Bitcoin and Global Climate Change: Emissions beyond borders

Supplementary documents

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PLAN

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Estimation the Carbon Footprint of Bitcoin

Chapter 1

Extract Data

Related Folder : Document-2020\Chaptre-1\N1-Extract-Data

Extract Data

Steps :

1- Write python script that download the data related to the bitcoin mined blocks

```python
import json
import requests
import datetime
import pandas as pd
from pandas.io.json import json_normalize

api_url = 'https://chain.api.btc.com/v3/block/date/'

# required to prevent the request from being blocked by the API
headers = {'User-Agent': 'Mozilla/5.0 (Macintosh; Intel Mac OS X 10_11_5)'
                         ' AppleWebKit/537.36 (KHTML, like Gecko) '
                        'Chrome/50.0.2661.102 Safari/537.36'}

blocks = []
start_year = 2018
end_year = 2018
start_date = datetime.date(start_year, 1, 1)
end_date = datetime.date(end_year, 12, 31)
n_days = 1 + (end_date - start_date).days

for offset in range(n_days):
    # prepare the url for the day start_date + offset
    date = start_date + datetime.timedelta(days=offset)
    url = '{}{}'.format(api_url, date.strftime('%Y%m%d'))

    # send a request to the API
    response = requests.get(url, headers=headers)
    if not response.ok:
        exit('The request for day #{} failed with error code {} ({}).'.format(offset+1,
                                                                               response.status_code,
                                                                               response.reason))

    response_data = json.loads(response.text)

    # append the results to the blocks list
    blocks.append(response_data['data'])
```

```
Usage

Here you can get help of
by pressing Ctrl+I in fron
on the Editor or the Cons

Help can also be shown
after writing a left parenth
an object. You can activa
behavior in Preferences

New to Spyder? Read

Variable explorer  Help

Console 1/A
Finished the first 109 days.
Finished the first 119 days.
Finished the first 129 days.
Finished the first 139 days.
Finished the first 149 days.
Finished the first 159 days.
Finished the first 169 days.
Finished the first 179 days.
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Finished the first 219 days.
Finished the first 229 days.
Finished the first 239 days.
Finished the first 249 days.
Finished the first 259 days.
Finished the first 269 days.
Finished the first 279 days.
```

The Script download the following Information :
height, version, mrkl_root, timestamp, bits, nonce, hash, prev_block_hash, next_block_hash, size, pool_difficulty, difficulty, tx_count, reward_block, reward_fees, created_at, confirmations, is_orphan, curr_max_timestamp, is_sw_block, stripped_size, weight, Mining_pool, miningpool_url

Extract Data

Result :

All information related to the Bitcoin mined block are downloaded for the following years:

- 2015
- 2016
- 2017
- 2018
- 2019
- 2020

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T
1		height	version	mrkl_root	timestam	bits	nonce	hash	prev_bloc	next_bloc	size	pool_diffi	difficulty	difficulty_	tx_count	reward_bl	reward_fe	confirmat	is_orphan	curr_max_
2	0	501961	5.37E+08	5d9afd1ac	1.51E+09	4.03E+08	3.02E+09	00000000(	00000000(	00000000(	1058225	1.06E+13	1.87E+12	1.87E+12	2533	1.25E+09	4.75E+08	162460	FALSE	1.51E+09
3	1	501962	5.37E+08	5b175e893	1.51E+09	4.03E+08	1.83E+09	00000000(	00000000(	00000000(	1066956	3E+12	1.87E+12	1.87E+12	2420	1.25E+09	3.86E+08	162459	FALSE	1.51E+09
4	2	501963	5.37E+08	f6efc8a8c(	1.51E+09	4.03E+08	3.34E+09	00000000(	00000000(	00000000(	1033629	3.34E+12	1.87E+12	1.87E+12	2014	1.25E+09	1.36E+08	162458	FALSE	1.51E+09
5	3	501964	5.37E+08	bb0ef6d4(	1.51E+09	4.03E+08	2.51E+09	00000000(	00000000(	00000000(	1041595	2.97E+12	1.87E+12	1.87E+12	1189	1.25E+09	2.06E+08	162457	FALSE	1.51E+09
6	4	501965	5.37E+08	b34ac9e4(	1.51E+09	4.03E+08	64781884	00000000(	00000000(	00000000(	1032120	6.3E+12	1.87E+12	1.87E+12	2004	1.25E+09	2.63E+08	162456	FALSE	1.51E+09
7	5	501966	5.37E+08	4e885b99(	1.51E+09	4.03E+08	7.74E+08	00000000(	00000000(	00000000(	1393545	2.29E+12	1.87E+12	1.87E+12	788	1.25E+09	1.18E+08	162455	FALSE	1.51E+09
8	6	501967	5.37E+08	fb5bfed96	1.51E+09	4.03E+08	1.56E+09	00000000(	00000000(	00000000(	1221060	6.76E+12	1.87E+12	1.87E+12	1452	1.25E+09	1.74E+08	162454	FALSE	1.51E+09
9	7	501968	5.37E+08	9e2e84eb	1.51E+09	4.03E+08	3.32E+09	00000000(	00000000(	00000000(	1035988	1.94E+12	1.87E+12	1.87E+12	1939	1.25E+09	4.09E+08	162453	FALSE	1.51E+09
10	8	501969	5.37E+08	b8817a33(	1.51E+09	4.03E+08	3.38E+09	00000000(	00000000(	00000000(	1071174	5.62E+13	1.87E+12	1.87E+12	2529	1.25E+09	4.5E+08	162452	FALSE	1.51E+09
11	9	501970	5.37E+08	4e29b1f3e	1.51E+09	4.03E+08	1.42E+09	00000000(	00000000(	00000000(	999297	2.56E+12	1.87E+12	1.87E+12	1033	1.25E+09	62146018	162451	FALSE	1.51E+09
12	10	501971	5.37E+08	5c7a09074	1.51E+09	4.03E+08	3.94E+09	00000000(	00000000(	00000000(	1044488	3.91E+12	1.87E+12	1.87E+12	2739	1.25E+09	5.69E+08	162450	FALSE	1.51E+09
13	11	501972	5.37E+08	397fd026f	1.51E+09	4.03E+08	1.46E+09	00000000(	00000000(	00000000(	1257962	1.11E+13	1.87E+12	1.87E+12	1703	1.25E+09	2.73E+08	162449	FALSE	1.51E+09
14	12	501973	5.37E+08	c9a7f7562	1.51E+09	4.03E+08	1.53E+09	00000000(	00000000(	00000000(	1484305	3.72E+12	1.87E+12	1.87E+12	813	1.25E+09	1.09E+08	162448	FALSE	1.51E+09
15	13	501974	5.37E+08	eb191de3(	1.51E+09	4.03E+08	2.84E+09	00000000(	00000000(	00000000(	1036036	3.91E+12	1.87E+12	1.87E+12	2118	1.25E+09	4.03E+08	162447	FALSE	1.51E+09
16	14	501975	5.37E+08	3b3dbf028	1.51E+09	4.03E+08	8.41E+08	00000000(	00000000(	00000000(	1007588	8.73E+12	1.87E+12	1.87E+12	1050	1.25E+09	70462819	162446	FALSE	1.51E+09
17	15	501976	5.37E+08	7750b049e	1.51E+09	4.03E+08	2.95E+09	00000000(	00000000(	00000000(	1056895	2.49E+12	1.87E+12	1.87E+12	2371	1.25E+09	4.84E+08	162445	FALSE	1.51E+09
18	16	501977	5.37E+08	ee912d39(	1.51E+09	4.03E+08	6.52E+08	00000000(	00000000(	00000000(	1051809	1.08E+13	1.87E+12	1.87E+12	2029	1.25E+09	3.58E+08	162444	FALSE	1.51E+09
19	17	501978	5.37E+08	3abc35b81	1.51E+09	4.03E+08	1.1E+09	00000000(	00000000(	00000000(	1021842	3.65E+12	1.87E+12	1.87E+12	1529	1.25E+09	1.6E+08	162443	FALSE	1.51E+09

Chapter 2

Estimation the energy consumption of Bitcoin

Related Folder : Document-2020\Chaptre-1\N2-EnergyConsumptionOfCountries

References :

1- **randi21.csv** database listing the processors currently used for mining.

The types of equipment included in the model are taken from Bendiksen et al.23 79.9% of the miners mod eled are Antminer S9, 7.6% Avalon 841, 6.7% Ebang E10, and the remaining 5.8% are modeled as other machines. Details on the methodology used to derive these values are provided in SI Section 4.

Mining_Hardwai	Hash_Rate(Ghash	Consumption(G	Energy_Efficiency(Mhash/J)
AntMiner S9	14000	0.000001375	10448
Avalon821	11000	0.0000012	9167
Ebit E10	18000	0.00000162	11111

-Bendiksen, C.; Gibbons, S.; Lim, E. The Bitcoin Mining Network - Trends, Marginal Creation Cost, Electricity Consump tion & Sources. Coin Shares Research & Three Body Capital; 2018.

- Köhler, Susanne, and Massimo Pizzol. "Life Cycle Assessment of Bitcoin Mining." Environmental Science & Technolo gy 53.23 (2019): 13598-13606.

References :

1- **Katie_TableS2** list of comp anies doing mining and the CO2e e mmisions of electricity generation in t heir claimed countries.

	Mining_p	Known_Se	CO2e/GW	Carbon/G	Mining_pool_website
	1Hash	China	661.73	180.4554	http://www.1hash.com/
	AntPool	China	661.73	180.4554	https://antpool.com
	BATPOOL	China	661.73	180.4554	https://www.batpool.com/
	BCMonste	U.S., Chin	580.04	158.1783	http://www.bcmonster.com/
	BitClub Ne	U.S.	498.34	135.8986	https://bitclubnetwork.com
	Bitcoin.co	Global	573.86	156.493	https://pool.bitcoin.com
	Bitfury	Georgia, F	132.6	36.16035	http://www.bitfury.org/
	BitMinter	U.S., E.U.	414.46	113.0243	https://bitminter.com
0	BTC.com	China	661.73	180.4554	https://pool.btc.com
1	BTC.TOP	China	661.73	180.4554	http://btc.top/
2	BTCC	China	661.73	180.4554	https://pool.btcc.com/
3	BW Pool	China	661.73	180.4554	https://www.bw.com
4	Canoe Poo	U.S.	498.34	135.8986	https://www.canoepool.com
5	ConnectB	China	661.73	180.4554	https://www.connectbtc.com/#

Mora, Camilo, et al. "Bitcoin emissions alone could push global warming above 2 C." *Nature Climate Change* 8.11 (2018): 931-933.

Steps :

1- Load Required Data :

-Load database containing all blocks mined in 2020

-Load database listing the processors currently used for mining

-Load list of companies doing mining and the CO2e emissions of electricity generation in their claimed countries

2- Process loaded Data :

- Convert units from giga hashes to hashes
- Convert units Megahashes per jule to hashes per J
-Estimate total number of hashes

Steps :

3- Calculate Carbon emissions of electricity generation in the countries o f Bitcoin mining companies:

-Select a list of processors equal o the number of blocks
-estimate total Jules of the block
-estimate carbon emissions from the given block in Ggtons of Carbon.

4- Displays Results:

- Energy Per Hashes Per country (WattHour/MegaHashes)
- Mean emissions per country
- Percentage Mean emissions per country
- Standard deviation for emissions per country
- Mean energy consumption per country
- Standard deviation for energy consumption per country

Estimation the energy consumption of Bitcoin

Result： Example 2019

```
EnergyPerHashes (WattHour/MegaHashes)
         EnergyPerHashes
Country
China          0.000730536
E.U.           0.000000178
Finland        0.000017931
Georgia        0.000017931
Global         0.000132849
Iceland        0.000017931
U.S.           0.000116497
Mean emissions per country:
            Emission
Country
China    18.042357967
E.U.      0.002682788
Finland   0.090838396
Georgia   0.090838396
Global    2.664090573
Iceland   0.090838396
U.S.      2.554859602
-------------------------------------
23.536506118046262
```

```
% Mean emissions per country:
            Emission
Country    Emission
China    76.656908532
E.U.      0.011398413
Finland   0.385946817
Georgia   0.385946817
Global   11.318972152
Iceland   0.385946817
U.S.     10.854880453
-------------------------------------
Standard deviation
for emissions per country:

Country Emission
China    0.009162960
E.U.     0.000061578
Finland  0.000171951
Georgia  0.000171951
Global   0.003346370
Iceland  0.000171951
U.S.     0.002323361
The mean and standard
deviation of the CO2
emissions across the
1000 iterations are:
23.536506118046262
+- 0.010592336369146816
```

```
Mean energy consumption per country:
Country Emission
China    27.724506618
E.U.      0.006467681
Finland   0.684495786
Georgia   0.684495786
Global    4.638610187
Iceland   0.684495786
U.S.      4.484380871
Standard deviation
for energy consumption
 per country:
Country Emission
China    0.013955473
E.U.     0.000148453
Finland  0.001295708
Georgia  0.001295708
Global   0.005826569
Iceland  0.001295708
U.S.     0.004084777
The mean and standard
deviation of the energy
consumption across
the 1000 iterations
are: 38.90745271604894
+- 0.01714837350473813
```

Result :

Years	Energy consumption TWh
2015	0.152092
2016	1.228189
2017	4.976362
2018	22.46275
2019	38.90745
2020	55.57515

Estimation the energy consumption

De Vries, A. 22−67 TWh/yr (mid-March 2018)
Köhler, Susanne, and Massimo Pizzol
31,29 TWh/yr (mid-March 2018)
43 TWh/ yr (October 2018)
TWh/yr (November 2018)
6452 TWh/yr (average of 2018)
39−83 TWh/yr (mid-November 2018)
105.82 TWh/yr (29 July 2018).

Result :

%	China	Finland	Georgia	Iceland	India	Sweden	U.S	Global
2015	59.75	4.53	4.53	4.53	-	-	19.47	6.71
2016	64.27	3.27	3.27	3.27	1.267	0.39	15.29	8.86
2017	71.89	1.89	1.89	1.89	2.52	-	9.45	10.23
2018	70.24	0.9	0.9	0.9	0.28	-	9.39	17.35
2019	71.25	1.76	1.76	1.76	-	-	11.52	11.92
2020	75.945	0.27321	0.27321	0.27321	-	-	16.112	7.122

Chapter 3

Estimation of carbon footprint for electricity generation by sector

Related Folder : Document-2020\Chaptre-2\N1-MRIO-LCSAModel

Estimation of carbon footprint for electricity generation by sector

Steps :

we calculate the carbon footprint impacts of the regional and intern ational supply chains. A Python p rogramming language was used t o carry out all matrix operations o f big matrix data and sectorial mu ltipliers for ten energy sources

```
Created on Sun Dec  2 13:05:34 2018
"L =np.power(IA, -1)
@author: QTTSC
"""
import os
from numpy import genfromtxt
import glob
import sys
import numpy as geek
import numpy as np
from numpy.linalg import inv

n = sys.argv

Number= int(n[1])

"""
--------------------x = (I-A)-1 * f      Number= int(n)     (eqn. 1)----------------------
"""
print('Read I')
I =np.identity(9800, dtype = float)
print('Read A')

F = genfromtxt(('Fcsv.csv'), delimiter=',',dtype="float")
np.place(F, F == 0, 0.0000000000000000001)
A = genfromtxt(('B.csv'), delimiter=',',dtype="float")

print('Test loss:', A[0])
print('Test accuracy:', A[1][1])

IA = I-A
print(' IA[1][1]:', IA[1][1])
```

Estimation of carbon footprint for electricity generation by sector

Result :

Screenshot of the part generated file that contains greenhouse gas emissions caused by electricity generation in China (The table involves all the global supply-chain sectors involved electricity generation in China)

Abreviation	Sector	CO2 - combustion - air(air-kg)	CH4 - combustion - air(air-kg)	N2O - combustion - air(air-kg)
CN	Electricity by coal	24118847.76	255.7464318	841.3677882
CN	Other Bituminous C	262125.0284	4.337452792	8.155646963
CN	Basic iron and steel	81923.84043	12.45610171	0.477637363
CN	Steam and hot wate	24828.79037	0.495026713	0.839828438
CN	Other non-metallic	11248.44819	0.248067262	0.162817433
CN	Coke Oven Coke	10052.67771	1.659153646	0.249724094
CN	Rubber and plastic	9672.216859	1.008277706	0.01398232
CN	Air transport servic	7025.701142	0.161808632	0.273299967
CN	Chemicals nec	5966.967248	0.644660034	0.07700643
CN	Coking Coal	5480.276696	0.090683597	0.170510997
RU	Other Bituminous C	5399.188529	0.074845764	0.08306013
CN	Other business serv	5211.830486	0.851275328	0.048797387
CN	Supporting and aux	5151.508507	0.598559199	0.086737968
CN	Sea and coastal wat	4886.710154	0.444831238	0.017808327
CN	Crude petroleum a	4851.92831	1.374437205	0.025146993
ID	Sub-Bituminous Co	4345.455751	0.045461989	0.067515718
CN	Inland water transp	3813.756388	0.356606836	0.070066695
CN	Electricity by gas	3557.976173	1.944614425	0.006345521
CN	Railway transportat	3538.292057	0.202735213	0.068570079

Chapter 4

Carbon Footprint for Electricity Generation of the Bitcoin-mining countries

Related Folder : Document-2020\Chaptre-2\N2-EstimationtheC.F.P.ElectricityCountry

Carbon Footprint for Electricity Generation of the Bitcoin-mining countries Footprint for Electricity Generation by country

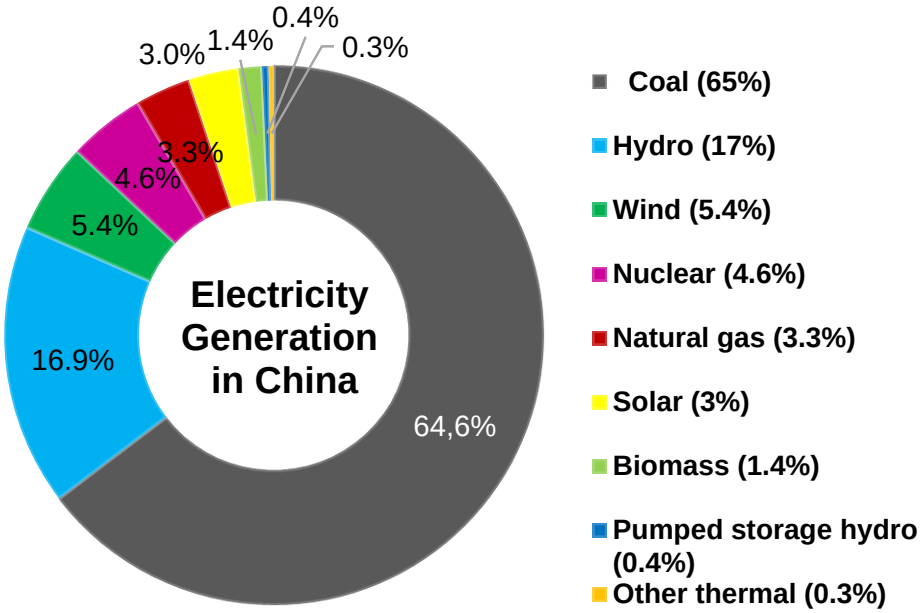
CHINA

Chapter 2 / N2-EstimationtheC.F.P.Bitcoin / China

Carbon Footprint for Electricity Generation by country

Steps :

Source of electricity	Electricity generation (%)
Coal	64.6%
Hydro	16.90%
Wind	5.40%
Nuclear	4.60%
Natural gas	3.30%
Solar	3%
Biomass	1.40%
Pumped storage hydro	0.40%
Other thermal	0.30%



Steps :

China Price Electricity :

Des /Country	India	China	USA	Finland	Sweden	Iceland	Georgia
Price In Euro	0.02	0.05	0.075	0.144	0.128	0.088	0.04
Value	0.868	0.813	0.647	0.365	0.016	0.017	0.08

Carbon Footprint for Electricity Generation by country

Steps :

Total = 0,64 X Coal + 0,031 X Natural gas + 0,042 X Nuclear +0,171 X Hydro + 0,052 X Wind +0,025 X Solar + 0,013 X Biomass

Carbon Footprint = Total X Cost 1 kWh

Carbon Footprint = 0.81 $kgCO_2/kWh$

Carbon Footprint for Electricity Generation by country

Result : China Carbon Footprint by Sector

Abreviatio	Sector	al Tax (M.E	ensation(M	ng Surplus	oyment(10	o hours(M	CO2 - combustion - air(air-kg)
AT	Paddy rice	0	0	0	0	0	0
AT	Wheat	-3.6E-16	1.17E-15	1.39E-14	5.18E-16	1.34E-15	8.2256E-09
AT	Cereal gra	-8.9E-16	2.53E-15	3.55E-14	1.13E-15	2.91E-15	2.00117E-08
AT	Vegetable	-2.1E-15	3.56E-15	5.14E-14	1.58E-15	4.09E-15	2.6701E-09
AT	Oil seeds	-6.9E-16	6.17E-16	1.89E-14	2.74E-16	7.08E-16	4.33516E-10
AT	Sugar cane	-2.5E-16	6.51E-16	7.67E-15	2.82E-16	7.29E-16	3.7411E-11
AT	Plant-base	-1.2E-19	2.27E-19	5.91E-17	1.01E-19	2.6E-19	1.71912E-12
AT	Crops nec	-7.7E-17	2.24E-16	2.94E-15	9.97E-17	2.58E-16	1.66604E-09
AT	Cattle	-1.7E-14	3.01E-15	1.47E-14	1.34E-15	3.46E-15	5.24876E-09
AT	Pigs	2.33E-16	3.19E-15	2.7E-14	1.42E-15	3.66E-15	4.43742E-10
AT	Poultry	7.84E-17	1.08E-15	1.46E-14	4.78E-16	1.24E-15	5.85882E-10
AT	Meat anin	-7.9E-16	2.22E-16	1.44E-15	9.87E-17	2.55E-16	3.03034E-10
AT	Animal pr	-8E-16	1.89E-16	1.14E-15	8.39E-17	2.17E-16	2.74429E-10
AT	Raw milk	-2.4E-15	5.93E-15	5.1E-14	2.63E-15	6.81E-15	5.78725E-09
AT	Wool, silk	-5E-19	2.42E-20	4.32E-19	1.08E-20	2.79E-20	3.39299E-11
AT	Manure (c	0	0	0	0	0	0
AT	Manure (b	0	0	0	0	0	0

Carbon Footprint for Electricity Generation by country

Result : China Carbon Footprint by Country

Abreviatio	Total Tax (	Compensa	Operating	Employme	Emp hours	CO2 - combustion -	CH4 - com	N2O - com
AT	2.14E-12	1.96E-11	1.56E-11	4.94E-13	8.36E-13	6.07278E-06	1.8E-09	1.73E-10
BE	2.81E-12	3.1E-11	2.41E-11	6.54E-13	1.07E-12	2.52414E-05	6.27E-09	3.7E-10
BG	3.58E-13	1.87E-12	2.68E-12	2.85E-13	6.04E-13	1.69226E-06	3.86E-10	3.6E-11
CY	6.22E-14	1.14E-12	1.07E-12	6.89E-14	1.45E-13	1.73632E-06	1.4E-10	1.26E-11
CZ	8.32E-13	7.95E-12	8.67E-12	5.15E-13	9.34E-13	1.0253E-05	1.17E-09	2.99E-10
DE	2.05E-11	3.59E-10	1.88E-10	8.48E-12	1.17E-11	0.000252989	3.32E-08	4.12E-09
DK	3.17E-12	2.38E-11	1.16E-11	4.15E-13	7.66E-13	2.51418E-05	2.9E-09	3.47E-10
EE	3.15E-13	1.5E-12	1.88E-12	1.01E-13	2.1E-13	2.07974E-06	3.48E-10	6.37E-11
ES	5.3E-12	4.98E-11	4.65E-11	1.71E-12	3.44E-12	4.55414E-05	5.6E-09	1.35E-09
FI	1.37E-12	1.58E-11	1.16E-11	3.54E-13	6.75E-13	8.99767E-06	1.2E-09	3.96E-10
FR	1.82E-11	1.52E-10	6.6E-11	3.01E-12	4.6E-12	6.47679E-05	7.22E-09	1.83E-09
GR	8.21E-13	3.9E-12	6.86E-12	2.35E-13	5.35E-13	2.46091E-05	2.3E-09	1.34E-10
HR	3.01E-13	2.58E-12	1.49E-12	1.22E-13	2.55E-13	2.06653E-06	7.48E-10	2.78E-11
HU	1.39E-12	7.63E-12	6.12E-12	5.33E-13	1.11E-12	5.80651E-06	2.85E-09	1.16E-10
IE	3.92E-12	2.68E-11	2.22E-11	6.65E-13	1.19E-12	1.70429E-05	1.51E-09	6.01E-10
IT	1.22E-11	5.69E-11	3.26E-11	1.45E-12	2.87E-12	3.13687E-05	7.24E-09	6.11E-10
LT	1.01E-13	1.56E-12	2.6E-12	1.34E-13	2.76E-13	1.15718E-06	3.64E-10	1.78E-11

Chapter 5

Estimation of Carbon Footprint of Bitcoin Equipment

Related Folder : Document-2020\Chaptre-2\N3-CarbonFootprintofBitcoinEquipment

Estimation of Carbon Footprint of Bitcoin Equipment

Steps :

List of Bitcoin processing hardware and their electricity consumption

Mining Hardware	Percentage	Hash Rate (Ghash/s)	Consumption (GWh)
AntMiner S9	79.9 %	14,000	1.38E-06
Avalon821	7.6.%	11,000	1.2E-06
Ebit E10	6.7%	18,000	1.62E-06
Others	5.8 %	23,260	1.83E-06

Estimation of Carbon Footprint of Bitcoin Equipment

Steps :

	Average Hashrate (TH/s)	Number Equipment	Value (M. USD)
2015	405341	28,453.4	33.44
2016	1,532,974	107,609.0	126.45
2017	6,306,453	442,689.6	520.21
2018	36,403,242	2,555,372.6	3,002.86
2019	67,023,852	4,704,825.9	5,528.72
2020	119,864,038	8,414,011.1	9,887.44

Estimation of Carbon Footprint of Bitcoin Equipment

Result : Carbon Footprint of Mining Equipment

Years	Carbon Footprint of Mining Equipment Per Transaction ($KgCO_2$)	Total Carbon Footprint of Mining Equipment ($MTCO_2$) Per year
2015	0.50	0.02288
2016	1.09	0.08934
2017	3.11	0.32184
2018	23.84	1.947067
2019	30.50	3.661283
2020	53.36	6.006096

Chapter 6

Estimation of Carbon Footprint of Bitcoin energy consumption by country

Related Folder : Document-2020\Chaptre-2\N4-CarbonFootprintofEnergyconsumptionOfBitcoin

Carbon Footprint of Bitcoin by country
(Document : Result-1)

Steps :

The number of transactions mined per year (Example 2019) :

Date	Number of transaction	Total Number of Transaction per year
1/2/2020	489274895	120034648
1/1/2019	369240247	

Carbon Footprint of Bitcoin by country (Document : Result-1)

Steps :

Average energy consumption per transaction:

$$AECTr_{i,t} = \frac{EC_{i,t}}{Tr_{i,t}}$$

Where, $AECTr_{i,t}$ is annual electricity consumption per transaction in country *i* in ye ar *t*. $EC_{i,t}$ is the total annual electricity consumption for bitcoin mining country *i* in y ear *t*. $Tr_{i,t}$ is total annual number transaction in country *i* in year *t*.

The average energy consumption per transaction for 2019 as follows:

$AECTr_{total,2019}$= 120034648 / 38.90745272

$AECTr_{total,2019}$= 3.24135E-07 (TWH) per transaction

$AECTr_{total,2019}$= 324.14 (kWh) per transaction

Carbon Footprint of Bitcoin by country (Document : Result-1)

Steps :

Average energy consumption per transaction:

$$AECTr_{i,t} = \frac{EC_{i,t}}{Tr_{i,t}}$$

Where, $AECTr_{i,t}$ is annual electricity consumption per transaction in country *i* in ye ar *t*. $EC_{i,t}$ is the total annual electricity consumption for bitcoin mining country *i* in y ear *t*. $Tr_{i,t}$ is total annual number transaction in country *i* in year *t*.

The average energy consumption per transaction for 2019 as follows:

$AECTr_{total,2019}$= 120034648 / 38.90745272

$AECTr_{total,2019}$= 3.24135E-07 (TWH) per transaction

$AECTr_{total,2019}$= 324.14 (kWh) per transaction

Carbon Footprint of Bitcoin by country (Document : Result-1)

Steps :

Average number of transactions mined per country:

$$ANTr_{i,t} = Tr_{i,t} \times MPr_{i,t}$$

Where, $ANTr_{i,t}$ is average number of transactions mined in country *i* in year *t.* $Tr_{i,t}$ is total annual number transaction mined in country *i* in year *t.* $MPr_{i,t}$ is t he mining percentage in country *i* in year *t.*

For example, we calculated the average number of transactions mined in 2019 in China as follows:
$ANTr_{China,2019}$= 120,034,648 *0.72 = 85533777.22 Transaction

Carbon Footprint of Bitcoin by country (Document : Result-1)

Steps :

Annual Carbon footprint of Bitcoin energy consumption per country per transaction

$$AFECBMTr_{i,t} = AECTr_{i,t} \times GWP100_{e,i}$$

Where $AFECBMTr_{i,t}$ is annual carbon footprint from electricity gene consumption r ation of the bitcoin-mining in country i in year t per transaction per kWh. $AECTr_{i,t}$ i s annual electricity consumption per transaction in country *i* in year *t*. $GWP100_{e,i}$ is GWP100 of electricity generation *e* in country *i.*

As an example, the annual carbon footprint of Bitcoin energy consumption per tran saction mined in China for 2019:
$AFECBMTr_{China,2019}$ = 324.1351839 *0.813166656 = 263.5759237 (kWh) per trans action

Carbon Footprint of Bitcoin by country (Document : Result-1)

Steps :

Annual Footprint of electricity needed for mining Bitcoin per Country

$$AFECBM_{i,t} = AFECBMTr_{i,t} \times Tr_{i,t}$$

Where $AFEBM_{i,t}$ annual carbon footprint from electricity consumption of the bitcoi n-mining in country *i* in year *t per* kWh. $AFEGBMTr_{i,t}$ is annual carbon footprint fr om electricity generation of the bitcoin-mining in country i in year t per transaction. $Tr_{i,t}$ is total annual number transaction in country *i* in year *t*

For example, we calculated the average number of transactions mined in China in 2019 as follows:

$AFECBM_{China,2019}$= 85533777.22 * 263.5759237

= 22544644334.45 kWh

Global Warming Potential per kWh of electricity generation

Result :

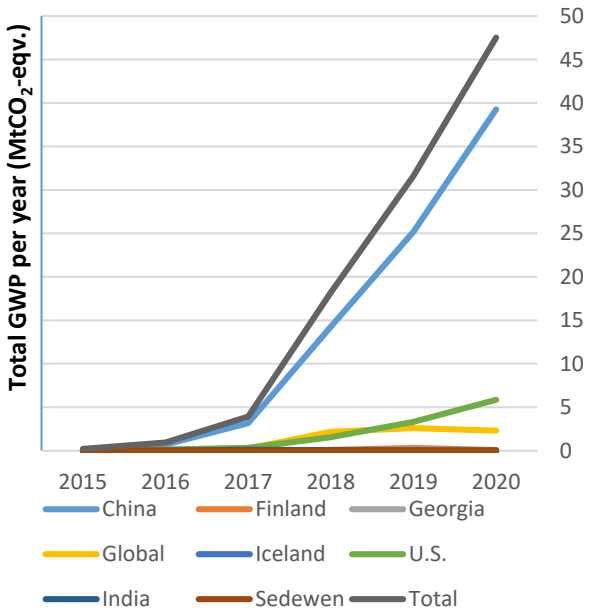
Des /Country	India	China	USA	Finland	Georgia
Value	0.868103	0.813167	0.647817	0.365052	0.080715

Des /Country	Iceland	Sweden
Value	0.017168	0.016335747

Carbon Footprint of Bitcoin energy consumption by country

Result :

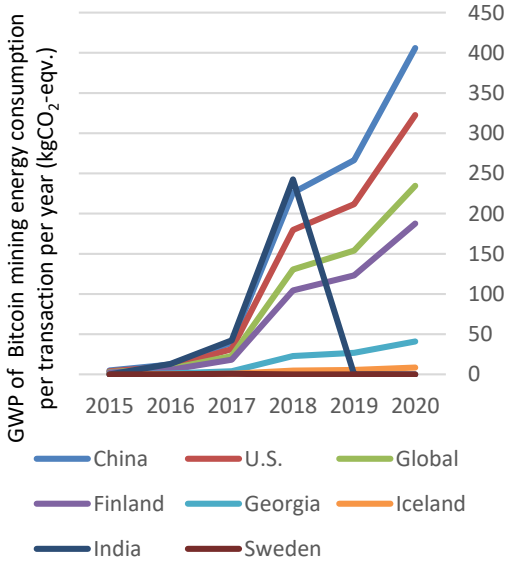
Countries	Total GWP per year ($MtCO_2$-eqv.)					
	2015	2016	2017	2018	2019	2020
China	0.13561	0.64899	2.94105	12.97205	22.79232	34.69843
U.S.	0.03512	0.12270	0.30717	1.37899	2.92891	5.84839
Unknown server	0.00880	0.05170	0.24183	1.85170	2.20334	1.88017
Finland	0.00476	0.01526	0.03581	0.07724	0.26006	0.05769
Georgia	0.00104	0.00334	0.00783	0.01690	0.05690	0.01262
Iceland	0.00022	0.00070	0.00164	0.00353	0.01188	0.00263
India	0.00000	0.01373	0.11098	0.05530	0.00000	0.00000
Sweden	0.00000	0.00008	0.00017	0.00000	0.00000	0.00000
Total	0.1855	0.8427	3.5353	16.3004	28.2534	42.4999



Carbon Footprint of Bitcoin energy consumption by country

Result :

Countries	GWP per transaction per year ($kgCO_2$-eqv.)					
	2015	2016	2017	2018	2019	2020
China	5.005	12.318	39.492	226.071	266.472	405.930
U.S.	3.976	9.787	31.375	179.607	211.704	322.500
Unknown server	2.892	7.117	22.818	130.621	153.964	234.542
Finland	2.313	5.693	18.251	104.479	123.150	187.601
Georgia	0.506	1.246	3.993	22.860	26.945	41.047
Iceland	0.106	0.260	0.834	4.772	5.625	8.569
India	0.000	13.219	42.379	242.598	0.000	0.000
Sweden	0.000	0.259	0.831	0.000	0.000	0.000



Carbon Footprint of Bitcoin energy consumption by country

Result : Example China by Country

Order	Country Code	P.A.D.* (%)	GWP per transaction per year ($kgCO_2$-eqv.)					
			2020	2019	2018	2017	2016	2015
1	CN	99.391%	403.456760	264.848098	224.693283	39.251060	12.243238	4.974400
2	WA	0.093%	0.378787	0.248654	0.210954	0.036851	0.011495	0.004670
3	US	0.092%	0.371707	0.244006	0.207011	0.036162	0.011280	0.004583
4	RU	0.077%	0.314406	0.206391	0.175099	0.030588	0.009541	0.003876
5	WM	0.042%	0.171322	0.112464	0.095413	0.016667	0.005199	0.002112
6	JP	0.037%	0.149740	0.098297	0.083393	0.014568	0.004544	0.001846
7	KR	0.037%	0.149300	0.098008	0.083148	0.014525	0.004531	0.001841
8	ID	0.035%	0.141601	0.092954	0.078861	0.013776	0.004297	0.001746
9	DE	0.031%	0.125893	0.082642	0.070113	0.012248	0.003820	0.001552
10	WL	0.025%	0.101351	0.066532	0.056445	0.009860	0.003076	0.001250

Carbon Footprint of Bitcoin energy consumption by country

Result : Example China by sector

Order	Country Code	Sector	P.A.D.* (%)	GWP per transaction per year ($kgCO_2$-eqv.)					
				2020	2019	2018	2017	2016	2015
1	CN	Electricity by coal	95.260%	386.689357	253.841181	215.355175	37.619811	11.734417	4.767667
2	CN	Electricity by gas	1.861%	7.552507	4.957823	4.206145	0.7347600	0.229187	0.093118
3	CN	Other Bituminous Coal	1.039%	4.218519	2.769235	2.349379	0.4104066	0.128015	0.052012
4	CN	Basic iron and steel and of ferro-alloys and first products thereof	0.386%	1.567937	1.029268	0.873216	0.1525397	0.047580	0.019332
5	CN	Steam and hot water supply services	0.119%	0.482845	0.316962	0.268906	0.0469745	0.014652	0.005953
6	CN	Other non-metallic mineral products	0.058%	0.236244	0.155082	0.131569	0.0229834	0.007169	0.002913
7	CN	Rubber and plastic products (25)	0.046%	0.185159	0.121547	0.103119	0.018013	0.005619	0.002283
8	CN	Coke Oven Coke	0.042%	0.171680	0.112699	0.095612	0.016702	0.005210	0.002117
9	CN	Air transport services (62)	0.039%	0.158272	0.103897	0.088145	0.015397	0.004803	0.001951
10	WA	Natural gas and services related to natural gas extraction, excluding surveying	0.032%	0.129924	0.085288	0.072357	0.0126399	0.003943	0.001602

Chapter 7

Estimation of Carbon Footprint of Bitcoin Mining

Related Folder : Document-2020\Chaptre-2\N5-CarbonFootprintOfBitcoinMining

Carbon Footprint of Bitcoin by country

Results : **Carbon Footprint of Bitcoin Mining = Carbon Footprint of Bitcoin energy consumption + Carbon Footprint of Bitcoin equipment**

Countries	Total GWP per year ($MtCO_2$-eqv.)					
	2015	2016	2017	2018	2019	2020
China	0.1477	0.6983	3.1682	14.2531	25.1848	39.2586
U.S.	0.0391	0.1344	0.3369	1.5504	3.3159	6.815
Unknown server	0.0102	0.0585	0.2418	2.1682	2.6036	2.3078
Finland	0.0057	0.0178	0.0418	0.0937	0.3192	0.0741
Georgia	0.0020	0.0059	0.0138	0.0334	0.1160	0.0290
Iceland	0.0011	0.0032	0.0076	0.0200	0.0710	0.0164
India	0.0000	0.0147	0.1190	0.0604	0.0000	0.0000
Sweden	0.0000	0.0004	0.0008	0.0000	0.0000	0.0000
Total	0.2058	0.9332	3.9299	18.1792	31.6105	48.5343

Carbon Footprint of Bitcoin by country

Results : **Carbon Footprint of Bitcoin Mining = Carbon Footprint of Bitcoin energy consumption + Carbon Footprint of Bitcoin equipment**

Countries	GWP per transaction per year ($kgCO_2$-eqv.)					
	2015	2016	2017	2018	2019	2020
China	5.453	13.255	42.541	248.396	294.443	459.279
U.S.	4.424	10.723	34.408	201.932	239.676	375.849
Unknown server	3.340	8.054	25.635	152.946	181.936	287.888
Finland	2.761	6.630	21.301	126.804	151.134	240.949
Georgia	0.954	2.182	7.043	45.185	54.929	94.395
Iceland	0.553	1.197	3.883	27.097	33.608	53.348
India	0.000	14.156	45.429	264.924	0.000	0.000
Sweden	0.000	1.196	3.881	0.000	0.000	0.000

Carbon Footprint of Bitcoin by country

Result : Example China by Country

Order	GWP per transaction per year ($kgCO_2$-eqv.)																	
	2020			2019			2018			2017			2016			2015		
	C.C.	P.A.D.* (%)	GWP	C.C.	P.A.D.* (%)	GWP	C.C.	P.A.D.* (%)	GWP	C.C.	P.A.D.* (%)	GWP	C.C.	P.A.D.* (%)	GWP	C.C.	P.A.D.* (%)	GWP
1	CN	98.35%	451.676	CN	98.54%	290.130	CN	98.58%	244.872	CN	98.75%	42.007	CN	90.38%	$8.58\ 10^{-1}$	CN	98.65%	5.379
2	WA	0.24%	1.100	WA	0.21%	0.627	WA	0.21%	0.513	WA	0.18%	$7.81\ 10^{-2}$	JP	1.45%	$1.74\ 10^{-1}$	WA	0.20%	$1.07\ 10^{-2}$
3	JP	0.20%	0.923	US	0.18%	0.533	US	0.18%	0.437	US	0.16%	$6.76\ 10^{-2}$	WA	1.35%	$2.58\ 10^{-2}$	US	0.17%	$9.20\ 10^{-3}$
4	US	0.20%	0.922	JP	0.17%	0.504	JP	0.16%	0.407	JP	0.14%	$5.88\ 10^{-2}$	KR	1.12%	$2.12\ 10^{-2}$	JP	0.15%	$8.33\ 10^{-3}$
5	KR	0.16%	0.745	KR	0.14%	0.410	KR	0.13%	0.332	KR	0.11%	$4.86\ 10^{-2}$	US	1.03%	$1.76\ 10^{-2}$	KR	0.13%	$6.84\ 10^{-3}$
6	WM	0.16%	0.715	WM	0.14%	0.398	WM	0.13%	0.323	WM	0.11%	$4.78\ 10^{-2}$	WM	1.02%	$1.44\ 10^{-2}$	WM	0.12%	$6.68\ 10^{-3}$
7	RU	0.13%	0.578	RU	0.12%	0.345	RU	0.12%	0.285	RU	0.11%	$4.57\ 10^{-2}$	DE	0.68%	$1.43\ 10^{-2}$	RU	0.11%	$6.09\ 10^{-3}$
8	DE	0.11%	0.489	DE	0.09%	0.273	DE	0.09%	0.222	DE	0.08%	$3.30\ 10^{-2}$	RU	0.49%	$1.21\ 10^{-2}$	DE	0.08%	$4.60\ 10^{-3}$
9	ID	0.06%	0.272	ID	0.06%	0.162	ID	0.05%	0.134	ID	0.05%	$2.13\ 10^{-2}$	IN	0.31%	$9.31\ 10^{-3}$	ID	0.05%	$2.84\ 10^{-3}$
10	IN	0.05%	0.229	IN	0.04%	0.129	IN	0.04%	0.105	WL	0.04%	$1.63\ 10^{-2}$	ID	0.25%	$5.31\ 10^{-3}$	WL	0.04%	$2.20\ 10^{-3}$

Carbon Footprint of Bitcoin by country

Result : Example China by Sector

GWP per transaction per year ($kgCO_2$-eqv.)

O.	2020				2019				2018				2017				2016				2015			
	C.C.	Sector	P.A.D.* (%)	GWP	C.C.	Sector	P.A.D.* (%)	GWP	C.C.	Sector	P.A.D.* (%)	GWP	C.C.	Sector	P.A.D.* (%)	GWP	C.C.	Sector	P.A.D.* (%)	GWP	C.C.	Sector	P.A.D.* (%)	GWP
1	CN	Elec. Coal	90.19%	414.226	CN	Elec. Coal	91.10%	268.279	CN	Elec. Coal	91.34%	226.879	CN	Elec. Coal	92.13%	39.194	CN	Elec. Coal	92.18%	12.218	CN	Elec. Coal	91.68%	4.999
2	CN	Elec. Gas	1.73%	7.931	CN	Elec. Gas	1.75%	5.156	CN	Elec. Gas	1.76%	4.365	CN	Elec. Gas	1.78%	$7.56\ 10^{-1}$	CN	Elec. Gas	1.78%	$2.36\ 10^{-1}$	CN	Elec. Gas	1.77%	$9.6\ 10^{-2}$
3	CN	Iron and Steel	1.68%	7.712	CN	Iron and Steel	1.44%	4.251	CN	Iron and Steel	1.39%	3.444	CN	Iron and Steel	1.18%	$5.04\ 10^{-1}$	CN	Iron and Steel	1.17%	$1.55\ 10^{-1}$	CN	Iron and Steel	1.30%	$7.1\ 10^{-2}$
4	CN	Bituminous Coal	1.07%	4.899	CN	Bituminous Coal	1.06%	3.126	CN	Bituminous Coal	1.06%	2.634	CN	Bituminous Coal	1.06%	$4.49\ 10^{-1}$	CN	Bituminous Coal	1.06%	$1.4\ 10^{-1}$	CN	Bituminous Coal	1.06%	$5.8\ 10^{-2}$
5	CN	Steam-Hot W. Sply.	0.67%	3.072	CN	Steam-Hot W. Sply.	0.57%	1.674	CN	Steam-Hot W. Sply.	0.54%	1.352	CN	Steam-Hot W. Sply.	0.46%	$1.95\ 10^{-1}$	CN	Steam-Hot W. Sply.	0.45%	$6\ 10^{-2}$	CN	Steam-Hot W. Sply.	0.51%	$2.8\ 10^{-2}$
6	CN	Rubber and plastic	0.37%	1.684	CN	Rubber and plastic	0.31%	0.907	CN	Rubber and plastic	0.29%	0.73	CN	Rubber and plastic	0.24%	$1.04\ 10^{-1}$	CN	Rubber and plastic	0.24%	$3.2\ 10^{-2}$	CN	Rubber and plastic	0.27%	$1.5\ 10^{-2}$
7	CN	O. machinery and computers	0.34%	1.543	CN	O. machinery and computers	0.28%	0.81	CN	O. machinery and computers	0.26%	0.647	CN	O. machinery and computers	0.21%	$8.9\ 10^{-2}$	CN	O. machinery and computers	0.21%	$2.7\ 10^{-2}$	CN	O. machinery and computers	0.24%	$1.3\ 10^{-2}$
8	CN	Chemicals nec	0.26%	1.207	CN	Chemicals nec	0.22%	0.649	CN	Chemicals nec	0.21%	0.522	CN	Chemicals nec	0.17%	$7.4\ 10^{-2}$	CN	Chemicals nec	0.17%	$2.3\ 10^{-2}$	CN	Chemicals nec	0.20%	$1.1\ 10^{-2}$
9	CN	Air transport services	0.19%	0.858	CN	Other mineral products	0.16%	0.478	CN	Other mineral products	0.16%	0.389	CN	Other mineral products	0.14%	$5.8\ 10^{-2}$	CN	Other mineral products	0.14%	$1.8\ 10^{-2}$	CN	Other mineral products	0.15%	$8\ 10^{-3}$
10	CN	Other mineral products	0.19%	0.851	CN	Air transport services	0.16%	0.471	CN	Air transport services	0.15%	0.381	CN	Air transport services	0.13%	$5.5\ 10^{-2}$	CN	Air transport services	0.13%	$1.7\ 10^{-2}$	CN	Air transport services	0.14%	$8\ 10^{-3}$

THANK YOU