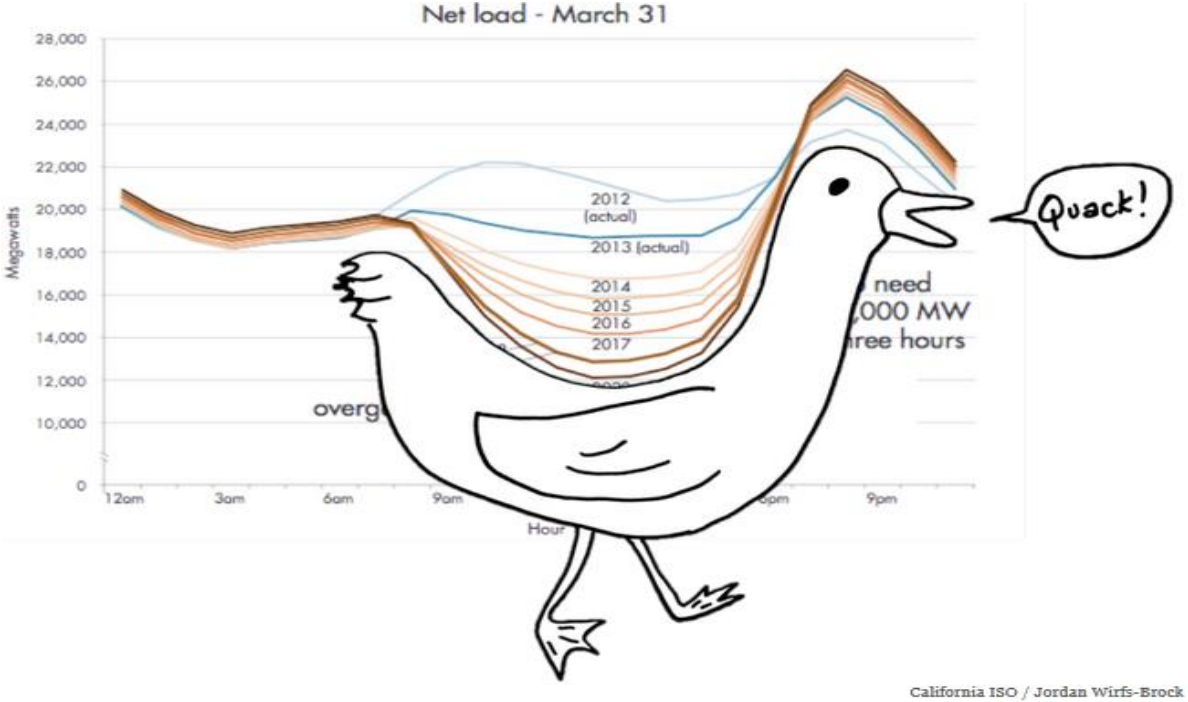
Background 1 – Curtailment of renewable

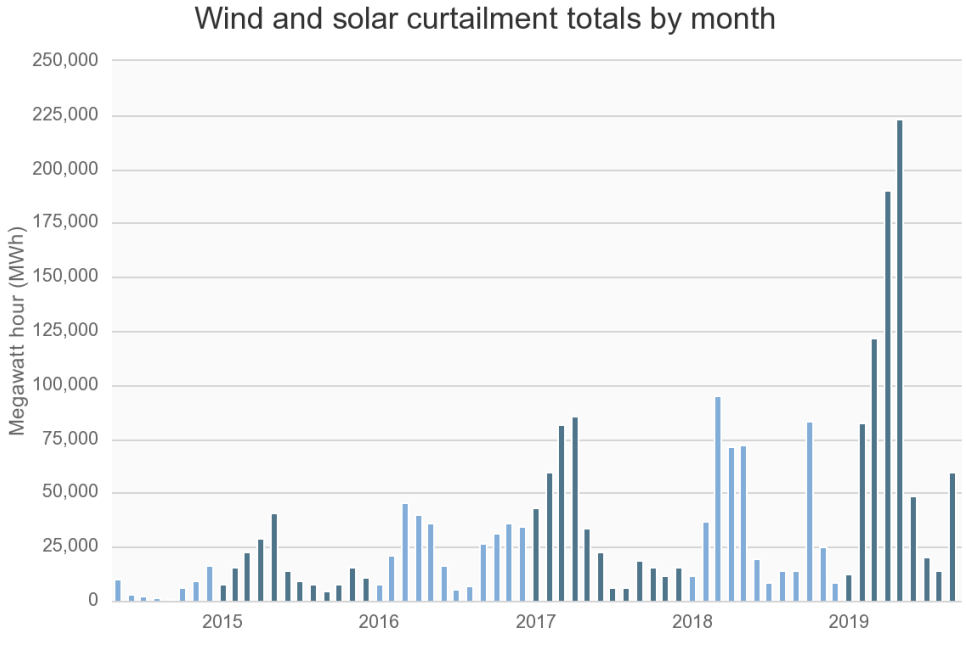


California ISO / Jordan Wirfs-Brock

http://insideenergy.org/2014/10/02/ie-questions-why-is-california-trying-to-behead-the-duck/

Background 1 – Curtailment of renewable

- Bitcoin mining is energy intensive:
  - 45.8TWh in 2018 with emission about 22.0-22.9 $MtCO_2$ (Stoll,2019)
  - comparable to the electricity consumption of Ireland (O'Dwyer, 2014)
- Severe curtailment in CAISO reduce the profitability of renewable power plants



Source: http://www.caiso.com/informed/Pages/ManagingOversupply.aspx

Background 2 – Price of Bitcoin

- Bitcoin prices can be volatile like any commodities and investment risky
  - January 2018 saw prices of Bitcoin at 10 000 Euros
  - Crashed to 3 000 Euros in January 2019
  - Up again at 6 500 Euros today
- Bitcoin are one of the most prone to “Industrial nomadism” explained by professor Gerbeti yesterday !

https://goldprice.org/fr/cryptocurrency-price/bitcoin-price

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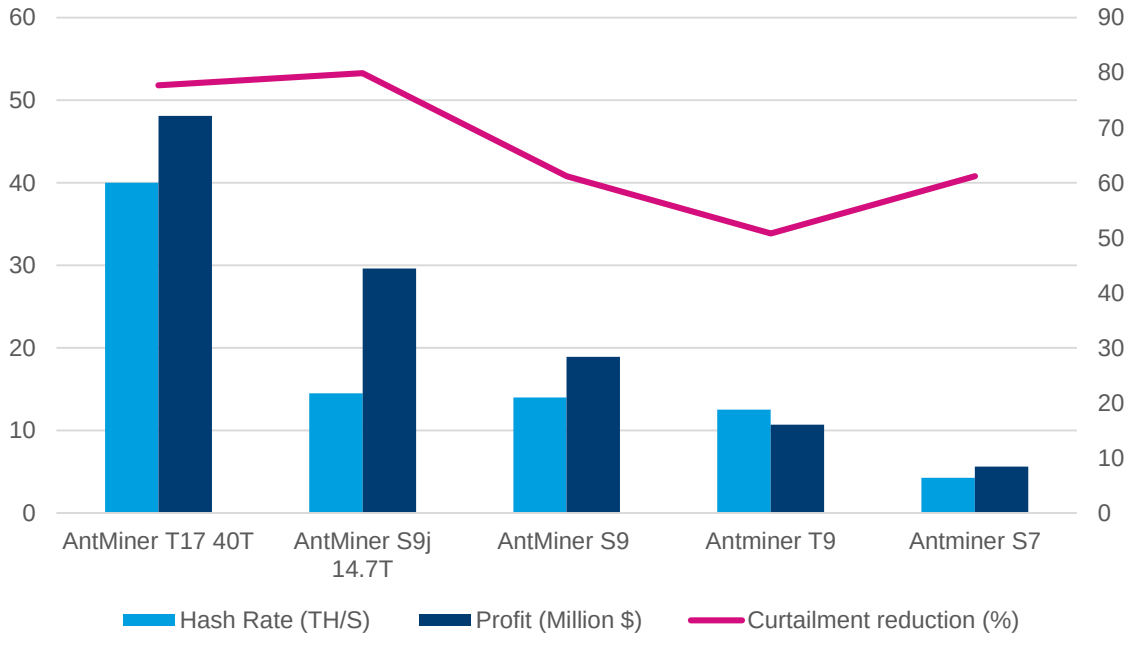
Background 3 – Price and choice of hash machine



Machine	Power Efficiency (J/TH)	Price (USD)
AntMiner T17	55	1125
AntMiner S9j	93.12	403
AntMiner S9	98	600
Antminer T9	126	636
Antminer S7	250	189

More efficient (hash rate) machine lead to higher profit and more curtailment reduction

Method and equations used for CAISO

The amount of Bitcoin mined is based on the following equation:

$$B_{machine,t} = \frac{H_{machine} * n_t}{H_{network}} * B_t$$

$B_{machine,t}$ denotes the Bitcoin mined by the machines on day t;
B_t denotes the Bitcoin produced by the network on day t. In 2018, $B_t = 1800$;
$H_{machine}$ is the hash rate of one machine (TH/s);
$H_{network}$ is the hash rate of the whole network (TH/s);
n_t is the number of working machines deployed in the system;

$$n_t = min\ (N, \frac{E_{curtail,t}}{Power * T_D})$$

$E_{curtail,t}$ is the curtailed energy in CAISO on day t in MWh;
$Power$ is the rated power of one mining machine, for Antminer S9, Power=1273W;
T_D is the time of a day, $T_D = 24hr$
N is the total number of machines in the CAISO system

Method and equations for profit measures

$$Profit = Revenue - Cost = \sum_{t=1}^{365} B_{machine,t} * Price_{BTC,t} - N * Price_{machine}$$

$$Rate\ of\ Return\ (ROR) = \frac{Profit}{Cost}$$

$Price_{machine}$ is the price of the mining machine at the beginning of the year
$Price_{BTC,t}$ is the average Bitcoin price on day t.

Note: **LIFETIME of Machine and MISMATCH in one day:** This « 365 days/year » equation is implicitly assuming the machines (AntMiner S9) have a lifetime value of only one year, very conservative according to many technical specialists but on the other hand intraday mismatch is not taken into account and revenue are the overestimated.

Turn one problem into a key to another problem

- Can renewable curtailment fuel the bitcoin miner in a profitable manner?

- Simulate CAISO system in 2018
  - Historical solar curtailment data
  - Historical Bitcoin price and hash rate
  - AntMiner S9 mining machine
  - Only use the free curtailment
  - Sell Bitcoin everyday no more trading
  - Simulate on the daily interval
  - Optimize the number of machines to maximize the profits

Simulation Result	
Number of machines	41,539
BTC collected	5,345
Profit (Million USD)	18.9
Consumed curtailment (%)	61.21

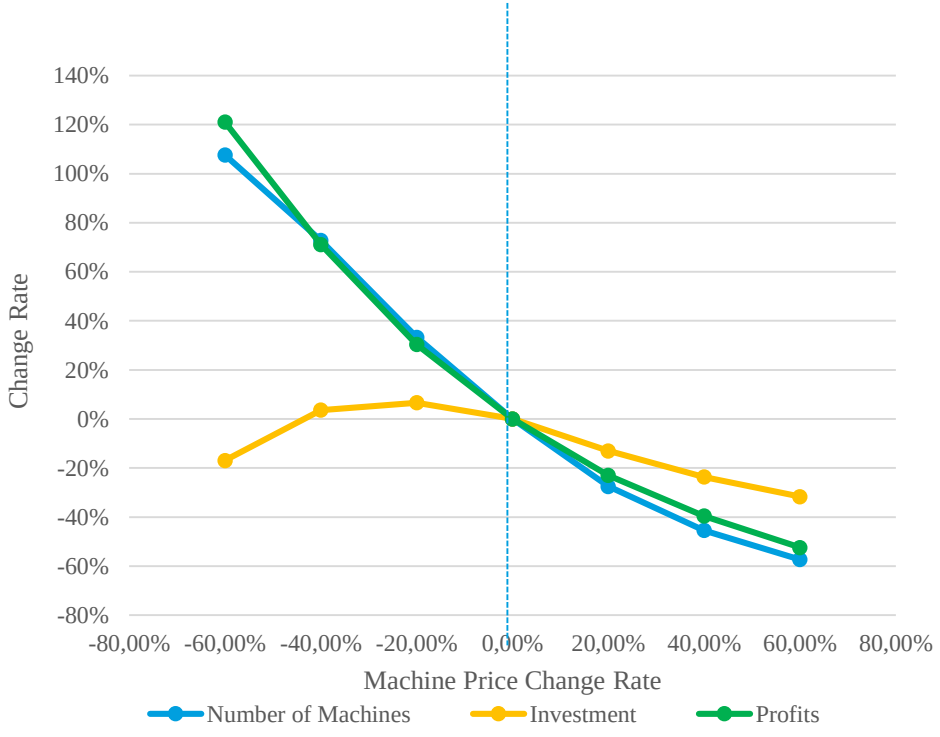
Result and Analysis

Objective	Maximize Profit	Consume all the curtailment
Number of machines	41539	502590
BTC collected	5345	8680.4
Profit (Million USD)	18.9	-229.8
Consumed curtailment (%)	61.21	100

Table 1 Simulation result of two different objectives

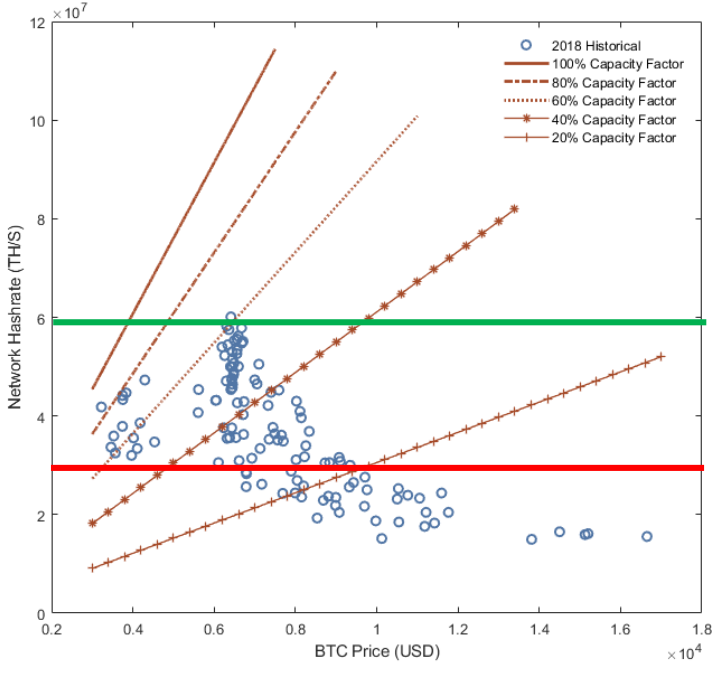
Sensitivity to machine price

- When machine price ($600) change ±60%
  - Optimal investment only change within 30%, not so sensitive to machine price
  - Maximum profit is sensitive to machine price, but still profitable ($8.9 million) in the worst case
- Spend all the budget could be a good strategy

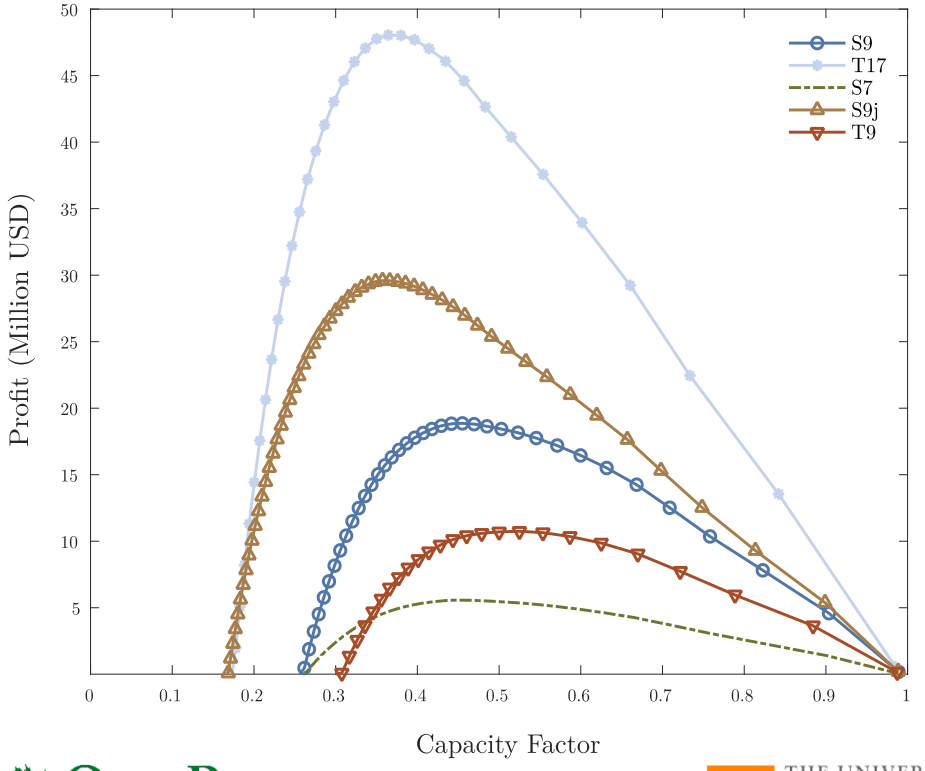


Sensitivity to Bitcoin price and network hash rate

- Higher capacity factors of mining machines have higher probability to make a profit
  - Evenly distribute investment cost to 365 days
  - Points on the critical lines (red lines) is when the daily revenue equal to the distributed cost
  - Area below the critical lines is where to make a profit (Red is low prices in 2018 and Green today's price December 2019)



Sensitivity of capacity Factors vs Profits



- The reason behind such relationship is the constraint from curtailed energy. The curtailed energy is an uncontrollable constant determined by the market and natural resources,
- There is a optimal number of machines, leading to a optimal capacity factor, since the machines will consume as much curtailment as they can

Discussion- Impact to Bitcoin miners

- Curtailment is not stable, miners might earn less comparing with stable electricity prices
  - A better rate design to attract more miners to work off-grid with solar power plants rather to consume electricity from the grid;

- More miners consume curtailment or cheap energy from renewable will force other miners to consume cheaper electricity to remain competitive, and finally more miners will work with renewable plants;

Discussion- Impact to the Electricity Industry

- Renewable plants:
  - Curtailment become valuable and brings more revenue
  - More incentives to invest in new renewable power plants

- If renewable plants supply more than curtailment to bitcoin miners off-grids:
  - Electricity price become higher, other plants can recover sank cost and more incentive to the general capacity expansion
  - Less pressure on all investors and system peak demand

- Bitcoin mining machines can also act as a fast demand response resource

Discussion- Impact to the Electricity Industry

- Any curtailment usage can bring more stable revenue to renewable projects:
  - Filling storage capacity
  - Producing hydrogen
- Some problems may arise:
  - Price of “goods” produced (Bitcoin or Hydrogen) may be linked to curtailment
- Utilities need to innovate in rate design:
  - Traditional “interruptible rate” are not enough

Concluding with …