Office of Science and Technology Policy

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Re: RFI Response: Climate Implications of Digital Assets

To Whom it May Concern:

Thank you for the opportunity to submit information for your Energy and Climate Implications of Digital Assets RFI. At Soluna Computing, Inc., our mission is to make renewable energy the next global superpower. We build modular green data centers to efficiently convert wasted renewable energy into global computing for digital assets. Below, we highlight some of the most important points from our RFI response.

Proof of Work is fundamental to the security of the blockchain

Critiques about crypto's energy needs often come down to its security processes, called Proof of Work (PoW) and Proof of Stake (PoS). Almost all cryptocurrencies use PoW, which is fundamental to the security of the blockchain. A transition to PoS is unlikely to occur, given how far the systems have come and the time and energy invested. As digital asset adoption accelerates, it is critical that their underlying technology finds a home in data centers which are designed from the ground up to efficiently operate on green energy. Soluna has proven this is possible, and policy makers should seek ways to incentivize the digital asset mining industry to move towards more sustainable designs.

Crypto's energy use is a feature, not a bug

We challenge the assumption that bitcoin's energy consumption is bad for the environment. Data centers designed to be servants of the grid (vs. the other way around) can be central to stabilizing our energy infrastructure and achieving clean energy goals. Research from Dr. Andrew Chien of the University of Chicago shows supply-following loads add substantially to grid flexibility and can enable much greater integration of renewable energy into a grid system at a fraction of the cost the grid would otherwise incur to absorb these resources.

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The bigger climate challenge: curtailment of renewables

Renewable energy is growing faster than the grid's ability to keep up with new generation potential, and curtailment is one of the most painful problems in the industry. Curtailment is excess energy that goes to waste because the grid lacks the capacity to transmit energy to where it needs to go. At the end of 2021, 12.1 TWh of wind and solar generation was curtailed — the equivalent of the energy needed to power the entire state of Montana for one year.

Soluna has developed an innovative data center that can be co-located with utility-scale renewable energy assets, like solar and wind, in remote locations. These modular data centers perform scientific, blockchain, and AI-related computing, creating unprecedented demand-side flexibility that matches intermittent power generation in real-time. Our architecture enables utility-scale renewable energy assets to be built larger, interconnect faster, have a higher capacity factor (i.e. provide more value), and contribute more to system reliability.

Smart policy can incentivize renewables & clean computing

The global adoption of digital assets will continue, and it's in the United States' best interest to be a leader in this space. Through smart policy, the US has the opportunity to leverage growing digital assets to support renewable energy and climate goals, modernize the grid and create sustained economic growth.

Governments should incentivize good behavior from data centers. We encourage policymakers to consider policies to incentivize the integration of computing operations into clean energy development via Tax Credits PTCs (wind) and ITCs (solar). We also support extension of the DOE Loan Guarantee and the ARPA-E program. Similarly, there should be incentives to encourage crypto miners to adopt sustainable energy and waste habits.

Thank you for your consideration. Following this cover letter you will find our detailed responses to the questions in your Request for Information. If you have any further questions, do not hesitate to contact me.

Sincerely,

John Belizaire, CEO
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RFI Response:

Climate Implications of Digital Assets

Table of Contents

1 / Protocols

> *Information on the climate impacts of the protocols used by digital assets. This includes the effect of cryptocurrencies' consensus mechanisms on energy usage, as well as potential mitigating measures and alternative mechanisms of consensus and the design tradeoffs those may entail. For example, many digital assets—including those that make use of smart contracts—use or are looking into less energy-intensive consensus mechanisms than "proof of work." Information is sought related to the benefits and drawbacks of those alternative mechanisms, as well as their different energy consumption profiles.*

Bitcoin is one of the most widely adopted cryptocurrencies with over 81 million users worldwide, and it has been secured using proof-of-work technology for more than thirteen years.

The two most common digital asset protocols are proof-of-work (PoW) and proof-of-stake (PoS). As its name implies, PoW has "digital work" at its core, relying on proof that sufficient computational resources have been spent by the person or miner validating transactions.

PoS shifts the focus from energy-dependent digital work to "staking," where transactions are validated by network participants based on the number of coins (i.e. their "stake") they have. While PoS is successful in reducing energy use and computational power, that comes with a decrease in security, which undermines the decentralized quality that built the trust in Bitcoin's platform.

Because of these tradeoffs, there is no one protocol that works best for all digital assets. PoS works well for companies that want to deploy private blockchains, but it is incompatible with a public ledger with decentralization and security at the core of its purpose. PoW has been fundamental to Bitcoin's success, and given the scale of its adoption it is highly unlikely it will migrate away from PoW. A change in protocol would require general agreement among those participating in the network to switch over to the new protocol, and for most participating in the network it's not worth risking the security of a system that has been proven to work for so long.

2 / Hardware

> *Information about the climate impacts from the physical components that run the protocols for digital assets. This includes the embodied emissions of specialized hardware and cooling equipment used to mine certain cryptocurrencies, as well as the waste generated from this equipment needing to be replaced frequently due to rapidly improving mining equipment. This also includes potential mitigating measures and technology improvements to reduce the environmental impact from hardware usage.*

E-waste is a concern for all businesses operating in industries that rely on information technology equipment. Soluna leverages best practices in a circular supply chain in order to minimize waste, including strategies around purchasing, mining operations, and recycling at the end of equipment's useful life.

Like others in Bitcoin mining, Soluna uses ASICs. The total average lifespan of ASICs in the past 10 years of crypto history is about 7 years, with failure rates around 3%-5% annually. Machines are typically retired due to economic obsolescence before the microchips no longer work. However, Soluna's model of monetizing curtailed renewable energy results in lower power costs and allows us to recover lightly-used equipment discarded by higher-cost, less-efficient peers. This model extends the useful life of equipment.

During mining operations, ancillary pieces of hardware (power supplies, onboard cooling, and ancillary control units) are the leading cause of failure. Soluna places an emphasis on better data center design, which not only reduces energy consumption but also reduces equipment failures. As OEMs improve these components moving forward, we expect the useful life of the equipment to increase.

Recycling is the last critical component of reducing e-waste. In response to the inherent challenges of safely handling end-of-life electronics, specialist IT asset disposition (ITAD) companies have evolved over the past 25 years to provide robust and compliant electronic waste disposal infrastructure. To date, Soluna has retained its decommissioned ASICs in order to recycle the reusable parts into other machines when repairs are needed. Soluna plans to partner with ITAD companies to handle end-of-use/end-of-life dispositions for our inventory. This ITAD provider will manage the rest of the e-waste process, including the recycling of ASIC components, and providers invited into the RFP process must meet certain certifications and standards to ensure the best e-waste outcomes.

3 / Resources

> *Information about the resources used to sustain and power digital assets. This includes the electricity that powers mining rigs and the water used to cool those operations, as well as potential mitigating measures to reduce the amount of electricity and water used. This also includes quantitative estimates of the total amounts of these resources used by particular types of digital assets, or by the digital asset ecosystem at large. This also includes information concerning whether the costs of resources used are borne equitably across society or are disproportionately borne by historically disadvantaged communities.*

Bitcoin's use of the proof-of-work mechanism and the associated energy consumption is a feature that ensures the security of the transactions on the network. While the Bitcoin network globally consumes less than 1% of worldwide electricity generation, it is nonetheless important to consider the manner in which Bitcoin and other digital currency mining consumes electricity and other resources.

Soluna's data centers are different from the typical hyperscale data centers that power video streaming and websites. They are purpose-built for batchable – or interruptible – computing, such as digital asset mining, scientific computing and artificial intelligence. Their design is based on eliminating two very important specifications that are critical in typical hyperscale and edge compute data centers – latency and 100% uptime. By relaxing these requirements, our data centers are more flexible and can be deployed in a wider range of settings. It also allows us to design our data centers from the ground up to minimize the use of extraneous resources. For instance, our data centers use no water for cooling; they are air-cooled. We use high efficiency, high airflow fans to improve cooling instead of relying solely on inefficient computer fans.

A measure of data center efficiency is called Power Usage Effectiveness (PUE). It is a ratio of total energy used by a facility over the amount of energy used by the computing equipment. In 2021, Google's best data center had a PUE of 1.06, and data centers worldwide average around 1.60. A PUE of 1.0 is perfect. Google's 1.06 means for every 106 Watts delivered to the site, 100 Watts are used for computing. The world average 1.60 means for every 160 Watts delivered to the site, 100 Watts are used for computing. Soluna has demonstrated a long term PUE of 1.02 and is continuing to improve. Our data centers operate with world-leading efficiency, and they do so without consuming any water.

4 / Economics

> *Information about how the energy use of digital assets is affected by the value of, demand for, and supply of particular digital assets or their underlying infrastructure. This includes the environmental and infrastructural effects from cryptocurrency miners moving to areas with cheaper electricity, as well as the incentives that exist for cryptocurrency miners to use renewable energy sources for mining. This also includes information about impacts on the electric grid and about the need for potential incremental grid investments, along with the impacts on electricity bills for customers near or in affected service territories.*

The incentive to participate in the mining of proof-of-work digital assets, such as Bitcoin, is driven by the reward for mining relative to the costs of mining. The reward for mining is primarily the "block subsidy" in the form of newly minted bitcoins, but it also includes transaction fees. The costs of mining consist mainly of equipment and electricity. For Bitcoin, the block subsidy is cut in half every four years, so the total bitcoin reward for participating in mining has a natural downward pressure and incentive to increase efficiency over time. Additionally, all miners are competing for the same reward, so the marginal value of mining reward decreases as more miners participate in the network. This competition for a set of fixed rewards creates resistance to continued increases in mining participation.

Because electricity is a large component of the cost structure of Bitcoin mining, miners are naturally incentivized to manage their electricity costs. Renewables' substantially lower total cost of energy as compared to conventional energy and its zero marginal cost input makes the use of renewables a natural fit for Bitcoin mining.

The interruptible nature of proof-of-work mining protocols allow for mining activities to integrate with renewable power plants in a unique way. The characteristics of the compute task allow for mining to be a flexible load allowing the optimization of both the economics of mining and the availability and price of power on the grid.

These flexible loads also allow for a greater integration of renewable fractions onto the grid, while limiting the cost of the overall grid. As Dr. Andrew Chien of the University of Chicago has shown in his research, supply-following loads add substantially to grid flexibility and can enable much greater integration of renewable energy into a grid system at a fraction of the cost the grid would otherwise incur to absorb these resources.

In the case of Soluna, data centers for mining Bitcoin are built at the same location in the grid as renewable power plants, reducing grid constraints and providing a consumer for renewable power at times when the electricity supply is overabundant and would otherwise be curtailed. Ensuring that new clean power plants can sell every megawatt, and avoid painful curtailment enhances the bankability of renewables, which will further incentivize renewable development. Simultaneously, data centers serve as an alternative to battery storage or transmission lines while requiring incrementally less grid investment.

6 / Potential energy or climate benefits

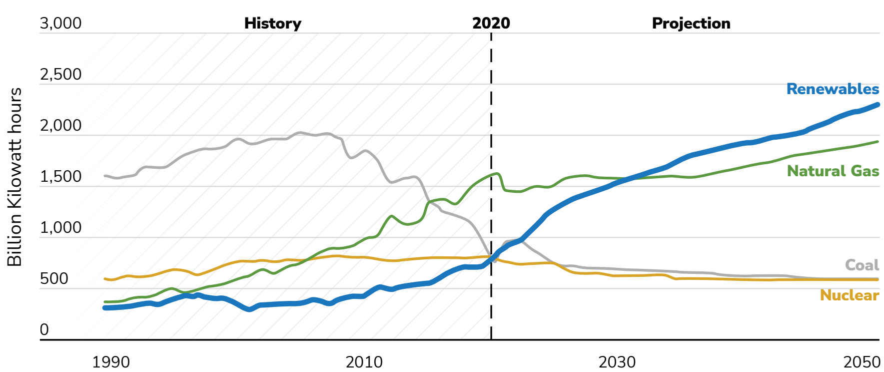
> *Information about how digital assets can potentially yield positive energy or climate impacts. This includes potential uses of blockchain that could support monitoring or mitigating technologies to climate impacts, such as opportunities for natural asset or emissions accounting, as well as the exchanging of liabilities for greenhouse gas emissions, water, and other natural or environmental assets. This also includes specific approaches to increase the likelihood of direct climate or emissions benefits from digital assets, or associated grid services that indirectly lead to climate or emissions benefits. Furthermore, information is sought supporting or rebutting claims made by some proponents of cryptocurrencies that the energy used by mining cryptocurrencies is a net climate positive, either because it occurs during demand lulls or because it increases demand for renewable electricity sources.*

Summary

- Low-cost renewables are growing faster than the grid can keep up with.
- Integration and curtailed energy is a problem for renewable power plants and it is going to get worse.
- Soluna's modular data centers used for Bitcoin mining and other cloud-based batchable computing tasks make it possible to co-locate this energy demand with utility-scale renewable energy assets in remote locations, bypassing transmission constraints and integration problems. This serves as a catalyst to improve the energy yield, interconnection speed, and economic value of utility-scale renewable generation.
- Soluna's data centers can also provide ancillary services to the grid, enhancing grid stability.
- If Bitcoin mining follows Soluna's model, it can bypass grid constraints, solve curtailed energy problems, and provide ancillary services to the grid, all of which serve as a catalyst and enabler for additional renewable power generation.

Increasing the amount of power generation produced by renewable resources — which results in significantly lower carbon emissions — is a common goal shared by a broad range of stakeholders across the public and private sectors. The economic competitiveness of these resources, especially utility-scale solar and wind energy, has become so advantageous that investor-owned electric utilities across the United States are filing integrated resource plans that stipulate the early retirement of coal and natural gas generation plants in favor of renewable energy. The forecast below [from the U.S. Energy Information Administration] points to continued growth of renewables through 2050.

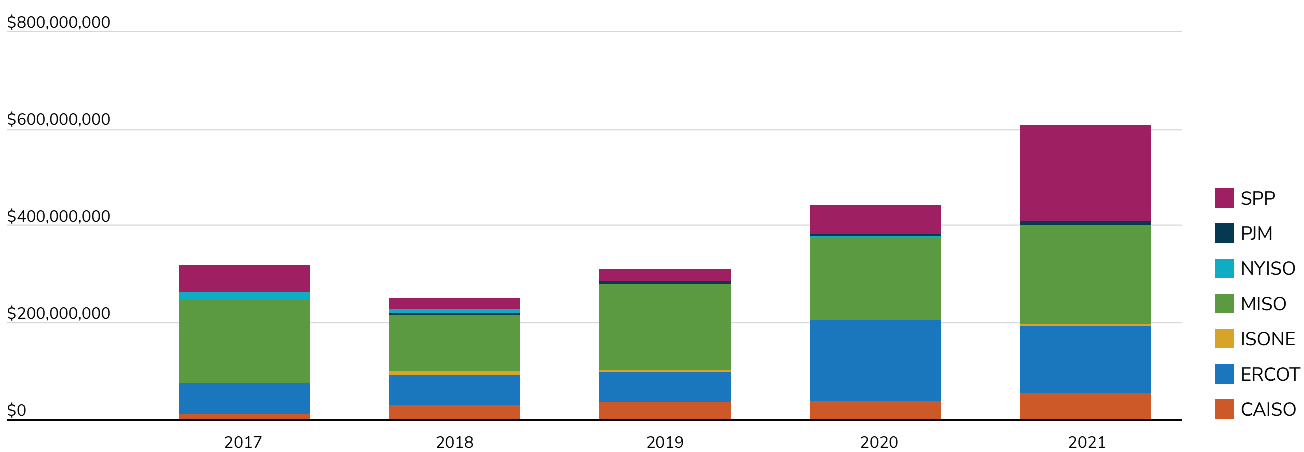
Reference case



Utilities and system operators understand the challenges of integrating large amounts of intermittent power plants such as wind and solar into the electric system. For example, wind energy now represents the dominant form of energy in some grid systems in the US. The rapid expansion in renewable energy capacity, however, has been severely limited by the availability of transmission capacity to carry that energy from the remote areas where wind and land are most abundant to the urban centers where reliable energy is most in demand. This constrained transmission network capacity has resulted in a massive backlog for new renewable energy projects, slowing development of carbon-free electricity production. At the end of 2019, that backlog totaled 362GW of planned solar developments alone. The risk from the uncertainty of the interconnection process significantly increases the cost of capital for utility-scale renewable energy projects and increases the cost of energy for customers. To illustrate, transmission capital costs can increase the direct cost of utility-scale solar by as much as 33% and network upgrade costs borne by solar developers have risen more than 100% in some US markets. These increased costs are ultimately borne by consumers, businesses, and industry.

For existing renewable power plants, problems still persist in the form of curtailed or wasted power generation. This is power that would be produced and sold to the grid but is instead locationally stranded and unable to reach the demand at positive prices. At the end of 2021, 12.1 TWh of wind and solar generation was curtailed—the equivalent of $430 million dollars in lost revenue. This is an increase from 7.9 TWh in 2017 or $225 million in lost revenue.

Renewable curtailment revenue by ISO & RTO



Currently, the vast majority of curtailment has come from wind generation. How much energy is this? According to the Energy Information Administration, in 2020 Delaware consumed 7.1 TWh and Montana consumed 11.6 TWh. We are throwing enough renewable energy away in 2021 to power the entire state of Montana for a year. Over the last 5 years, the value of curtailed energy has increased at a Compound Annual Growth Rate (CAGR) of 14.2%. Currently, curtailment only accounts for up to 5% of total wind energy and 8% for solar energy ISOs and RTOs. A forecast from the New York ISO (NYISO) estimates that by 2029 curtailment in New York could reach 12% of renewable generation. Looking further out, a forecast from the Midcontinent ISO (MISO) estimates that 100% clean generation within the ISO's territory would result in between 57% to 65% curtailment of renewable generation. With low-cost renewables dominating planned new generation, this spilled energy trend is likely to continue if not addressed.

To combat these problems, Soluna has developed an innovative data center that can be co-located with utility-scale renewable energy assets in remote locations. This approach leverages the growing demand for cloud computing as a catalyst to improve the energy yield, interconnection speed, and economic value of utility-scale renewable generation.

By using renewable power plants (i.e. wind and solar) to power modular data centers that perform scientific, blockchain, and AI-related computing, we create unprecedented demand-side flexibility that matches intermittent power generation in real-time. Our architecture enables utility-scale renewable energy assets to be built larger, interconnect faster, have a higher capacity factor (i.e. provide more value), and contribute more to system reliability.

When compared to existing solutions to the curtailment problem, our approach to integration of intermittent generation assets is economically superior. Today the industry relies on smart inverters, storage batteries, and traditional demand response. These state-of-the-art approaches are each subject to limitations. Inverter controls function by curtailing solar generation, which negatively impacts plant economics, and cannot ramp up output significantly. Storage batteries are passive sources of flexibility that are expensive and exhibit poor round-trip efficiencies. Traditional demand-side management resources are not localized, thus failing to address plant-level challenges.

Another significant challenge for the integration of intermittent renewable energy resources such as wind and solar power is that there needs to be sufficient responsive capability within the system to compensate for fluctuations in the supply-demand balance due to the variability of wind and solar. Traditionally, this responsive capability—often termed ancillary services—has been provided by fossil fuel power plants that can ramp their electricity output up and down to provide spinning reserves on time scales of approximately 5 minutes. Fossil fuel plants also have turbines that provide grid-frequency regulation on time scales of approximately 2 seconds. These ancillary services are critical to maintain the stability of the grid and prevent rolling blackouts. As renewable energy becomes the predominant source of electricity, fossil fuel plants are being phased out. The grid needs to provision ancillary services from other responsive resources such as storage batteries and demand-side management.

Soluna's proprietary data centers are capable of providing these ancillary services such as spinning reserves (i.e. help the system recover from unplanned contingencies by reducing load on-demand within 5 minutes of receiving a signal from the electricity system operator). This will enable utility-scale renewable energy facilities to support grid stability comparably with dispatchable fossil generation.

Renewables continue to get cheaper and are increasingly part of our energy generation mix. However, as renewable energy continues to grow so will challenges related to grid integration, energy curtailment, and ancillary services. As Soluna has proven, implementing modular data centers for scientific, blockchain, and AI-related computing can be a solution to these challenges. Our modular data center model can bypass grid constraints, solve curtailed energy problems, and provide ancillary services to the grid, all of which serve as a catalyst and enabler for additional renewable power generation.

8 / Implications for U.S. policy

> *Information about how the climate impacts of digital assets might have implications for U.S. policy. This includes implications for energy policy, including as it relates to grid management and reliability, energy efficiency incentives and standards, sources of energy supply, greenhouse gas intensity, and the transition to a net-zero emissions economy by 2050.*

The global adoption of digital assets will continue, and it's in the United States' best interest to be a leader in this space. Through smart policy, the US has the opportunity to leverage growing digital assets to support renewable energy and climate goals, modernize the grid and create sustained economic growth.

Being a leader in the digital asset space means setting expectations and establishing best practices to ensure the industry develops responsibly. If digital asset mining doesn't happen in the US, it will happen somewhere else, possibly from dirty energy sources that contribute to the global climate crisis. Policymakers have the opportunity to incentivize responsible mining practices and use the unique characteristics of these loads to solve problems that will otherwise only grow as renewable penetration increases.

Specifically, we believe that the federal government can attract digital asset mining investment and jobs to the US through the following routes:

- **Extend Tax Credits –** Incentivize green energy project developers to integrate computing or crypto mining operations through extended PTCs (wind) and ITCs (solar).
- **Investment Tax Credit –** Create a special ITC for crypto mining operations that use green energy AND serve as Flexible Load Resources to the grid.
- **DOE Loan Guarantee –** DOE loan programs geared toward renewable energy transmission and batteries could be extended to encourage the development of green crypto mining operations and other flexible computing. This encourages infrastructure funds to invest in the industry catalyzing the growth of batchable computing as an alternative or additional solution for wasted energy.
- **Flexible Load Resources –** Incentivize crypto mining facilities to ramp up or ramp down their consumption during peak demand through premium prices for serving as a Flexible Load Resource.
- Continue prudent investments in innovation such as funding the **ARPA-E** program.

- Provide clarity and guidance on tax, money transmitters, and other laws which govern the crypto industry; where appropriate ensure that reporting requirements are not onerous and encourage ease-of-doing business.
- **With regards to electricity –** encourage large TSOs to provide market reforms that allow more creative participation in power markets and allow for the development of new business models, such as including availability price signals in bulk power markets, improved net-metering rules, and allowing off-takers to provide certain ancillary services.

Digital assets have the potential to catalyze job creation in the US in tandem with being a catalyst for renewable energy development. Data center jobs powering digital assets are becoming available in previously isolated and rural areas otherwise lacking technology opportunities for students coming out of schools. We find local communities are eager to give their students access to the tech industry right in their backyard. As job creation grows in small towns, so does the local economy and the community's opportunities to build small businesses that economic development demands. We have built relationships with the local Workforce Solutions agencies, high schools, community colleges, VA's and congressional offices in order to hire displaced workers, returning vets and students. By connecting digital assets with renewable energy, our job opportunities also generate greater appreciation for the large wind farms that are going up in their communities.