POLICY STUDY 02|2021

German Economic Team

GEORGIA

Development of cryptomining in Georgia 2018-2021

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Summary I: implications for electricity market

- Previous GET study: approx. 6% of total electricity consumption (excl. Abkhazia) in 2017
- Purpose of this study: data-based update on the development of cryptomining since then
- Methodology: own estimation based on data by ESCO and CBECI, time-span: May-18 to Sep-21
- Georgia is attractive for cryptomining due to low electricity prices (approx. 0.05 USD per kWh)
- Consumption share is volatile, ranging from 0.4% to 14.1% of total (excl. Abkhazia)

		May - Dec 2018	2019	2020	Jan - Sep 2021
% of total consumption (excl. Abkhazia)	Professional	5.3	7.4	1.4	5.0
	Small	1.3	1.1	1.0	1.0
	Total	**6.6**	**8.5**	**2.4**	**6.0**
	Min / Max	**5.5 / 7.6**	**3.5 / 14.1**	**0.4 / 5.2**	**4.3 / 7.6**
m kWh	Professional	380	788	132	396
	Small	91	122	96	75
	Total	**471**	**910**	**228**	**471**

Sources: German Economic Team, ESCO, CBECI

- Explanation for results: developments in global network capacity and price movements affect mining profitability and thus electricity consumption
- Cryptomining contributed to rise in electricity demand and imports
- Electricity imports come mostly from Azerbaijan and Russia, mainly generated from fossil fuels

➢ **Cryptomining has strong effect on the Georgian electricity market**

➢ **Adverse environmental impact due to electricity imports from fossil fuels**

Summary II: further economic analysis / policy implications

- Previous GET study: cryptomining accounted for approx. 1.2% of GDP in 2017
- Georgia is attractive for cryptomining due to low taxation in free industrial zone
- Overall, revenues have declined in recent years due to increased competition and lower rewards for cryptominers due to the design of the Bitcoin algorithm ("Bitcoin halving" in May-21)
- Correspondingly, profits in the sector and its contribution to GDP have declined

	May - Dec 2018	2019	2020	Jan - Sep 2021
Revenue	47	140	19	96
Profits	**-11**	**38**	**-29**	**44**
GDP	13,739	17,471	15,888	13,709
% of GDP	**-0.1**	**0.2**	**-0.2**	**0.3**

Source: German Economic Team

- 2020: low revenues due to low cryptomining activity, 2021: revenues increasing again
- Low job creation: largest company Bitfury employed an average of 72 people in 2019
- Profits accrue almost fully to only a few companies, low economic benefits for the country
- Currently: cryptomining very profitable, likely to continue at current level in short-run

➢ **Problems for electricity sector much more substantial than economic benefits**

<u>Open for discussion</u>

➢ **Need for state intervention? Regulation?**

➢ **Implications for international cooperation in the field of energy efficiency**

Summary III: cryptomining in Abkhazia

- Very low electricity prices (0.005 USD per kWh) create large economic incentive for cryptomining
- Electricity consumption per capita in Abkhazia is approx. four times as high as in rest of Georgia
- Data availability limited, but rough estimate by power company Chernomorenergo: at least 40-45 MW of capacity for cryptomining
- Likely: use of older (less efficient) hardware which is cheaper but can be run profitably in Abkhazia
- Own estimation using capacity estimate and conservative assumptions on mining hardware:

Lower estimate of cryptomining for 2020	
Electricity consumption	**395.3 m kWh**
% of total consumption	**15.5 % of total**
Revenue	15.4 USD m
Gross profits	**13.4 USD m**
% of GDP	**2.5 % of GDP**

Sources: German Economic Team, ESCO, Chernomorenergo, State Committee of the Republic of Abkhazia on Statistics; Note: GDP data for 2019

- Note: actual figures likely to be even higher
- Cryptomining blamed for contributing to electricity blackouts
- Result: de-facto authorities extended ban on cryptomining until May 2022; seizures of hardware
- But: cryptomining profitable as long as price remains above approx. USD 2,200
- Ban hard to enforce due to high profitability and spacial scattering of hardware

➢ **Strong effect of cryptomining on Abkhazia, topic to remain relevant due to high profitability**

Outline

Outline

4. **Outlook and policy implications**
   1. Outlook
   2. Policy implications
5. **Cryptomining in Abkhazia**
   1. Background
   2. Estimation and current developments

Annex

1. Introduction and methodology

1.1. Introduction

Motivation

- Intensive discussions about cryptocurrencies in recent years
- Cryptocurrencies like Bitcoin (BTC) have to be produced ("mined") using electricity
- ➢ **Cryptomining has effects on the real sector**

Situation in Georgia

- Previous GET research (estimate for 2017):
  - Electricity consumption: approx. 6% of total (excl. Abkhazia)
  - Profits: approx. USD 178 m
  - Contribution to GDP: approx. 1.2%
- Anecdotal stories: crypto boom for some time, but recently less activity → Why?

Purpose of this Policy Study

- Provide a data-based analysis on the development of cryptomining
- Key differences to previous study:
  1. Longer time-span (May-18 to Sep-21)
  2. Use of monthly data allows intra-annual analysis
  3. Differentiation between professional and small mining
  4. Short analysis on Abkhazia for 2020

1.2. Data sources and methodological notes (I)

Professional mining

- Since May-18: ESCO collects data on direct contracts with professional mining companies, so electricity consumption is known on a monthly basis
- By assuming 24/7 production in months with maximum electricity consumption, it is possible to infer a lower limit for installed capacity
- The amount of mined BTC (and thus the revenue in USD) can be estimated by making assumptions on the hardware used and its efficiency
- Additional assumptions on costs for labour, hardware etc. allow estimating mining profits

Small / private mining

- Since Sep-19: Cambridge Bitcoin Electricity Consumption Index (CBECI) provides average monthly share of countries in the worldwide hash rate
- Assumption: the CBECI share is only indicative for small miners (see annex for explanation)
- Using similar assumptions as for professional miners allow estimations on electricity consumption and revenue

General remarks

- The goal is to provide an approximation; results are sensitive to changes in assumptions
- However: assumptions could be modified if better data becomes available

Note: Additional explanatory remarks and sample calculations are provided in the annex.

1.2. Data sources and methodological notes (II)

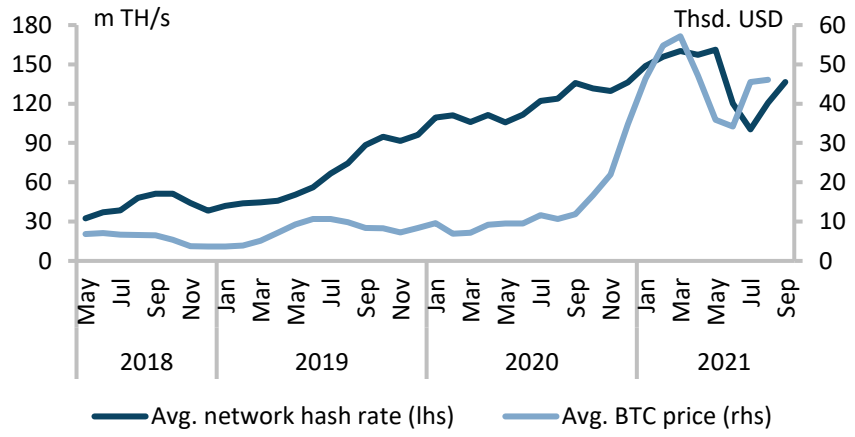
- Challenge 1: different cryptocurrencies are mined
- Assumption: only BTC are mined in Georgia
- Challenge 2: key variables change drastically over time
- Solution: monthly averages when available and reasonable assumptions (see below)

Variable	Calculation / Assumptions
Bitcoin price	Monthly average
Total network capacity	Monthly average
BTC revenue	Block reward: 12.5 BTC until May-2020, 6.25 BTC since; transaction fees: monthly average
Electricity price	Professional miners: 0.05 USD per KWh (tax-free) Small miners: 0.06 USD per KWh (incl. tax)
Efficiency	Until Mar-19: Antminer S9 (13.5 TH/s; 1,375 W) Since Apr-19: Antminer S17 (45 TH/s; 2,385 W) Efficiency losses and cooling add 20% to the electricity used for the mining itself. *Note: Newer miners (e.g. Antminer S19, introduced May 2020) are excluded as electricity consumption data suggests little adoption in GEO.*
Costs of hardware	Approx. 2,000 USD; lifetime: 2.5 years

Note: A more detailed explanation of the variables and their effect on mining profitability can be found in the annex

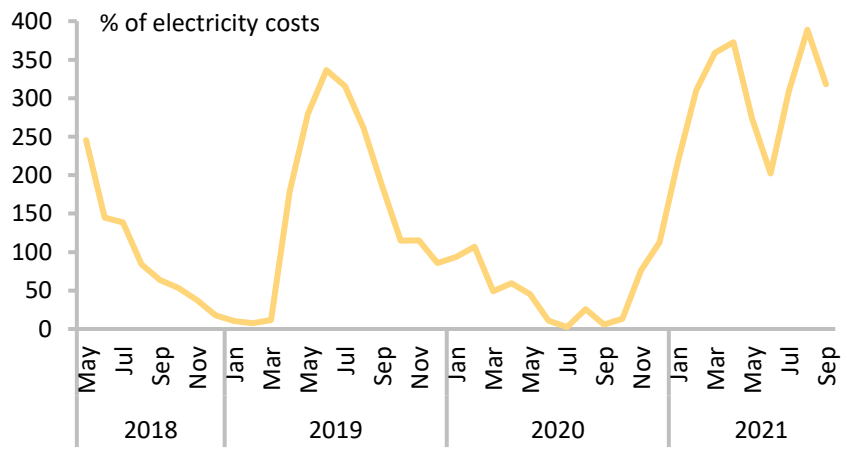
1.3. Determinants of mining profitability

Development of network capacity and BTC price



Sources: German Economic Team based on data by blockchain.com

Gross profit ratio



Sources: German Economic Team based on data by blockchain.com

General remarks

- All miners form a worldwide network and compete trying to solve the Bitcoin algorithm
- All else being equal, mining profitability increases when the price increases stronger than the capacity of the network

Gross profit ratio

- Combines information on price and network capacity, BTC revenue, electricity costs and efficiency into a single measure
- Gross mining profits (i.e. revenue minus electricity costs) over electricity costs
- Other costs (hardware, etc.) are excluded
- Assumptions on costs and efficiency:
  - USD 0.05 per KWh
  - Antminer S9 until March 2019, Antminer S17 since April 2019*
  - 20% additional cooling costs

➢ **High in 2019, low in 2020**

** Note: The newer Antminer S19 (introduced May 2020) or comparable models would show much higher profit ratios due to better efficiency. They are excluded here, because electricity consumption data suggests little adoption in GEO.*

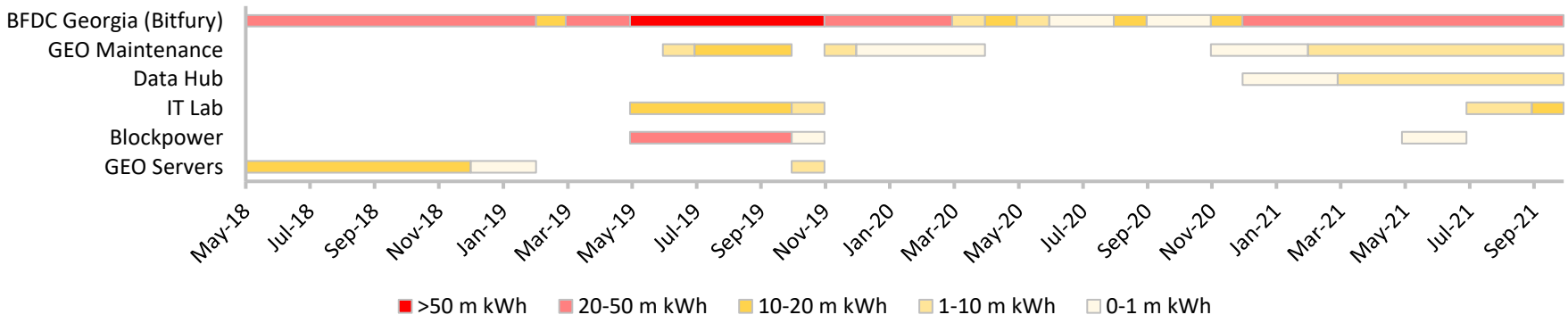
2. Cryptomining and the electricity market

2.1. Mining facilities and market structure

Professional mining (around 80-90% of total mining)

- Largest company: BFDC Georgia (>80% of professional mining for most of the period), operates out of Tbilisi Free Zone, a free industrial zone owned by its parent company Bitfury
- Installed capacity peaked in summer 2019 (approx. 130 MW*); strong decline afterwards, in summer 2021: approx. 65 MW*

Monthly electricity consumption of professional cryptomining companies



Source: own display based on data by ESCO

** This is derived from the electricity consumption data assuming 24/7 utilisation. Actual figures may be higher if additional capacity was/is not used.*

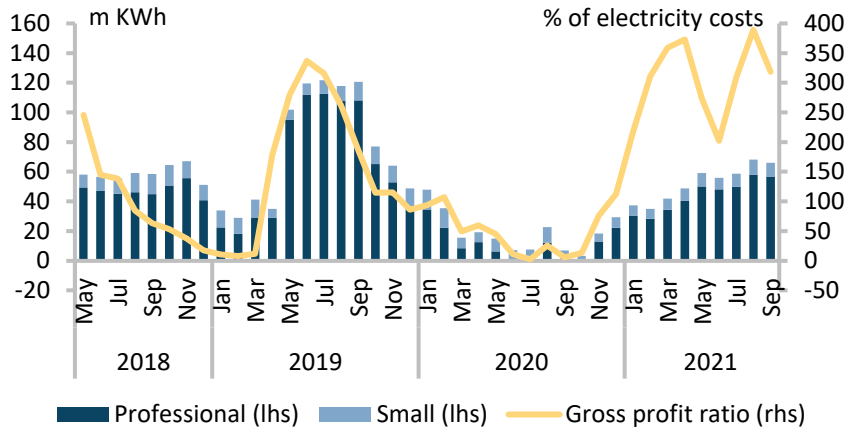
➢ **Peak in 2019, followed by weak 2020 and recovery in 2021. Why?**

Small mining (10-20% of total mining)

- Households are also active in mining
- Typically: only small number of mining computers

2.2. Electricity consumption

Electricity consumption by month



Sources: German Economic Team, ESCO, CBECI, blockchain.com

Electricity consumption

(% of total, m kWh)	May - Dec 2018	2019	2020	Jan - Sep 2021
Professional	5.3	7.4	1.4	5.0
Small	1.3	1.1	1.0	1.0
Total	**6.6**	**8.5**	**2.4**	**6.0**
Min / Max	**5.5 / 7.6**	**3.5 / 14.1**	**0.4 / 5.2**	**4.3 / 7.6**
Professional	380	788	132	396
Small	91	122	96	75
Total	**471**	**910**	**228**	**471**

Sources: German Economic Team, ESCO, CBECI

Note: % of total excludes Abkhazia

Development

- Strong correlation between electricity consumption and gross profit ratio
- Dominance of professional mining
- 2019: high profits/consumption in summer, decline afterwards
- 2020: very limited activity
- 2021: resumption of mining
- Probable: selling/discontinuation of some hardware after 2019

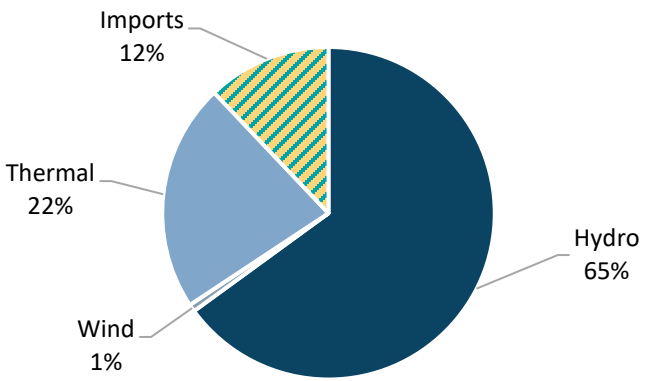
Larger context on electricity market

- Peak in 2019: 8.5% of total electricity consumption (excl. Abkhazia)
- Summer 2019: up to 14.1%
- Autumn 2020: low of 0.4%
- 9M2021: approx. 6.0% on average

➢ **Strong effect on electricity market and high volatility in demand**

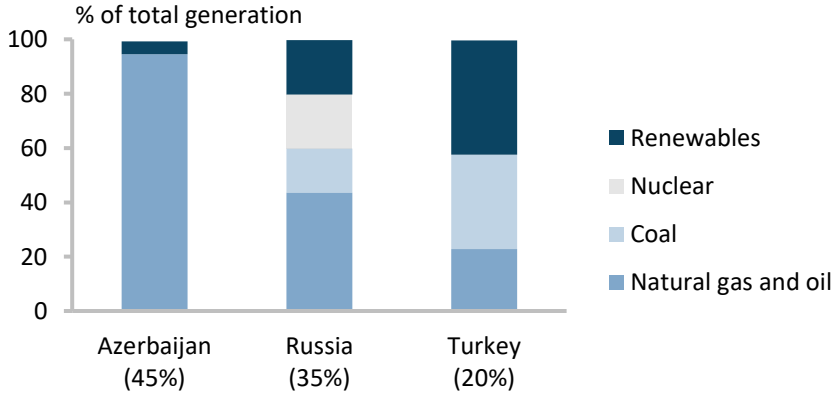
2.3. The role of imports for environmental impact

Electricity supply 2020



Source: ESCO

Electricity generation by energy source 2020



Source: IEA; Notes: Figure in parentheses denotes the country's share in Georgian electricity imports in 2020; renewables include hydro, solar, wind, geothermal and biofuels; other sources (<1% of total generation) omitted

Georgia's electricity sector*

- Electricity consumption in Georgia increased by 25% from 2015 to 2019**
- Main source: hydropower (65% of total)
- Carbon emissions thus relatively low
- However:
  - Since 2017: net importer of electricity
  - 2020: imports equal to 12% of supply

Role of cryptomining for electricity imports

- Imports: Azerbaijan, Russia and Turkey
- Mainly generated through fossil fuels
- Cryptomining contributed to rise in electricity demand and thus imports

➢ **Negative environmental impact due to electricity imports from fossil fuels**

**) Note: Our Electricity Monitor Georgia 2021 provides further analysis regarding the Georgian electricity market*

***) This figure excludes Abkhazia, but findings would be similar if the region was included. In 2020, there was a slight decline in demand due to COVID-19. However, electricity demand has been rising again in 2021*

2.4. Conclusions on electricity market

- Georgia is attractive location due to low electricity prices (0.05 USD per kWh)
- Cryptomining dominated by professional companies (approx. 80-90% of total)
- Main company: BFDC Georgia / Bitfury (usually >80% of professional mining)
- Electricity demand by cryptominers in Georgia influenced by global developments of Bitcoin price and the capacity of the Bitcoin network
  - Higher Bitcoin price → beneficial for cryptominers due to increased revenue
  - Higher network capacity → harmful due to increased competition by other miners
- High volatility in monthly demand, ranging from approx. 0.4% to 14.1% of total consumption (excl. Abkhazia), reflecting global price and network trends
- 9M2021: approx. 6.0% of total consumption on average
- Cryptomining has contributed to rise in electricity demand and imports
- Electricity imports (from AZE, RUS and TUR) generated mainly from fossil fuels

➢ **Cryptomining has strong effect on the Georgian electricity market**

➢ **Adverse environmental impact due to electricity imports from fossil fuels**

3. Cryptomining and the economy

3.1. Cryptomining revenue

Estimated mining revenue

	May - Dec 2018	2019	2020	Jan - Sep 2021
BTC				
Professional	5,746	14,505	1,166	1,843
Small	1,321	1,993	743	339
Total	7,067	16,498	1,909	2,182
*USD/BTC**	*6,415*	*7,373*	*11,068*	*44,583*
USD m				
Professional	38	125	12	81
Small	9	15	7	15
Total	**47**	**140**	**19**	**96**

Sources: German Economic Team, ESCO, CBECI, blockchain.com

Mining revenue includes block reward and transaction fees

Assumption: sale of BTC in month of production (no stock formation)

Assumption for 2020/2021: no upgrade in technology to Antminer S19 (introduced May 2020), instead continuation of Antminer S17. Reasoning: decline in electricity use during 2020 and only slow increase in 2021.

** Average exchange rate during timespan. Monthly data was used to calculate revenue; differences between BTC and USD revenue are the result of data aggregation*

2019

- Mining lucrative in summer
- Total: USD 140 m

2020

- Very low revenues
- Reason: virtually no mining in summer

Jan – Sep 2021

- Resumption of mining
- So far, lower revenues than 2019 despite sixfold increase in price
- Reasons:
  - Since May-20: lower block reward of 6.25 BTC ("Bitcoin halving")
  - Growing worldwide network capacity
- However: high profitability in Q4 may cause higher overall revenues in 2021

➢ **Sizeable revenues in 2019**

➢ **Recovery in 2021 after low level in 2020**

3.2. Cryptomining profits (I)

- When accounting for costs, it is possible to estimate mining profits
- Problem: cost structure of cryptomining industry unknown
- Therefore, assumptions have to be made
- Labour:
  - 1% of revenue (lower end of industry estimates)
  - Only relevant for professional miners
- Hardware:
  - Derive approximate number of mining computers through electricity consumption (see annex for details)
  - Average cost: USD 2,000
  - Depreciation over 2.5 years (average economic lifetime)
- Other costs:
  - Includes renting of sites, financing costs, costs of cooling equipment, etc.
  - Assumption: USD 5 m per year
  - Only relevant for professional miners
- Important: changes in assumptions could significantly affect estimates

3.2. Cryptomining profits (II)

Estimated mining profits

(USD m)	May - Dec 2018	2019	2020	Jan - Sep 2021
Professional				
Revenue	38	125	12	81
Electricity	-19	-39	-7	-20
Labour	-1	-3	<1	-2
Hardware	-25	-43	-25	-18
Other	-3	-5	-5	-4
Profits	**-10**	**35**	**-25**	**37**
Small				
Revenue	9	15	7	15
Electricity	-5	-7	-6	-4
Hardware	-6	-5	-5	-4
Profits	**-2**	**3**	**-4**	**7**
Total				
Revenue	47	140	19	96
Electricity	-24	-46	-13	-24
Labour	-1	-3	<1	-2
Hardware	-31	-48	-30	-15
Other	-3	-5	-5	-4
Profits	**-12**	**38**	**-29**	**44**

Source: German Economic Team

General remarks

- Significant effect of electricity and hardware costs on profits
- Small mining negligible
- Note: Losses result from investment costs, but these are sunk costs. Mining remains profitable in the short run since the revenue exceeds the sum of electricity, labour and other costs
- No income tax for Bitfury due to location in Tbilisi Free Zone

Development

- Greatest profits in 2021 on the back of favorable price-network trend
- Weak years 2018/2020 do not allow to recover (hardware) costs
- Recently: profits increasing again
- Open question for future: profitability of existing mining hardware?

➢ **Volatile profitability**

3.3. Effect on GDP and balance of payments

Estimated contribution to GDP

(USD m)	May - Dec 2018*	2019	2020	Jan - Sep 2021
Revenue	47	140	19	96
Electricity	-24	-46	-13	-24
Hardware	-31	-48	-30	-22
Other	-3	-5	-5	-4
Profits	**-11**	**38**	**-29**	**44**
GDP	13,739	17,471	15,888	13,709
% of GDP	**-0.1**	**0.2**	**-0.2**	**0.3**

Sources: German Economic Team, Geostat
** GDP data for Q2-Q4 2018*

Estimated impact on balance of payments

(USD m)	May - Dec 2018*	2019	2020	Jan - Sep 2021
BTC exports	47	140	19	96
Electricity	-24	-46	-13	-24
Hardware	-31	-48	-30	-22
Other**	-1	-2	-2	-1
Net impact	**-9**	**44**	**-26**	**49**
% of GDP	**-0.1**	**0.3**	**-0.2**	**0.4**

Sources: German Economic Team, Geostat
** GDP data for Q2-Q4 2018*
*** Assumption: 1/3 of other costs are imported*

Contribution to GDP

- Profits/losses generally small
- Maximum in 9M2021: 0.3% of GDP
- Note: this contribution is only partly captured by official data
- Lower profits than in previous study for 2017 (1.2% of GDP) can be attributed to the increasing network capacity and the "Bitcoin halving" in May-21 (reducing revenue by 50%) which outweigh price increases

Balance of payments

- Assumption: electricity generation independent from mining
- Implication: full effect of mining on balance of payments statistics
- Result: Cryptomining implies lower exports and higher imports
- Note: partially unrecorded in official data
- Overall: small impact

➢ **Limited effect on GDP and balance of payments**

3.4. Conclusions on the economy

- Georgia is attractive location due to very low taxation for cryptomining
- Largest company BFDC Georgia, owned by Bitfury, located in Tbilisi Free Zone
  - No income tax
  - No input VAT, including reduced electricity costs
- Number of jobs in cryptomining sector very low
- Illustration: Average number of employees by BFDC Georgia
  - 2017: 128
  - 2018: 159
  - 2019: 72
- Profits have likely decreased in recent years. Main reason: Revenue decline
  - Strong increase in network capacity results in stronger competition
  - "Bitcoin halving" in May-20
- Contribution to GDP very low (currently around 0.3% of GDP)

➢ **Economic benefits accrue almost exclusively to cryptomining companies**

➢ **Limited economic benefits for Georgia**

4. Outlook and policy implications

4.1. Outlook (I)

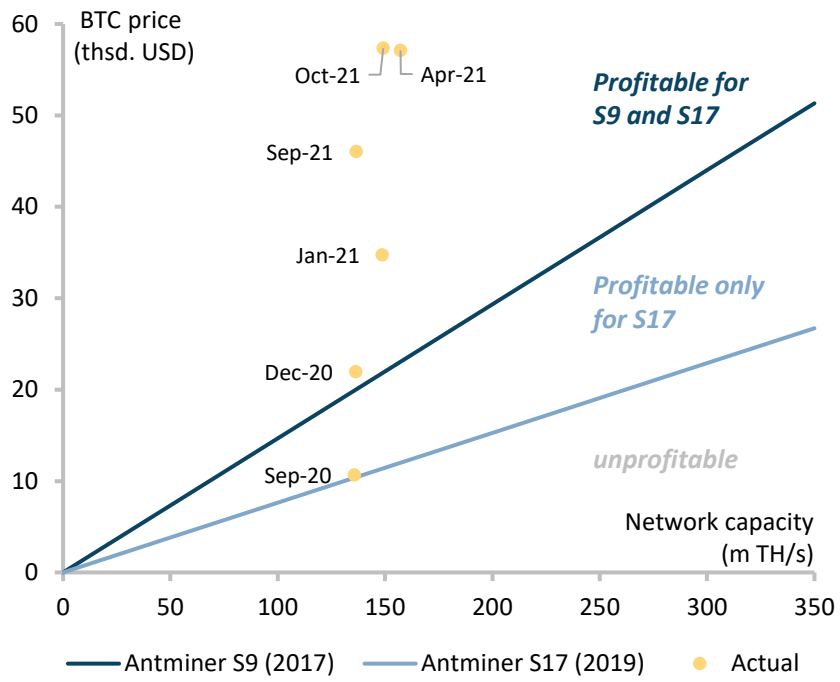
Global developments

- Overall, mining has become less profitable for individual miners in recent years as the growth of the network tends to outpace the price increases
- Globally, policymakers take different views on cryptomining: increased awareness of environmental impact vs. potential for economic development (jobs, taxes)
- Result: costs and business conditions become even more relevant factors
- In recent years: significant boom in China (around 70% of worldwide mining). Reasons:
  - Low electricity prices (comparable to GEO or lower)
  - Main point: many hardware producers are located in China and active in cryptomining themselves → faster setup times, closer proximity to production and lower costs
- However, since spring 2021: government ban on cryptomining. Reasons:
  - Mainly: increased awareness for adverse environmental impact
  - Ensuring financial stability and fighting black market trade
- Results:
  - Initially: strong decline in network capacity (-38% between May and July)
  - Some Chinese miners move to other locations (Texas, Kazakhstan)
  - Network is still below previous maximum, thus less competition for remaining miners
- Overall effect on global cryptomining sector and effects on GEO currently unclear

➢ **Key issue: (legal) developments in China**

4.1. Outlook (II)

Break-even thresholds and actual outcomes



Sources: German Economic Team, blockchain.com

Assumptions:

- *Electricity costs: 0.05 USD per KWh*
- *Efficiency/cooling losses: 20%*
- *Newly mined BTC per day: 900*
- *Daily transaction fees (BTC): 100*
- *Hardware and other costs not included*

Reading note: the hardware (S9/S17) can be run profitably if a combination of network capacity and BTC price lies in the area above the respective graph.

Situation in GEO

- Likely: old hardware still in use in GEO
- Reasoning:
  - Low electricity prices in GEO allow for (gross) profits even at lower efficiency
  - Explanation for decline in summer 2020
  - High global demand and high prices for newer generations of mining hardware
- Price spike starting in late 2020 made old hardware economically viable again
  - Illustration: even hardware introduced in 2017 can currently be run profitably as long as the BTC price remains above approx. USD 22,000; for newer models this threshold is even lower
  - But: In the long run, network growth tends to outpace price growth and is thus likely to eventually make old hardware unprofitable

➢ **Key issue: profitability of GEO hardware**

4.1. Outlook (III)

- Trend: GEO's share in the global hash rate is declining as the (actually used) capacity is stagnant around 70 MW, while the network is steadily increasing
- Renewing or expanding the hardware with newer models is difficult due to strong global demand for hardware and limited availability at the moment due to the global semiconductor shortage
- It would also require significant capital investment. Illustration:
  - Price for new Antminer S19 Pro: currently approx. USD 13,000
  - Price for 10 MW (approx. 3,100 units): USD 40 m (without additional cooling)
  - While profitability is high at the moment, potential buyers bear the risk of adverse price and network developments

- **Currently: continuation of mining in GEO likely to continue at present level**
- **Medium-term: depends on global price and network trend, older hardware likely to become unprofitable eventually**

4.2. Policy implications

Electricity market

- Cryptomining is important factor for the Georgian electricity market
- During time-span of May-18 to Oct-21: 0.4% to 14.1% of total consumption (excl. Abkhazia)
- Demand volatility presents challenge for electricity grid, with possible implications for generation capacities and imports
- Rise in cryptomining drove increase in electricity imports mainly generated by fossil fuels, thus driving CO_2 emissions

Economic effects

- Overall, cryptomining is a small sector (up to 0.3% of GDP)
- Tax revenue very low due to location of major cryptomining activities in free industrial zone
- Limited employment opportunities since cryptomining requires little labour

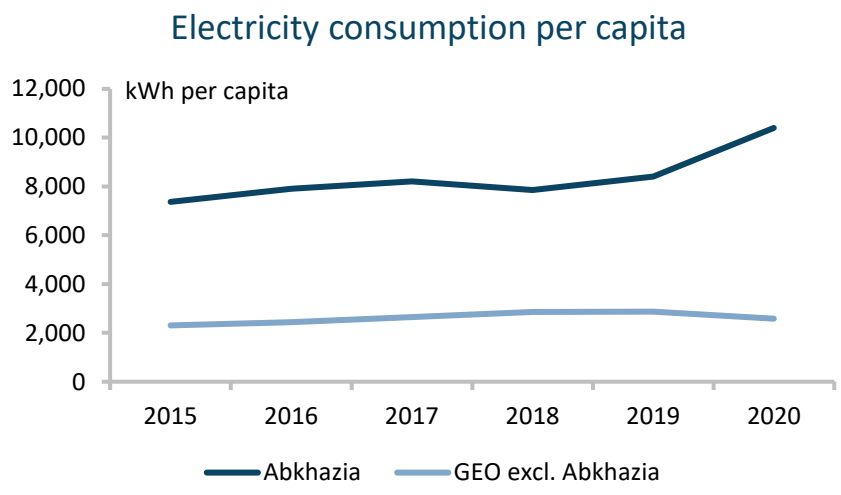
- **Cryptomining has negative effects on Georgian electricity market, economic benefits very low**
- **Problems for electricity sector much more substantial than economic benefits**
- **Development should be closely monitored**

Open for discussion

- **Need for state intervention? Regulation?**
- **Implications for international cooperation in the field of energy efficiency**

5. Cryptomining in Abkhazia

5.1. Background



Sources: ESCO, State Committee of the Republic of Abkhazia, Geostat

Background

- Electricity price: 0.005 USD/KWh, only 10% compared to rest of GEO
- Electricity consumption per capita in Abkhazia four times as high as in rest of Georgia
- Growth in electricity consumption outpaces GDP growth

Cryptomining

- Rough estimate for 2020 by local power company Chernomorenergo: mining hardware of at least 40-45 MW
- Likely: use of (cheap) hardware that is not economically viable elsewhere

➢ **Very low electricity price incentivizes mining**

➢ **Electricity consumption data suggest significant mining operations**

5.2. Estimation and current developments

Lower estimate of cryptomining for 2020	
Electricity consumption	
m kWh	**395.3**
% of total consumption	**15.5**
Revenue and costs (USD m)	
Revenue	15.4
Electricity costs	2.0
Gross profits	**13.4**
GDP (2019)	539.2
Gross profits as % of GDP	**2.5**

Sources: German Economic Team, ESCO, Chernomorenergo, State Committee of the Republic of Abkhazia on Statistics

Note: GDP data for 2019, as more recent data currently not available

Own estimation

- Lower estimate using official data and conservative assumptions on hardware (see annex for details)
- Hardware costs excluded; probably low as older hardware can be run profitably
- Result: very sizeable effect on electricity market and GDP
- Actual figures likely to be even higher

Development

- Cryptomining blamed for contributing to electricity blackouts
- Result: de-facto authorities extended ban on cryptomining until March 2022; seizures of hardware
- But: low electricity costs result in mining being profitable as long as the price remains above USD 2,200 (at curr. network capacity)
- Ban hard to enforce due to high profitability and spatial scattering of hardware

➢ **Strong effect of cryptomining on Abkhazia**

➢ **Cryptomining to remain topical despite ban**

About the German Economic Team

Financed by the Federal Ministry for Economic Affairs and Energy, the German Economic Team (GET) advises the governments of Ukraine, Belarus, Moldova, Kosovo, Armenia, Georgia and Uzbekistan on economic policy matters. Berlin Economics has been commissioned with the implementation of the consultancy.

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Implemented by

Annex: what determines mining profitability?

Variable	Notes/Explanation	Trend	Effect of increase on profitability
General / common			
Bitcoin price	Exchange rate	Boom/bust	positive
Total network capacity	Level of competition; Q: How much computing power is devoted to mining worldwide?	Increasing	negative
BTC revenue	1. Block reward for solving the bitcoin algorithm, awarded every 10 min (since May-20: 6.25 BTC) 2. Transaction fees	Halves approx. every 4 years No trend	n/a increasing
➢ **Key question: Does the price rise faster than the level of competition?**			
Individual			
Electricity costs	Main variable cost; determine threshold for engaging in mining in short-term (i.e. stop mining if electricity costs exceed revenue)	Ca. USD 0.05 per KWh in GEO	negative
Efficiency	Computations of own hardware per unit of energy	increasing	positive
Cost of hardware	Main fixed cost, average (economic) lifetime: 2.5 yrs; long-run investment choice: can costs be recovered?	increasing	negative
➢ **Key question: Do expected revenues exceed the (total) cost of mining?**			

Annex: example estimation for professional miners

Data from Sep-19 is used for this example.

How many hashes are produced worldwide and how many bitcoins do miners receive?

- World hash rate: 88,364,731 TH/s
- Worldwide hashes: 88,364,731 TH/s * 30 d * 24 h * 3,600 s = **$2.290*10^{14}$ TH**
- Bitcoin production: 1930.11 BTC per day * 30 d = 57,903 BTC (see note below)
- Transaction fees: 30.83 BTC per day * 30 d = 925 BTC
- Total bitcoin revenue for miners worldwide = 57,903 BTC + 925 BTC = **58,828 BTC**

How many hashes are produced in GEO by professional miners?

- Electricity consumption by professional mining companies (data by ESCO):
  107.980 m KWh = 107,980,000,000 Wh * 3,600 s per hour = $3.887*10^{14}$ J
- Assumption: 20% efficiency losses, esp. for cooling → $3.887*10^{14}$ J ÷ 1.2 = $3.239*10^{14}$ J for mining
- Mining hardware used in Sep-2019: Antminer S17 (45 TH/s; 2,385 W) → 1 TH = 53 Ws = 53 J
- $3.239*10^{14}$ TH ÷ 53 J/TH = **$6.112*10^{12}$ TH**

Share of GEO professional miners in total network and revenue (incl. transaction fees)

- Share of professional miners: $6.112*10^{12}$ TH ÷ $2.290*10^{14}$ TH = **2.67%**
- BTC for professional miners: 2.67% * 58,770 BTC = **1,571 BTC**
- Revenue = 1,569 BTC * 9,835 USD/BTC = **USD 15.5 m**

Note: On average, bitcoin production should be equal to the block reward in Sep-19 (12.5 BTC) every 10 minutes, thus 1,800 BTC per day (= 54,000 BTC in Sep-19). Discrepancies are due to volatility in network capacity. These can reduce the time between blocks below 10 minutes and thus increase the amount of new bitcoins above the targeted average. In this Policy Study, the exact (monthly averages of) daily values by blockchain.com are used.

Annex: example estimation for small miners (I)

Data from Sep-19 is used for this example.

Explanatory remarks

- Starting point: data by Cambridge Centre for Alternative Finance
- Cambridge Bitcoin Electricity Consumption Index (CBECI) uses data by four large mining pools to estimate countries' average monthly share in worldwide hash rate
- Key assumption: CBECI share accounts only for small miners in GEO
- Reasoning:
  - For most months, CBECI share for GEO is smaller than the share for professional mining alone (even after accounting for potential efficiency losses)
  - Example (Sep-19): 0.32% (CBECI) < 2.67% (professional miners; see previous slide)
  - Also: most of the professional mining is done by BFDC Georgia owned by Bitfury, which operates its own mining pool (not represented in the CBECI sample)
- CBECI data only available for Sep-19 to Aug-19. Assumptions for missing months:
  - May-18 to Aug-19: 0.3% (based on data in Sep-19: 0.32%)
  - Sep-20: 0.15% (based on average since Apr-20, and declining overall trend)
- Small miners do not have sufficient computing power to generate revenue by mining only for themselves. Instead, they join a mining pool. This generates fees (around 3%), which are deducted from their revenue

Annex: example estimation for small miners (II)

Revenue by small miners (incl. transaction fees)

- BTC for small miners: 0.32% * 58,828 BTC * (100% - 3% mining fee) = **183 BTC**
- Revenue: 183 BTC * 9,835 USD per BTC = **USD 1.8 m**

Electricity consumption by small miners

- Worldwide hashes in Sep-19: $2.290*10^{14}$ TH
- Hashes by GEO professional mining: $6.112*10^{12}$ TH (see slide 22)
- Rest of worldwide hashes: $2.290*10^{14}$ TH - $6.112*10^{12}$ TH = $2.229*10^{14}$ TH
- Hashes by small miners in GEO: 0.32% * $2.229*10^{14}$ TH = $7.134*10^{11}$ TH
- Mining hardware used in Sep-19: Antminer S17 → 1 TH = 53 Ws = 53 J
- $7.134*10^{11}$ TH * 53 J / TH = $3.781*10^{13}$ J = 10.5 m KWh
- Assumption: additional 20% for efficiency losses and cooling

  → 10.5 m KWh * (100% + 20%) = **12.6 m KWh**

Annex: assumptions and sample calculations for hardware

- Starting point: electricity consumption data
- Assumption: use of Antminer S9 until Mar-19, Antminer S17 afterwards
- Average price: 2,000 USD; average lifetime: 2.5 years; depreciation over lifetime
- For professional miners in 2018:
  - Nov-18 is month of maximum consumption (55.6 m KWh)
  - Assuming 20% cooling losses: 55.6 m KWh ÷ 1.2 = 46.3 m KWh
  - Assuming 24/7 production: 46.3 m KWh ÷ (30 d * 24 h) = **64.4 MW**
  - Represents the minimum amount of hardware that must be present for mining
  - Antminer S9 (1,375 W) → 64.4 MW ÷ 1,375 W ≈ **46,800 units**
  - Cost per year: 46,800 units * 2,000 USD ÷ 2.5 years = **37.5 m USD**
- For professional miners from 2019 to present:
  - Jun-18 is month of maximum consumption (112.0 m KWh)
  - Using methodology from above and power consumption of Antminer S17 (2,385 W) results in estimate for capacity of around **130 MW** in Jun-2019 (approx. **54,000 units**)
  - Important: some of this hardware seems to have been used only in summer 2019
  - Assumption: significant sell-off in hardware afterwards, for 2020 onwards: only approx. **70 MW** of capacity (mostly by BDFC Georgia)
- A similar approach has been used to estimate hardware costs for private miners

Annex: calculations for Abkhazia (I)

Assumptions

- Starting point: estimate for 2020 by Chernomorenergo (40-45 MW)
- → Capacity: 45 MW at 24/7 utilization
- 20% efficiency and (additional) cooling losses
- Mining equipment: Antminer S9 (45 TH/s; 2,385 W) → 1 TH = 101.9 J
- Reasoning: Antminer S9 not (always) profitable in other locations, cheap hardware

Hashes and mining revenue in 2020 worldwide

- Average worldwide hash rate: 116,513,234 TH/s
- Worldwide hashes: 116,513,234 TH/s * 366 d * 24 h * 3,600 s = **$3.684*10^{15}$ TH**
- Newly mined BTC in 2020: 453,387 BTC
- BTC revenue due to transaction costs: 26,242 BTC
- Total revenue: 453,387 BTC + 26,242 BTC = **479,629 BTC**

Annex: calculations for Abkhazia (II)

Electricity consumption due to mining in Abkhazia

- 45 MW * 24 h * 366 d = 395,280 MWh ≈ **395.3 m KWh**
- Total electricity consumption: 2,552.4 m KWh
- Share of cryptomining: 395.3 m KWh ÷ 2,552.4 m KWh = **15.5%**

Mining revenue in Abkhazia

- Assumption: 20% efficiency losses → 395.3 m KWh ÷ 1.2 = 329.4 m KWh for mining
- 329.4 m KWh = 329,400,000 Wh = $1.186*10^{15}$ J
- Hashes in Abkhazia: $1.186*10^{15}$ J ÷ 101.9 J/TH = **$1.164*10^{13}$ TH**
- Share of Abkhazia in worldwide mining: $1.164*10^{13}$ TH ÷ $3.684*10^{15}$ TH = **0.316%**
- BTC for Abkhazian miners: 0.316% * 479,629 BTC = 1,516 BTC
- Revenue in USD: 1,520 BTC * 10,137 USD/BTC = **15.4 m USD**
- Electricity cost: 395.3 m KWh * 0.005 USD/KWh = **2.0 m USD**
- Gross profit: 15.4 m USD - 2.0 m USD = **13.4 m USD**