Bitcoin Energy Estimates

Estimating the energy use of the Bitcoin network using various approaches.

by Steven Black
Project home: https://github.com/StevenBlack/bitcoin-energy-estimates
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Introduction

Bitcoin mining uses a Proof-of-Work consensus mechanism. This is controversial for some because that supposedly requires a lot of electrical energy. We see claims the bitcoin network "*uses as much electricity as a small country*", or "*requires as much electricity as Belgium, or Chile.*"

This study assessed those notions using the following approaches:

1. ***Presuming Bitcoin mining is marginally profitable, how much energy can be used compared to actual mining rewards over time?***
2. ***Given the reported hashrate, how much energy would be required to achieve that.***

This paper uses **Canadian dollars**, partly because that's my fiat currency, and because Canada publishes particularly good statistics about electricity generation and costs.

Bitcoin price, block rewards, and fees

Bitcoin Price

For the purpose of discussion, what is the current price of Bitcoin in Canadian dollars?

In[717]:=

```
Now
```

Out[717]=

Sat 21 Oct 2023 15:42:33 GMT–4

In[718]:=

```
BTCPrice =
 CurrencyConvert[Quantity[1, "Bitcoin"], Quantity[1, "CanadianDollars"]]
```

Out[718]=

C$40 885.41

Bitcoin Block Rewards

Bitcoin miners are compensated with the block reward for blocks they successfully mine, plus all the transaction fees in that block. In the current epoch (2020 - 2024) the block reward is 6 1/4 BTC.

In[719]:=

```
blockreward = Quantity[6.25, "BTC"]
```

Out[719]=

฿6.25

ASSUMPTION: the average of transaction fees per block is 0.08 BTC.

In[720]:=

```
blockfees = Quantity[0.08, "BTC"]
```

Out[720]=

฿0.08

Therefore, the total Bitcoin paid to miners for an average block, denominated in Bitcoin.

In[721]:=

```
blockRewardPlusFees = (blockreward + blockfees)
```

Out[721]=

฿6.33

The Actual Block Rate

Historically Bitcoin blocks land at a rate faster then the block time target (6 per hour, or 144 blocks per day). Let's recon an average block rate over a sample interval to present day:

In[722]:=

```
blocksample = 100 000;
blocktime = UnitConvert[
  (Now - BlockchainBlockData[-blocksample]["Timestamp"]) / blocksample,
  MixedUnit[{"Minutes", "Seconds"}]]
```

Out[723]=

9 min 49.4525 s

In[724]:=

```
blockrate = Quantity[Quantity[1, "Hours"] / blocktime, "per Hour"]
```

Out[724]=

6.10736 per hour

In[725]:=

```
blockRewardPlusFeesPerHour = blockRewardPlusFees * blockrate
```

Out[725]=

฿38.6596 per hour

Hourly Economics

Global Revenue Per Hour

The value, in Canadian Dollars, of all Bitcoin mined globally, per hour.

In[726]:=

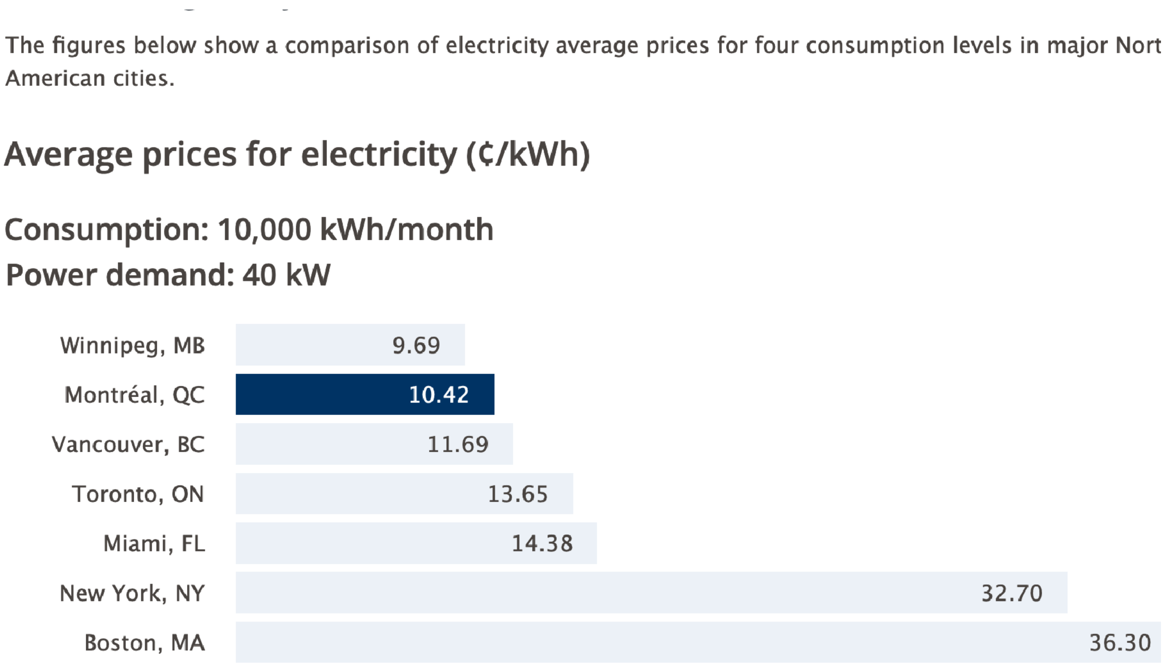
```
blockCADperHour =
 Quantity[QuantityMagnitude[blockRewardPlusFeesPerHour], "per Hour"] * BTCPrice
```

Out[726]=

$C\$1.58061 \times 10^{6}$ per hour

Electricity Cost, per kWh

See: https://www.hydroquebec.com/business/customer-space/rates/comparison-electricity-prices.html



Let’s presume that nobody in their right mind would want to mine Bitcoin in New York or Boston. Here's the distribution of electricity input costs from the other 5 locations.

In[727]:=

```
electricityInputCost = Quantity[
   Around[
    {0.0969, 0.1042, 0.1169, 0.1365, 0.1438}
   ]
   , "CanadianDollars"
  ] / Quantity[1, "kWh"]
```

Out[727]=

C$ (0.120 ± 0.020) per hour per kilowatt

Business Cost Assumption

Let’s presume 85% of mining revenue is available to pay electricity cost.

In[728]:=

```
availableForElectricity = 0.85
```

Out[728]=

```
0.85
```

Energy Economically Sustainable

In[729]:=

$$\text{btcPower} = \frac{\text{blockCADperHour} * \text{availableForElectricity}}{\text{electricityInputCost}}$$

Out[729]=

$$(1.12 \pm 0.19) \times 10^{7}\ \text{kW}$$

Cognitively we can say, Bitcoin's power consumption is in the order of 11 GWH.

In[742]:=

```
AnnualEnergyConsumption = btcPower * Quantity[365 * 24, ("Hours" / "Year")]
```

Out[742]=

$$(1.12 \pm 0.19) \times 10^{7}\ \text{kW}$$

Comparisons

Let’s compare the energy that can be economically used by the Bitcoin network with various things.

Robert-Bourassa generating station — a.k.a. “LG-2”

See https://en.wikipedia.org/wiki/Robert-Bourassa_generating_station

In[731]:=

```
RobertBourassaDam = 5616 MW // UnitSimplify // N
```

Out[731]=

```
5.616 GW
```

What is Bitcoin’s global energy use in terms of LG-2?

In[732]:=

```
btcPower / RobertBourassaDam
```

Out[732]=

$$(2.00 \pm 0.34)$$

Province of Québec

In 2019 the Province of Québec produced 212.9 TWh of electricity.

What is Bitcoin’s global energy use as a proportion of Québec’s electricity production in 2019?

In[733]:=

```
Québec2019 = 212.9 h TW
```

Out[733]=

```
212.9 h TW
```

In[734]:=

```
Québec2019day = Québec2019 / (365 days) // UnitSimplify
```

Out[734]=

```
24.3037 GW
```

In[735]:=

```
btcPower / Québec2019day
```

Out[735]=

```
(0.46 ± 0.08)
```

Province of Ontario

See https://www.cer-rec.gc.ca/en/data-analysis/energy-markets/provincial-territorial-energy-profiles/provincial-territorial-energy-profiles-ontario.html

In 2019, annual electricity consumption per capita in Ontario was 9.6 megawatt-hours (MWh).

In[736]:=

```
Ontario2019PerCapita = Quantity[9.6, "Hours" * "Megawatts" / "People"] / Quantity[24 * 354, "Hours"];
Ontario2019PerCapita = UnitConvert[Ontario2019PerCapita, kW / people]
```

Out[737]=

```
1.12994 kW/person
```

In[743]:=

```
(btcPower / Ontario2019PerCapita)
```

Out[743]=

$(9.9 \pm 1.7) \times 10^{6}$ people

United States

See https://www.worlddata.info/america/usa/energy-consumption.php

In[739]:=

```
USAPerCapita = Quantity[11.757, "Hours" * "Megawatts" / "People"] / Quantity[24 * 354, "Hours"];
USAPerCapita = UnitConvert[USAPerCapita, kW / people]
```

Out[740]=

```
1.38383 kW/person
```

In[744]:=

```
(btcPower / USAPerCapita)
```

Out[744]=

$(8.1 \pm 1.4) \times 10^{6}$ people