

Accepted manuscript version:

Lally, Nick, Kelly Kay, and Jim Thatcher. 2019. "Computational parasites and hydropower: A political ecology of Bitcoin mining on the Columbia River." *Environment and Planning E: Nature and Space*. <https://doi.org/10.1177/2514848619867608>.

Computational parasites and hydropower: a political ecology of Bitcoin mining on the Columbia River

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ABSTRACT

Over the past three years, the dams of Chelan County, Washington, its watershed and fish, the electrical grid and the laborers who maintain it, and cleared land with warehouses filled with computers, have all been enrolled as part of the decentralized digital infrastructure of Bitcoin. While popular accounts of the Bitcoin network correctly report the massive scale of energy it consumes and its potential environmental ramifications, in practice, the material geographies of Bitcoin are highly uneven and intertwined with specific infrastructural, ecological, and economic systems. In this article, we examine Bitcoin's impacts on Chelan County, untangling the processes that occur as the distributed, digital infrastructure consumes the very real material resources of one place to produce digital goods used in another. In so doing, we examine not only the material costs of networks like Bitcoin, but also their historical ties to older processes of accumulation.

KEYWORDS: Bitcoin, resource extraction, materiality, algorithms, Columbia River

Highlights:

- Cryptocurrency miners have flocked to central Washington state, drawn by hydropower's cheap electricity rates.

- The material geography of Bitcoin is highly uneven and intertwined with the infrastructural, ecological, and economic systems on which it depends.
- The technological form and resulting material entanglements of Bitcoin grow out of the ideology of the Austrian school of economics.
- Political ecology provides a framework for understanding how Bitcoin acts as a parasite, enrolling itself within historical and spatially situated socio-ecologies and processes of accumulation.

1. Introduction

Uncle Sam took up the challenge in the year of thirty three
 For the farmer and the factory and all of you and me
 He said, "Roll along Columbia. You can ramble to the sea
 But river while you're ramblin' you can do some work for me"
 Woody Guthrie, "Grand Coulee Dam"

Drawn to some of the cheapest electricity rates in the world, cryptocurrency miners have flocked to central Washington, straining the existing power infrastructure of the largely rural Chelan County. Powered by dams like the Grand Coulee (Ortolano and Cushing 2000, White 1995), low electricity rates allow miners to maximize the ever-narrowing profit margins of cryptocurrencies like Bitcoin whose production, by design, requires increasing amounts of computational power over time. While Bitcoin's own ideology is predicated on the idea of a decentralized, peer-to-peer network, its growing energy needs anchor it to specific places. If Bitcoin's infrastructure allows anyone with a computer to plug into the network and begin mining, it is only those with specialized hardware and cheap electricity who can turn the production of new Bitcoins into a profitable venture. So while popular accounts of Bitcoin's energy usage describe the massive, abstract amounts of electricity that the network consumes, in practice, the geography of Bitcoin is highly uneven and intertwined with the infrastructural and ecological structures on which it depends.

The shifting infrastructure of Bitcoin touches down in particular places as miners connect their computers to the blockchain—whether attracted by free dorm room electricity (Paul 2018), plentiful cool air in northern latitudes that help regulate the temperatures of overheating hardware (Popper 2013), or cheap electricity prices drawn from the seemingly inexhaustible supply of hydropower—the network enrolls the world in ways familiar to scholars of political ecology. The dams of Chelan County along with the river and its watershed and fish; the electrical grid and the laborers who maintain it; and the cleared land with warehouses filled with computers all become the infrastructure of the distributed algorithmic infrastructure that is Bitcoin. The network is incredibly flexible and able to harness nearly any computer with an internet connection. Yet, when it converges en masse in places like Chelan County, it produces deep, material marks as it enrolls itself within existing circulatory systems of energy, resources, and capital.

The popular invocation of "mining" to describe the creation of Bitcoins correctly connects Bitcoin's abstract computational functions to biophysical environments. But, rather than taking the mining analogy at face value, our analysis shows the parasitic nature of Bitcoin's material relations in Chelan County. There, cryptocurrencies parasitically feed off of existing circulatory systems of energy and capital, disrupting the very conditions that make it a desirable place for cryptocurrency mining. Owing to Bitcoin's material dependence on a host for survival while providing little in return, we contend that it acts as an infrastructural parasite in this case study. In what follows, we develop an analysis of Bitcoin's unique computational properties while arguing for a political ecology approach to understanding its uneven, variegated, and

parasitic relationship to the environment. Relying on and producing uneven geographies of infrastructure, energy, and the environment, the digital geographies of Bitcoin cannot be understood outside of the political, social, economic, and ecological relations in which they are embedded.

In order to theorize the material impacts of a decentralized technology like Bitcoin, we build upon an emerging body of work within and beyond geography that investigates the growing intersections between digital technologies and political ecology. Much of this work is concerned with the role of computation in the production of both physical natures and ecological knowledge around the globe (Büscher 2016, Nost 2015, Carver 2015, Mahmoudi and Levenda 2016, Gabrys 2016, Thatcher et al. 2016). Recent work builds on longstanding research programs in political ecology that focus on the intersections of power and control over nature and the production of scientific knowledge of the biophysical world, particularly through the use of the ecological sciences and geospatial technologies like GIS mapping and remote sensing (e.g., Robbins 2001, Harris and Hazen 2006, Turner 2003, McCarthy and Thatcher 2017). Similarly, there is an increasing intersection of political ecology and science and technology studies (STS) that focuses on the agential nature of technical processes and objects, and shares an interest with the aforementioned work in the conditions under which environmental knowledge and environmental markets are made (e.g. Lave 2012, Lave et al. 2014, Birkenholtz 2013, Robertson 2006).

We seek to add to this body of literature, while diverging slightly from the focus that existing research has placed on knowledge production. This is not to deny the importance of the production and reproduction of ecological power/knowledge. Instead, we hope to retain a focus on the power of discourse, while shifting our gaze more squarely toward the materialities of the digital. We see cryptocurrencies like Bitcoin as a perfect vector for exploring the complex intersections between computation and socio-ecological processes. Political ecology, as a field which is at its core concerned with the scalar (e.g., Blaikie's 2016 [1985] "chains of explanation") and networked (e.g. Rocheleau 2008) linkages between the local and the global, and with the simultaneously material and social character of the biophysical world (Bakker and Bridge 2006), provides an ideal lens for investigating the place-based and "earthly" characteristics of the distributed computational processes that make up the "cloud." Establishing these "chains of explanation" helps to underscore the local impacts of global capitalism, offering up, as Paul Robbins puts it, "a map for the way value flows out of the landscape, through local communities, and toward sites of accumulation far away" (Robbins 2012, 88).

Political ecological approaches, particularly those that have drawn from economic geography and critical political economy, have been productive in making visible the often invisible socio-ecological relationships around economic processes. Consider, for example, approaches like commodity chain analysis that investigate what goes unseen in socio-ecological processes like metals mining (Hartwick 1998), food systems (Guthman 2014, Friedberg 2009) and energy production (Ribot 1998). Similarly, in charting Bitcoin's material presence in and around Chelan County, we build upon Ingrid Burrington's (2016) explorations of the data centers of northern Virginia, highlighting the historical factors that influence how digital systems integrate with particular places and infrastructures (see also Pickren this issue). Similarly, work on e-waste has shown that the proliferation of computing technologies has produced a novel set of uneven geographies around pollution, waste disposal, and recycling (Pickren 2014, Gidwani and Reddy 2011, Corwin 2018) that are deeply place-based, localized, and relational.

In this article, we combine the sociomaterial focus of political ecology with an analysis of specific computational processes to avoid fetishizing attempts to simply make technical infrastructures visible—a warning highlighted by Louise Amoore (2018) and Shannon Mattern (2016). This is to say that while code and other technologies indeed play a key role in producing *space* (Thrift and French 2002), so too do the existing materialities and imaginaries of space produce *code*, and they do so only within concrete temporal and cultural contexts (Kitchin and Dodge 2011). In the same way that humans and their environments are recognized to be co-productive (Smith 2010, Castree and Braun 2001), our digital and material worlds are deeply entwined, and should be understood to be mutually affecting and reshaping one another.

To begin to untangle these relationships, first, we discuss the technical functioning of Bitcoin, demonstrating how an ideological commitment to the Austrian School of economics undergirds the technical functioning of the network. Next, we turn to a situated history of hydroelectric development in the Pacific Northwest, emphasizing the key role that public ownership and investment played in energy development in the region. With these relations in mind, we examine the specific situation of cryptocurrency miners in Chelan County, showing how Bitcoin operations act in a parasitic relationship with existing circulatory systems of energy, money, and social relations. We conclude by highlighting how a political ecological lens is particularly well suited for examining digital materialities.

2. A Near History of a Digital “Gold Rush”

“I’ve been working on a new electronic cash system that’s fully peer-to-peer, with no trusted third party.” Satoshi Nakamoto, post to the `gmane.comp.encryption.general` Newsgroup, October 31, 2008.

The idea of a distributed, anonymized cryptocurrency dates back to at least 1983 (Chaum 1983); however, it was not until the creation of Bitcoin that any such system found widespread success. An individual going by the pseudonym Satoshi Nakamoto first posted the Bitcoin design paper to an encryption newsgroup on October 31, 2008. Two months later, on January 3, 2009, Bitcoin’s “genesis block” was created, beginning the growth of a currency that would eventually be valued at over \$300 billion and use massive amounts of energy. At the time of writing in early 2019, the network consumes approximately the same amount of electricity as Romania, a nation with a population of a little over nineteen million.¹ In order to understand how cryptographically hashed strings of data have developed into a multi-billion dollar industry with extensive and uneven material impacts, it is first necessary to understand the underlying technological concepts behind Bitcoin and their underpinnings in the Austrian school of economic thought. In this section, we briefly review how Bitcoin functions, with a particular emphasis on its use of blockchain, and examine how the ideologies and metaphors around its creation and proliferation stem from this particular brand of economic thinking.

At its most basic, Bitcoin operates through public-key encryption. In each Bitcoin “wallet” a user stores their private key. Their matching public key is widely available and they may use it to request funds from any wallet on the network. Any transfer request must be approved (decrypted) by using the payer’s unique private key². When a payer approves a payment, the transaction information is sent out to the Bitcoin network for verification. Each node in the Bitcoin network represents a computer (or computers linked together). These nodes are continuously attempting to bundle together a series of approved transactions into a “block” and add this block to the blockchain. A new “block” is a sequence that bundles together new transactions with the immediately preceding block; in this way, every new block is “chained” backwards in time to the original fifty bitcoins that make up the “genesis block.” The Bitcoin blockchain is a “series of linked blocks, in which each block contains a set of transactions that don’t conflict with each other or with previous blocks” (Greenspan 2015).

Instead of a centrally controlled ledger keeping track of exchanges, each block acts as a stamp upon Bitcoin’s public, distributed ledger, cryptographically securing that *these exchanges have occurred at this time*. New blocks are added when a node in the network solves an equation that uniquely bundles together

¹ Bitcoin’s estimated yearly energy consumption can be found at the Bitcoin Energy Consumption Index (https://web.archive.org/web/*/https://digiconomist.net/Bitcoin-energy-consumption). While the numbers are necessarily imprecise, they speak to the scale and scope of Bitcoin’s energy consumption.

² Public-key cryptography is a common method of securing digital information across an open network. For a technical introduction to such systems, see Buchanan 2004.

a set of transactions to produce a desired result against the Bitcoin network's algorithm³ and propagates this solution through the network. Generating new blocks occurs through a "Proof-of-Work" system in which *finding* a new block is difficult, but *verifying* a new block, once found, is not. The system is designed to automatically adjust the difficulty of this process such that a new block is created approximately every ten minutes. Once a new block that satisfies the network's algorithm is found, the node that found the block attempts to propagate the new, longer blockchain throughout the entire network. At any given time, several candidate blocks may be waiting for final confirmation and propagation throughout the system; as the network is designed to always select the longest chain, in terms of computing power used, as valid, these alternatives dwindle with time until a final algorithmic consensus is reached⁴. This process has several ramifications both ideologically and materially, as it is simultaneously the only means of creating new bitcoins, the source of the system's security, and the cause of its growing use of resources.

The process of creating a new block on the blockchain and propagating it throughout the network is the only means by which new bitcoins are created. According to Nakamoto's original design and current specifications, there will never be more than twenty-one million bitcoin in existence. This decision has both technological and ideological roots. In terms of its technological roots, the data type used to record Bitcoin transaction outputs has a maximum value of 20,999,999.9769. This reflects the technical limitations of the data format itself and, while it could be changed in the code, the limit will remain so long as Bitcoin uses it. This upper limit of bitcoins produced is enforced programmatically by periodically halving the number of coins generated with each new block. This halving will occur roughly every four years (or 210,000 blocks) beginning at 50 Bitcoins per block and is estimated to reach zero in the year 2140⁵.

Ideologically, Bitcoin is rooted in a brand of "cyberlibertarian" thought (Columbia 2016) that draws its political and economic ideology from far-right economic theory, particularly, the Austrian school of economics (Columbia 2016). Proponents of this school of thought, including Bitcoin's pseudonymous founder Satoshi Yakamoto, focus on the individual and their desires (rather than the collective or the institution), making them inherently suspicious of government oversight or centralized banking, both of which are understood to distort economies. Followers of the Austrian school also strongly believe in the need for a market-selected money-form with a finite supply, leading many of them to advocate for a return to the gold standard. For this reason, the upper limit is purposeful in the design of Bitcoin, and derives from the Austrian school of economics' suspicions of fiat currency (Voorhees 2012). Similarly, Friedrich von Hayek's (1976) *Denationalisation of Money*, with its emphasis on the necessity of privately issued currencies in order to avoid the use of force to support fiat currencies, has been cited as a particularly influential work (Matonis 2012).⁶ The upper limit of bitcoins is meant to provide a "known supply and a known inflation schedule, unlike fiat money" (Hoegner 2015). The asymptotic, continual growth towards the twenty-one million bitcoin limit is meant to ease deflation and encourage exchange, preventing early adopters from holding the vast majority of wealth stored within the system. However, in practice, the known fixed limit of bitcoins has created speculation and deflationary properties that have led some to decry it as a failure as currency (see, for example, O'Brien 2013). As the total value of the Bitcoin system has grown, the hard-coded upper limit in the number of bitcoins has led to concerns over Bitcoin's function as a

³ Bitcoin uses a double SHA-256 hash function for its encryption. SHA stands for a Secure Hash Algorithm, a type of cryptographic function developed by the United States National Security Agency, which "takes an arbitrary length input and produces a fixed length 'fingerprint' string" (Penard and van Werkhoven 2008, 1).

⁴ For a more detailed explanation on this process, see Greenfield 2017, pages 124-129.

⁵ It is important to note that 21 million is the upper limit of bitcoins that can be *produced* and does not reflect the maximum number that may one day be in circulation. Bitcoins may be lost or purposefully destroyed through a variety of means.

⁶ At time of writing, Hayek's (1978) *Denationalisation of Money: The Argument Refined* is available in Portable Document Format (pdf) at the Satoshi Nakamoto Institute: <https://web.archive.org/web/https://nakamotoinstitute.org/literature/>.

speculative store of value rather than a currency meant to ease the exchange of goods and services (Krugman 2013).

From its very inception, the process of “mining” new Bitcoins has been compared to mining for gold. Similar to the enforced cap on total possible bitcoins, this analogy has an ideological connection to the Austrian school of economics’ belief in the value and importance of a gold standard: “[t]he steady addition of a constant amount of new coins is analogous to gold miners expending resources to add gold to circulation” (Nakamoto 2008, 4). The resources to produce bitcoins are computational power and the electricity required to power said computation, but the metaphorical link to “mining” and to natural resource extraction is explicit in the founding documents of Bitcoin. Maurer *et al.* (2013, 262) suggest a “digital metallism” undergirding Bitcoin, one which grounds “value, inspired by gold standard economics, through algorithmic control of the money supply.” Bitcoin is not the first asset to be likened to gold; however, Maurer *et al.* (2013, 268) argue that the intentional use of “[t]he ‘mining’ metaphor is a deliberate nod to precious metal-based monetary systems.” Bitcoin, from its very design, purposefully attempts to mimic the perceived advantages of gold-based monetary systems as outlined by Austrian school thinkers; namely, that an existing upper limit would prevent excessive inflation and that individuals could enter into its use without coercion by an existing state (von Mises 1953).

These ideological commitments to the tenets of monetary policy found in the Austrian school of economics have very specific implications for how and why the Bitcoin network consumes electricity at such a prodigious rate. Technically, when a new block is “mined,” the network accepts the “longest” chain as the legitimate one; however, “longest” here refers not simply to the chain with the most blocks, but to the chain that has taken the most amount of computing power to process. As Nakamoto (2008) put it:

“The longest chain not only serves as proof of the sequence of events witnessed, but proof that it came from the largest pool of CPU power. As long as a majority of CPU power is controlled by nodes that are not cooperating to attack the network, they’ll generate the longest chain and outpace attackers.”

In other words, Bitcoin protects itself from false transactions by automatically accepting the chain with the greatest combined difficulty to produce as measured through computational power used.

Through this process, Nakamoto (2009) sought to “solve” what he, drawing from Austrian school thinkers like Menger, Von Mises, and Hayek, perceived as one of the irreconcilable problems of fiat currencies: “all the trust that’s required to make it work.” In a technical sense, this is achieved through the functioning of the network and its algorithm which secures the blockchain so long as no single node controls more than 51% of the network. But, ideologically, this trust is placed not simply in the network and algorithm, but, as Hardy (2014) has argued, in the existence of a “borderless world of hyper-empowered individuals, alive mostly through the Internet” that will make use of said system. Fiat currency, ultimately, relies upon a general public acceptance of its value, that it can be exchanged for goods and that its value is, in some way, secured through the country that issued it (Krugman 2018). Trust in the issuer substitutes for trust in the currency. With Bitcoin, as something collectively issued, that trust has been transferred into the security of the network itself.

If the need to transfer trust from a central bank to an algorithmic system is ideologically drawn from Austrian school economic theory, the technological means by which security is achieved - through a scaling of the difficulty to produce a new block on the blockchain - is the direct cause of the Bitcoin network’s consumption of natural resources. As the production of new blocks is both the only means of exchanging Bitcoins and the only means of creating new Bitcoins, “miners” are forced into a continual race to solve mathematical problems whose difficulty scales with the size of the network itself. Each block is usually created by whichever node on the network is able to throw the greatest amount of computational power at the problem. By scaling the difficulty of these problems to keep the rate of block discovery relatively

constant, Bitcoin creates a system in which greater computational power is continuously rewarded with no upper bound.

Computation requires electricity and produces heat. Since Bitcoin miners are not typically producers of electricity, their ability to turn a profit through “mining” is tied to the computational demands of mining, the climate of a given region, and the cost of electricity in said region. This is what produces the uneven terrain of the Bitcoin mining network. While the currency itself is predicated upon the desire for a decentralized network built on an algorithmically-produced and enforced system of trust, the technical system created to secure and maintain the network enforces a variegated circulation in which mining touches down in particular places, at particular times, to produce material effects upon the lands and people. With this in mind, we now turn to the historical context of hydropower in the Pacific Northwest.

3. Hydropower Histories

In a recent paper, Eric Nost writes that “the consequences of code for nature remain understudied” (2015: 2573), noting that political ecologists are particularly well-suited to understand them. We agree with this point, using it as a framework for understanding the material effects of both Bitcoin’s code and the attendant infrastructures that make it possible. Doing so requires first exploring the environmental histories of hydropower in the Columbia River Basin, a region that is fundamentally rooted in the river and its circulations. Understanding the geographies of emerging technologies like Bitcoin requires one to recognize their embeddedness in the physical world, as well as their engagements with existing power structures and property relationships. Political ecology—a field of study centrally concerned with understanding environments as co-produced by nature and society through both material transformation and discursive construction—offers a particularly useful lens for doing so.

In his landmark environmental history of the Columbia River, Richard White describes the river as an “organic machine” (White 1995). For him, the Columbia can only be understood as a fundamentally *socio-ecological* system, one that has functioned historically and into the present to circulate labor and energy—of the water, workers, salmon, and many other entities that are bound together and whose relationships to one another can only be understood through their various entanglements with the river. Through the process of eating and migrating, anadromous fish like salmon and steelhead convert solar energy into body mass, which is required for their long journey to spawn. Native Americans, local fisherpeoples, commercial canning operations, and others have relied on the conversion of these salmon bodies into food to sustain themselves both nutritionally and economically. Meanwhile, through hydroelectric dams like those operated by the Chelan Public Utility District (PUD), the large volumes of energy that flow through the river are captured and turned into electricity. Yet, these dams are highly contested, as the capture and circulation of electricity impedes the flow of other systems and livelihoods.

Dams along the Columbia, including the three dams operated by the Chelan PUD (Rocky Reach, Rock Island, and Lake Chelan), were all built during the “era of big dam building” in the United States (Magilligan et al. 2017, 78). While the Columbia has historically served as the lifeblood of the Pacific Northwest and as the singular feature which unites the region (Voge, 2011), the deep dependence of the region on the river was solidified in new ways with the building of big hydropower following the New Deal (Billington and Jackson 2017). Throughout the region, public investment was leveraged at a range of scales to generate power, promote flood control, and substantially alter the landscape with the aim of widespread electrification, employment, and rural development (Walker and Brechin 2010, Billington and Jackson 2017). While many of the Columbia’s largest dams, like the Grand Coulee, were the result of direct federal government investment through entities like the Works Progress Administration, the more modest dams of Chelan County came to exist through the formation of community-managed public utility districts that could leverage public funds to generate and distribute power throughout the rural Northwest (Leighninger Jr. 2007, Balmer 1982). The large volumes of cheap electricity that the dams produced powered a range of natural resource industries and large-scale industrial ventures, including, until recently, a large aluminum

smelting plant in Chelan County that employed over 400 people (Banse 2017). Unlike other nearby watersheds, the Columbia River Basin came to be particularly dependent on public hydropower (Brooks 2009), often produced on public lands and overseen by public utilities commissions (PUDs). The public character of hydropower is particularly pronounced in Central Washington. While many of the PUDs in Washington State purchase power in bulk and distribute it to their customers, all three dams in Chelan County are owned and managed by the PUD, meaning that they both make and distribute their own power. The production of hydropower also takes place largely on public land—within the Lake Chelan watershed, for example, 87% of the land is publicly owned (Chelan County Natural Resources Department 2012). The region thus came to be:

“home to a strong movement in favor of publicly owned electrical power, a movement led by farm, labor, and some industrial interests. In 1930, advocates in the states of Washington and Oregon had used citizen initiatives to pass landmark laws enabling residents to form county-based public utility districts.”(Vogel 2017, 45).

Dams are a large-scale intervention that fundamentally reshaped the region in their image during the New Deal era—their physicality embodies a modernist vision of rural development and the control of nature, supported through government intervention, investment, and localized control and management (White 1995). Yet, this vision of a Pacific Northwest powered and irrigated by hydroelectric dams was not an uncontested ideal or one without major social and ecological costs, and the 1990s and early 2000s saw a fundamental reevaluation of the socio-ecological relations around hydroelectric power. While the Columbia River is the greatest producer of hydropower in the Western Hemisphere (Cosens and Williams 2012), economic restructuring in many parts of the rural Pacific Northwest has meant that there has not been a local sink to absorb the huge quantities of power being produced. And, as many salmonid species have gained protection under the US Endangered Species Act—including eight species of salmon and four species of steelhead that make their home in the wider Columbia River Basin—the costs and benefits of large scale hydroelectric power began to shift over time (Cosens and Williams, 2012), as dam relicensing often requires the costly installation or upgrading of fish passage (Sumner, 2017). The voice of the region’s Indigenous tribes, many of whom have had their ancestral territories and livelihoods irreparably altered through the installation of dams, have also played a critical role in dam decommissioning and removal (Guarino 2013, Fisher 2004, Wilson 1999).

In addition to the fact that they impede ecological function, many dams that were built in the heyday of big dam building are decaying, inefficient, or filled with sediment (McCully, 1996). Furthermore, the majority of these dams were built with a 50 year lifespan (Guarino 2013), and changing economies in rural areas can present challenges to generating profits from locally-sold hydropower, especially given that the costs of operation consistently rise over time. As a study from Canada’s Ontario Hydro has shown, this is because of maintenance issues:

“operating costs rise dramatically after around 25–35 years of operation due to the increasing need for repairs. When the cost of maintaining an old dam exceeds the receipts from power sales, its owners must decide either to invest in rehabilitating the dam, or, if the cost of repairs would be prohibitive, to disconnect the dam from the grid and cease producing power” (McCully 1996, 126).

These maintenance issues are compounded by the fact that, since the New Deal when many US dams were constructed, the restructuring of the political economic system in ways that favor privatization has meant that funding for repairing or replacing aging infrastructure has declined precipitously. Thus, since 1975, over 1,000 dams of varying sizes have been removed in the US (O’Connor et al., 2015). This includes three high profile dam removals in Washington State: the Condit Dam removal from the White Salmon River in 2011 and the Elwha (2012) and Glines Canyon (2014) dams from the Elwha River. The Elwha Dam removal was the largest dam removal in US history, and was celebrated by environmentalists and tribes, as a major victory and recognition of the rights of both Indigenous peoples and anadromous fish, including salmon

(Guarino 2013). In the case of the Elwha, dam removal meant the retreat of the reservoir, and as a result, the uncovering of Lower Elwha Klallum cultural sites, allowing the tribe to gather at their peoples' creation site for the first time in a century (NPS 2012). While many of the recently decommissioned and removed dams in Washington state reflect a situation where a changing economy made ecological transformation a viable option, cryptocurrency mining operations are providing new local uses for the energy still produced by hydroelectric dams. On the one hand, this potentially tips the balance towards repairing rather than removing dams, while, on the other, it simultaneously lowers the profit margin of the energy produced as it is increasingly sold locally rather than exported and sold at a higher rate (Roberts 2018b).

4. Plugging in

While the Bitcoin network is made up of a dispersed, global network of computers that have plugged into the blockchain, places with infrastructural and ecological conditions that best favor the profitable mining of Bitcoins—places like Chelan County, Washington—disproportionately feel the material effects of the network. As Bitcoin miners plug into existing electrical infrastructures to power their mining equipment, they become part of complex circulatory systems of electricity, resources, and capital that have been central to the production of the spaces of Central Washington. Massive dam projects in the area have not only provided residents with cheap electricity, they have also changed the landscape, disrupted existing metabolic processes, attracted power-hungry industries, and subsidized social services in the largely rural area. The newly-arrived profiteers, armed with plug-and-play mining machines that can quickly convert massive amounts of electricity into speculative digital value, threaten to further change the spaces of Chelan County while providing little in return.

Within the county, there has been growing concern over Bitcoin mining's impact on existing infrastructures and fear that mining operations will vanish once the profitability of Bitcoin recedes or other geographic locations prove to be more desirable (Virgin 2018). Miners have strained local electricity grids, requiring the building of new power substations and other electrical infrastructure to handle the increased power loads (Roberts 2018a). If miners decide to pick up and leave, the county will have to foot the bill for these infrastructural investments that far exceed existing residential and industrial electricity needs. The extraction of valuable cryptocurrencies made possible by abundant, cheap energy produced by Chelan County's dams has not led to jobs or even the promise long-term industry in the region (Noland 2015),⁷ prompting public debates on how to handle the burgeoning industry. In response, the Chelan PUD has implemented a number of measures to regulate and often discourage mining operations. On January 1st, 2017, for example, the PUD increased electricity rates for "high density loads" like server farms and cryptocurrency mining operations (Craig 2016). The changes, however, did not effect then-current operations, which would have a five-year window before feeling the rate hikes. Then in March of 2018, the PUD, citing strained electricity grids and safety concerns, placed a moratorium on new applications for cryptocurrency mining operations (Craig 2018a). The PUD argued that further study of the impacts of cryptocurrency mining were needed before approving more operations. If approved, pending applications for mining ventures at the time would have matched the existing power consumption of the entire county (Roberts 2018b). Later in the year, the PUD proposed rate hikes that would approximately double electricity rates for both industrial and home mining operations (Banse 2018). As the potential long term impacts of Bitcoin mining come into focus, the Chelan PUD scrambles to regulate an industry whose flexible form poses a unique threat to existing social and material relations of the county.

The PUD's continuing changes are, in part, a response to the asymmetric relationship between Bitcoin miners and the infrastructures on which they depend. Miners largely rely on highly mobile capital, in the form of mining computers, that can easily be moved and plugged in somewhere else that promises better profit margins. Local infrastructure that is required to support mining operations becomes sedimented in

⁷ Despite evidence to the contrary, some proponents of cryptocurrency mining, however, have argued that mining will attract high tech workers that will lead to new industry in the area (Robinson 2016).

the form of cables, substations, and other electrical components that are immobile and serve no other purpose if future electricity usage declines. As Susan Leigh Star and Karen Ruhleder (1996) argue, infrastructure emerges in relation to practice, so it is a matter of asking “when—not what—is an infrastructure” (113). From the point of view of Bitcoin miners, local infrastructure primarily consists of electricity rates, capacity for high draw operations, local business regulations, high speed internet connections, and the physical climate, which can provide free cooling for computers working at the limits of their computational abilities. For miners, complex processes that connect infrastructure and ecology (which are often taken as one and the same) are irrelevant footnotes in the rush to consume electricity at the lowest rates possible. This narrow view means miners scour the globe for places with similar infrastructural conditions to exploit, drawing them to places like Inner Mongolia (Li and Marchi 2017) and Iceland (Popper 2013). For the PUD, however, high draw operations throw existing systems into chaos, as the infrastructures for mining becomes the county’s difficulty (see also: Star 1999). Existing standards, practices, and materialities that make the production and transmission of electricity possible, and which had become the taken for granted grounds of daily life in the county, must now be rethought in the face of inflated power demands.

Local electrical infrastructure centers around the dams that generate hydropower—described as “the county’s precious jewel” by the PUD’s board Vice President Garry Arsenault (Craig 2018d). Hydropower is fed through an electrical infrastructure of transmission cables and substations that can handle the loads demanded by local residents, as well as transfer excess electricity to surplus markets. The dam also enrolls the Columbia River as infrastructure, encompassing practices of management, control, and regulation that allow for the efficient powering of the grid⁸. Laborers who work to construct and maintain a functioning electrical grid become part of the wider infrastructural system of the county. As Bitcoin mining diverts labor away from existing maintenance priorities (Craig 2018a), infrastructural arrangements must be reassessed in order to keep up with growing demand. For those who are tasked with maintaining electric grids, protecting the fish of the Columbia River, and providing public services, the effects of Bitcoin mining reverberate throughout a complex network of infrastructural, financial, ecological, social, and material relations.

Bitcoin miners intervene in and disrupts local networks of relations as they plug into an existing circulatory system of electricity, capital, and social services. Citing the growing interest in cryptocurrency operations, the PUD observed that the “recent surge in inquiries is putting a strain on the PUD to provide the best for the most for the longest because the existing business plan, revenue forecast and resource allocation does not include the type of personnel demand, nor infrastructure, that will be required to adequately respond” (Chelan County PUD n.d.). In Chelan County, only about 15% of the electricity produced by local dams is sold to local retail customers (based on 2015 numbers, see: Chelan County PUD 2015). The rest is sold to other energy markets, producing nearly 100 million dollars in surpluses that are circulated back to local residents through subsidized social services. Subsidies support artificially low electricity rates, which are sold to consumers at a loss of over \$10 million, as well as fund water and wastewater services, local parks, and a fiber-optic network that provides high speed, reliable internet service across the county (Chelan County PUD 2015). Miners not only rely on these services—subsidized electricity and high speed internet services, in particular—they actively consume the energy that makes the existence of such services possible. In the interest of making quick profits, cryptocurrency profiteers threaten the very conditions that make Chelan County a desirable place for mining, potentially leading to increased electricity rates across the board (Roberts 2018b) and reduced funding for public services.

Bitcoin mining, then, enables the circulation of Bitcoin by validating the cryptocurrency’s transactional ledger, but it does so as a parasite⁹ in relation to the circulatory system of energy in Central Washington.

⁸ Similarly, Ashley Carse (2014) shows how watershed forests become infrastructure for the Panama Canal, which conflicts with how campesinos understand the forest.

⁹ The term ‘parasite’ has a contested and fraught history in relation to social issues. From Marx’s parasitic vision of capitalist vampires to racist social imaginaries of the ‘other,’ it has often been leveraged as a metaphor to describe

Only by embedding itself within and feeding off of the existing flows of energy and capital does Bitcoin become valuable and, in so doing, transfers that value throughout the globally dispersed Bitcoin network. As Chelan County struggles to balance subsidized electricity and social services with the desire to support economic growth in the region¹⁰, Bitcoin miners contribute to neither. Due to their ever-increasing demand for electricity, combined with low labor needs and production of value that relies on subsidized electricity rates, we contend that Bitcoin mining exists in a parasitic relationship with the infrastructure of the county and, thus, the historical legacy of public works projects in the region. This is not to say that all Bitcoin mining operations are parasitic, but rather, in this particular case, Bitcoin exists in a parasitic relationship with the stated desires of the PUD. This relationship is further enabled by the unique technical affordances of cryptocurrency, whereas highly mobile and modular mining machines can be plugged in where conditions are ripe for exploitation¹¹. Recognizing this parasitic context has led the PUD to threaten to prosecute unsanctioned miners with power theft (Craig 2018d). In a situation where electricity is sold below operating costs to local residents, theft is a fitting charge for those who attempt to leverage subsidized public services to increase profit margins on cryptocurrency mining. On smaller scales, such theft is tempting as plug-and-play mining machines are easy to obtain and relatively hard to detect.

The technological development of mining hardware and facilities has made it easier for miners to simply plug in to existing infrastructure where conditions are advantageous and begin converting electrical currents into currency. Early mining was performed using specialized software running on central processing units (CPUs) and later graphics processing units¹² (GPUs) commonly found in personal computers. To increase computational efficiency and maximize return rates in relation to electricity consumption, mining later moved to more specialized hardware: first field-programmable gate arrays (FPGAs) and later application-specific integrated circuits (ASICs) (Taylor 2013). The latter are highly specialized circuits whose only possible function are to efficiently mine the specific cryptocurrency for which they were designed. Housed within mining rigs designed to maximize thermal efficiency in order to move heat away from overtaxed circuits (Wilson 2018), ASICs provide a scalable channel for capital investments that promise quick returns. In Chelan County, ASIC mining operations run the gamut from miners who run illicit home operations using a handful of ASIC machines to massive, industrial-sized operations that fill warehouse spaces with these plug-and-play devices. Additionally, facilities are designed to further regulate thermal flows, drawing hot air away from mining machines often using giant fans. Mimicking the plug-and-play nature of ASIC machines are cheaply and quickly built structures, sometimes resembling sheds and sometimes using converted shipping containers that can be filled with ASIC machines and placed anywhere with adequate electricity currents and high speed internet (Noland 2015).

social relations. In contrast, here we use it to describe a specific machinic function of computing, leveraged at multiple scales by a wide range of actors, with a contested relationship to existing economic and social circulations. The political potential and impacts of the computational parasite are not known in advance—this article only traces one specific case. In doing so, we hope to provide a framework for political ecology approaches that seek to understand the material relations of computing as they exist in specific places.

¹⁰ “More power used within the county means less power available to sell on the wholesale market, and less revenue available to keep retail rates low – but it could also spur local economic development” (Chelan County PUD 2015).

¹¹ Data centers that moved to the region to take advantage of cheap electricity rates have also had fraught relationships with the public and PUDs (Glanz 2012). The distributed nature of Bitcoin mining, however, contrasts with the centrally-owned nature of large data centers.

¹² In response to high demands for GPUs that could be used to mine cryptocurrencies, GPU prices skyrocketed. Prices have recently relaxed as GPU mining has become unprofitable and mining has shifted to ASIC machines (Forrest 2018).



A Giga Pod being built by GigaWatt (<https://web.archive.org/web/https://twitter.com/WTTtoken/status/893292088502226944>), a company in East Wenatchee, WA (right across the river from Chelan County) that offered cryptocurrency mining services powered by hydropower. The company filed for bankruptcy in November of 2018.



A made to order “cryptocurrency Mobile Mining Unit” that can be shipped anywhere in the world ([https://web.archive.org/web//https://powerniningshop.com/products/cryo-mining-container](https://web.archive.org/web/*/https://powerniningshop.com/products/cryo-mining-container))*

These assemblages of specialized ASIC mining machines linked together within customizable and shippable containers form an infrastructural parasite par excellence, ready to converge anywhere and efficiently convert massive electrical currents into speculative digital value. While utility districts scramble to come to terms with the massive electricity draws of sanctioned operations they must simultaneously attempt to detect illegal operations by monitoring unusual spikes in energy draws and search for the sound of massive fans that move hot air away from overheating ASICs miners (Roberts 2018a). Large scale operations in residential areas often draw far more power than wiring was designed for, which can result in the destruction of electrical equipment and fires (Craig 2018b). In addition to shutting down illicit operations and levying fines, the Chelan PUD has used social media to communicate the dangers of illegal operations as a means to dissuade residents from buying miners and plugging into the Bitcoin network¹³. The crackdowns have been met with resistance, leading the PUD to increase security measures at their headquarters (McDaniels 2018) and driving some miners to move further down the Columbia River to The Dalles, Oregon. The Dalles, which also benefits from cheap hydropower, will soon be facing many of the issues that their neighbors to the north are currently grappling with (Shepherd 2018).

Like many digital services, Bitcoin mining functions in a parasitical relationship to existing infrastructure while failing to contribute to its building or maintenance (Langley and Leyshon 2017, Smicsek 2017). Before regulations, studies, or long term impact assessments are able to grapple with the social, ecological, and material effects of them, digital services are rolled out as massive social experiments that quickly accumulate

¹³ For example, the PUD produced a Bitcoin PSA based on the popular TV series *Stranger Things*: https://web.archive.org/web/*/https://www.facebook.com/chelanpud/videos/1615282811903856/_

capital. Here, we argue that it is not enough to understand these systems in the abstract or through their imagined uses—there is a need for studies that show how specific algorithmic systems plug into existing local infrastructural systems and processes of circulation. These processes include the circulation of energy, capital, resources, and other social and material relations that experience far-reaching, uneven, unpredictable, and localized impacts when disrupted by parasitical digital services. The histories and specificities of these relations are key in understanding the possibilities and impacts of digital systems like Bitcoin. All of this plays out, as aluminum and plutonium production did during another era, through the flowing of the Columbia River, creating a new era in which this vast ecological system is enrolled within systems of political-economic production.

5. Conclusion: Towards digital political ecologies

Up the Columbia River from the toxic remains of the Hanford nuclear power plant lies the unfinished structures of GigaWatt—one of the largest and earliest corporate mining operations to move to central Washington. On November 20, 2018, GigaWatt, filed for Chapter 11 Bankruptcy protections (Roberts 2018c). Just across the river from Chelan County, GigaWatt’s shuttered facilities might be a sign of things to come. The steep decline in cryptocurrency prices, including Bitcoin, since their peak in late 2017 has caused some to believe Bitcoin has entered a “death spiral” from which it cannot recover (Sarin 2018). Written during a previous decline in usage and before its most recent peaks in valuation, Greenfield (2017, 146) described Bitcoin itself as a “dead letter as a method for the exchange of value at any meaningful scale ... but it functioned beautifully as a proof of concept.” While Greenfield is neither the first nor last to declare the failure of Bitcoin as a currency (see, inter-alia, O’Brien 2013, Hearn 2016, Shiller 2018, Zook and Blankenship 2018), enthusiasm for blockchain technologies, including cryptocurrencies, means the parasitic relationships between computing and local environments will continue to reemerge. For example, despite the emergence of second and third generation cryptocurrencies that have moved away from both the “mining” metaphor and its associated proof-of-work blockchain securitization, at the time of writing Bitcoin maintains a market capitalization larger than the next ten currencies combined. Thus, it becomes increasingly critical to understand that these types of technologies tend to leverage and build upon existing infrastructures, and that these infrastructures have politicized pasts, presents, and futures. Given its central focus on excavating power dynamics, historical context, and inter-scalar linkages—using concepts like “chains of explanation” (Blaikie's 2016 [1985]) or “networks” (Rocheleau 2008)—political ecology offers a useful toolkit for illuminating the uneven and deeply place-based materialities and political lives of these “decentralized” and “web-based” technologies. In Chelan County, for example, in addition to enrolling local energy systems into a global processes of circulation and profit-making, miners are also enrolling themselves into existing struggles over land-use, energy systems, and for justice and recognition.

In this paper, we have illuminated some of the myriad material entanglements and social relations that miners are literally “plugging into” when they come to Central Washington seeking cheap electricity. In section 2, we demonstrated how Bitcoin’s technical systems and underlying ideology mutually reinforce one another. Section 3 situated the current explosion in Bitcoin mining in Chelan county within environmental histories of hydropower development in the Pacific Northwest. This history is necessary for understanding the public nature of the system and the future of hydroelectric power in a region where it has long been contested and dams are actively being decommissioned and removed for the sake of salmon and Indigenous communities. In section 4, we contrast the fixity of hydroelectric power infrastructure with the mobility of cryptocurrency mining operations, arguing in turn that Bitcoin miners in the region should be understood as parasites on the system—benefiting from social services and cheap power that are a legacy of public investment in and control over the energy system—but give little in return. Bitcoin mining produces value but does not reinvest, and if fortunes change in the markets or cheaper power becomes available elsewhere, these actors will likely move, leaving the Public Utility District in a bind. As it stands today, the long term impacts of the infrastructural detritus that Bitcoin leaves in its wake remains to be seen in Chelan County and beyond. Yet, is certain that blockchain technologies will have lasting impacts on a place that has been continually remade by the work of the mighty Columbia River. In so doing, we contribute to a growing

literature that leverages political ecology, with its attentive concern for the links between the local and the global and to the current and historical power dynamics embedded in socio-natural configurations like energy systems.

Disruption is the stated aim of much of the tech industry. Yet narratives of disruption rely upon, but often elide, the very real environmental and social histories of the times and places at which they converge. Building upon previous work that shows how the design and deployment of specific database structures, algorithms, and analytics can set the very limits of what can be seen or known of individuals, land, and knowledges, here we show how sociotechnical assemblages, and their underlying ideologies, can result in global networks converging in specific places, at specific times, to feed off of existing circulatory systems. Disruptions of this sort intervene in grounded relations between individuals, land, energy, and society.

It is important to keep researching connections between data structures and digital infrastructures, and exploring the political constitutions and assemblages enabled and constrained by digital media. Further, it is necessary to turn a continual eye to the economic and social structures that contribute to the regional geographies of technology industries (Saxenian 1996; Zook 2005). But, we suggest additional focus on the historical-material conditions under which these infrastructures, algorithms, and computational systems emerge. “Infrastructure begets infrastructure” (Mattern 2017, vii) and “[n]etworks build atop networks” (Burrington 2016), but how this occurs is deeply entwined with both the ideologies undergirding these technologies and the sociomaterial relations of a place. More than the materiality of the digital, of its presence or absence in various forms, digital political ecologies opens for consideration systems and relations that are always-already both ephemeral and sedimented, both knowledge and power.

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