Codes of Practice

The purpose of these Codes of Practice is to provide easy-to-use set-by-set guidance on how to conduct energy and/or environmental footprint studies in the Blockchain domain.

How to use these Codes of Practice :

We strongly recommend you start by first reviewing the article behind these guidelines here: ***Promoting Rigour in Blockchain's Energy & Environmental Footprint Research: A Systematic Literature Review (Currently under peer review)***

After reading the article, you should move on to the Details & Guidelines section of the website and follow all the steps in a sequence. We have supplied templates to help you through the process at each step.

How to follow the guidelines?

Step 1 helps you adhere to the scientific method while step 2 will provide you with more specific instructions on how to design/improve your blockchain energy projects.

Ideally, we hope that you will follow both steps 1 and 2 in their entirety. However, we understand this may not align with your project's intended outcome particularly if its an industry-focused project.

In that case, we strongly suggest you consider the following 2 points regarding Step 1:

1. Following the scientific method as illustrated in Step 1 can help your project be easy to understand, replicate and consequently make it trustworthy.
2. You will be able to identify the gaps in your approach while also building upon existing work.

Still convinced you do not need to follow Step 1? Please move on to Step 2.

Details & Guidelines

Expand on the definition of each guideline below

Step 1: Structuring your study
Planning your study design is important, we have developed a 7 step process in line with the guidelines of Kothari (2...

Step 2: Research Methodology Specific Practices
Quantitative Energy Modeling · Literature Reviews · Data Analysis and Statistics · Case Studies · Experiments

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How rigorous is your work?

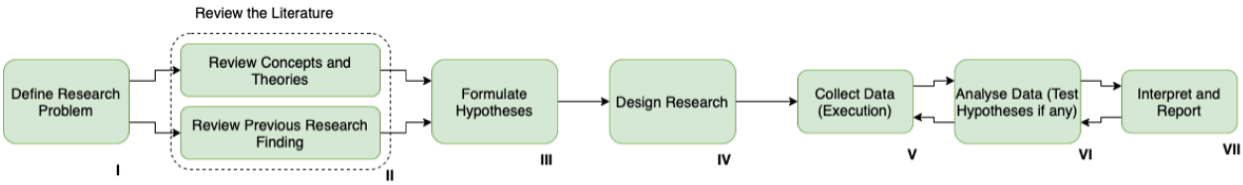
If you wish to understand how rigorous your (or a specific study) is, you may use a table as follow to guide your investigation. This table is based on the criteria mentioned in Steps 1 and 2. Your rigor table may look different from ours (this is expected!).

	Explicit Research Methodology	Sharing the Data	Sharing the Source Code	Traceable & verifiable justifications	Using or collecting geographic data	PUE Value
Study 1	**Yes**	**Partially**	No Test Routines	**Yes**	**Using unvalidated sources**	**Using Cambridge Value**

↑ Codes of Practice

Step 1: Structuring your study

Planning your study design is important, we have developed a 7 step process in line with the guidelines of Kothari (2004)



Tasks

- [ ] Download the template document: click here

Blockchain Energy Model Template.docx
DOCX File
16.0 KB

- [ ] Define the problem
- [ ] Review and document the literature
- [ ] Define the hypothesises
- [ ] Document your methodology
- [ ] Collect Data

- [ ] Conduct the analysis
- [ ] Interpret and report the results

Define Problem

You need to be as concise as possible in defining a problem. For instance, if you intend to estimate the energy consumption of a specific cryptocurrency, you may phrase your research problem as follows:

In this study, we attempt to estimate the energy consumption of Bitcoin using the rational agent theory.

- ▼ More than one problem?
  - ▶ Include more explicit research questions rather than combining everything in one question.

Review and Document Literature

A detailed description of how to conduct a literature review is presented by Kitchenham et al. (2007)

You may find it helpful to break the process down into four steps:

1. Document Search Strategy: You should document what you searched (search string) and where (search platforms, e.g. Google Scholar).
2. Shortlisting Relevant Literature: Depending on the number of articles/blogs/documents retrieved from the search, you may decide to review the whole document or just a part of it to determine its relevance. It is important to document the process used for shortlisting (e.g. review of title, abstract, etc).
3. Determine the Quality of Shortlisted Literature: Not all of the shortlisted literature would be of the same value to your problem thus it is important to further define the quality of each shortlisted article. For example, while examining the carbon footprint of Bitcoin, you may come across models specifically designed for Proof-of-Stake currencies, while being of high interest, it may not be of the highest value to your research problem thus you may decide to assign it a low-quality marker (note that the quality here is subjective to your problem and does not refer to the rigour of the article you are reviewing).
4. Document all the Shortlisted Literature: This is the easy bit, all you need to do now is list all of the high-quality relevant literature! Feel free to use of the template for this.

Need a starting point? Look at the list below to find inspiration from existing research:

- ▼ Energy consumption:
  - ▼ Proof-of-Work based systems?
    1. The Cambridge Model for Bitcoin (CCAF), you should read their methodology section.
    2. Read Vranken (2017)
  - ▼ Proof-of-Stake based systems?
    1. Review the model designed by UCL, London here
    2. Review the model designed by CCRI here

- ▼ Something else?
    1. You can still use one of the above-suggested starting points to get a sense of how these models work and then follow our guidelines based on your choice of research method.

- ▼ Carbon emission:
    - ▼ Emission at a protocol level:
        1. A good starting point is the seminal article by Stoll et al. (2019)
    - ▼ Emission at a consumer level:
        1. Only want to understand your carbon emission within a crypto-system? You should start by reviewing the hybrid methodology put forth by the South Pole and CCRI

Literature Review.xlsx
XLSX File
13.0 KB

Formulate Hypothesis

Now that you have a clear research problem and a good overview of the literature, you need to concisely define a hypothesis (or hypotheses).

An example of a very simple hypothesis is: "*Blockchain X consumes less electricity than Bitcoin*". You may (and should) come up with a hypothesis that can be tested by your research design, and this can be used by your reader to test your work.

- ▼ Confused ?

  You can start with your research problem as most research problems usually have an implicit hypothesis in them. For example, if your research problem is understanding the carbon emission of your cryptocurrencies using the methodology proposed by Stoll et al. (2019), your hypothesis can be "Bitcoin carbon emission methodology can also be reliability applied to other crypto-assets".

  Still confused? You may benefit from reading the ASU guidelines on hypothesis formulation here

  Still cannot figure it out? It may be okay to move with the rest of the guidelines

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From this point onwards, you will benefit from jumping around in the guidelines a bit. For example, if you need assistance in understanding how best to design your model, you will likely benefit from first reviewing the best practices from Step 2. Please do not be afraid to go back and read the rest of the guidelines if you find anything confusing.

Design Methodology

A clear research design is foundational for any reproducible or verifiable research work. Depending on your problem, literature review, and hypothesis, you already know what type of research you would be conducting. At this point, we recommend that you review guidelines specific to your preferred research methodology.

Irrespective of the research methodology picked, you should try and do the following:

- [ ] Clearly document all of the steps taken to conduct your research (this may include the parameters you used for your model)
- [ ] If possible, include a concise figure of your research method
- [ ] Acknowledge the limitations of the method
- [ ] Document all the assumptions

Collect Data

Reliable data is difficult to obtain in decentralised systems making it even more important that you sufficiently document how you collected and validated the data.

- [ ] Document the data collection process in sufficient details
- [ ] Perform and document validation steps

Analyse and Report Data

If you designed a model to measure/estimate/predict carbon emission or electricity consumption, your model likely contains assumptions (hopefully all of them are already documented in your research design step). Now is the time to explicitly acknowledge the impact of your assumptions on the results from your model.

- [ ] Include confidence intervals and/or sensitivity analysis with your results

↑ Codes of Practice

Step 2: Research Methodology Specific Practices

Quantitative Energy Modeling

▼ What is quantitative energy modelling?

Quantitative models rely on a robust datas
used in conjuncture with a social, econom
technical model of the blockchain.

For instance, the CCAF model is an example
computational economic model while the Dig
model is an example of a socio-economic mo
these models are based on the use of quanti
analysis for the estimation of energy consum
The exact model composition within quantita

Literature Reviews

▼ What is a literature review?

A narrative review of the literature can provi
insights into existing models and the potenti
and weaknesses of these models. These revi
targeted toward different crowds, some of th
exclusively on experts in the domain (Lei et a
while others are a more general introduction
energy and environmental footprint of Blockc
(Vranken, 2017).

Literature reviews are widely used in a numb
cognizant fields such as Information System

Data Analysis and Statistics

▼ What is a Data Analysis and Statistics?

Unlike quantitative energy modelling, a m
relies on data analysis and basic statistics
sophisticated. These models often rely on
or multivariate analysis of variables assoc
the energy or environmental footprint of
cryptocurrencies.

Think about a very simple model (such as the
model), in this case rather than focusing on t
consumption of the whole network, you only

Case Studies

▼ What is a case study?

Case studies allow us to take an in-depth l
specific instance of a broader phenomeno

In energy studies of Blockchain, these case s
often specific to cryptocurrencies and their e
environmental footprint. There is a wealth of
the selection and execution of case study an
ensure that the studies are of high relevance
broader field.

Tasks

☐ Appropriate case selection

Experiments

▼ What is an experiment?

In some instances where it might be diffic
extract information from observation, it m
useful to conduct experiments.

In the Blockchain energy domain, these expe
often done to calculate the energy consumpt
specific device and then use that information
generate measurements for a subset or the v
network.

Tasks

☐ If feasible, read the COBP Document by US

Quantitative Energy Modeling

▼ What is quantitative energy modelling?

Quantitative models rely on a robust dataset that is used in conjuncture with a social, economical, or technical model of the blockchain.

For instance, the CCAF model is an example of a computational economic model while the Digiconomist model is an example of a socio-economic model. Both of these models are based on the use of quantitative analysis for the estimation of energy consumption.

The exact model composition within quantitative modeling can be based on any combination of the social, economic, and technical variables above thus the exact quality indicators vary significantly depending on the model formulation and the intended use.

Tasks

- [ ] Traceable & verifiable justification for hardware assumption
- [ ] Traceable & verifiable justification for the economic assumption
- [ ] Documenting collection and validation of geographic data
- [ ] Empirically backed PUE value
- [ ] Not using a faulty study for data or methodological insights
- [ ] Avoid improper units of comparison
- [ ] Timestamp everything!

Traceable & verifiable justification for hardware assumption

One of the biggest issues with quantitative energy modelling studies is the lack of evidence for assumptions made by studies on the hardware. We specifically suggest that the authors:

- [ ] State the assumptions within the text and not in supporting material
- [ ] Add sensitivity analysis or confidence intervals when filling in missing data

Traceable & verifiable justification for economic assumption

Similar to assumptions about the hardware in use, in economic models, it is vital that the authors back their assumptions with evidence.

- [ ] Include both capital and operational costs for different agent types (small, medium, and large)
- [ ] Cost of electricity should be as granular as possible, if data is missing, use location-based metric
- [ ] Hardware lifespan assumption should be validated using real-world data

Documenting collection and validation of geographic data

The geographic data plays a crucial role in modelling the environmental footprint of these crypto-assets. We recommend that you:

- [ ] Avoid using mining pool IP address, if used, it should be accompanied by sensitivity analysis or appropriate confidence intervals
- [ ] Avoid using non-academic literature and unvalidated sources for location
- [ ] Include the date of data collection
- [ ] Do not extrapolate location data, if done, accompany it with sensitivity analysis or confidence intervals

Empirically backed PUE value

PUE value can have a huge impact on your final predictions, we suggest that you base your PUE value on empirical evidence.

- [ ] If you do not have reliable data on PUE, try to model different types of agents (small, medium, and large) as each of them likely has different PUE values

Not using a faulty study for data or methodological insights

Avoid unreliable sources of data such as proven faulty studies (Mora et al., 2018))

▼ Not sure if the study you have selected is reliable?

Our article provides an in-depth discussion of scientific rigour and different quality measurements, please review the quality measures for quantitative energy modelling.

Avoid improper units of comparison

You should avoid using improper units of comparison.

For instance, Bitcoin and Ethereum do not consume electricity per unit of transaction but per block (Sedlmeir et al., 2020). Comparing per trans- action electricity consumption of Bitcoin or Ethereum may be inaccurate or misleading according to (Sedlmeir et al., 2020).

Timestamp everything!

Timestamp everything that can be timestamped: data, predictions, measurements

↑ Step 2: Research Methodology Specific Practices

Literature Reviews

▼ What is a literature review?

A narrative review of the literature can provide useful insights into existing models and the potential strengths and weaknesses of these models. These reviews can be targeted toward different crowds, some of these focus exclusively on experts in the domain (Lei et al., 2021) while others are a more general introduction to the energy and environmental footprint of Blockchain (Vranken, 2017).

Literature reviews are widely used in a number of cognizant fields such as Information Systems and Computer Science thus there is a wealth of guidelines on the quality of these reviews.

Tasks

- [ ] Follow the 4 steps listed here
- [ ] Select a Rigorous Type of Review
- [ ] Explicit Document Criteria
- [ ] Select Appropriate Search Database
- [ ] Document Sampling Process

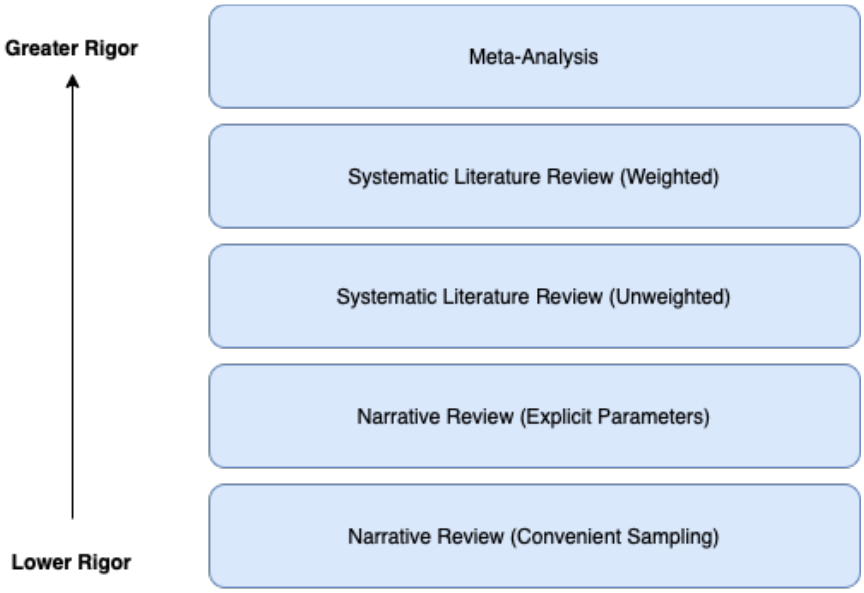
Follow the 4 steps

Follow the 4 steps listed in the structuring your study section (click here)

- [ ] Document Search Strategy
- [ ] Shortlist Relevant Literature
- [ ] Determine the Quality of Shortlisted Literature
- [ ] Document all the Shortlisted Literature

Select a Rigorous Type of Review

If possible, we recommend that you use a more rigorous type of review such as a Systematic Literature Review or a meta-analysis.



▼ Not sure what each of these categories means?

Start by reading the literature review section in Savocool et al. (2018)

If you still need more instructions on how to conduct a review, you can refer to Kitchenham et al. (2007)

Explicit Document Criteria

For these reviews, it is important that you indicate why you pick a specific study or why you excluded some studies. The easiest (and most accurate) way of documenting your selection process is through explicit inclusion and exclusion criteria.

- [ ] Document inclusion criteria
- [ ] Document exclusion criteria

Select Appropriate Search Database

When we conducted our review, we noticed that there is significant research being done in blockchain energy science in both academia and industry. Thus we strongly recommend that you include scientific and grey literature in your review.

- [ ] Included scientific literature from the popular repository (Google Scholar, IEEE Xplore, ACM, etc)
- [ ] Included grey literature (cryptocurrency-specific models, models developed/employed by firms involved in the crypto climate accord)

Document Sampling Process

When you search for relevant literature to include, you might end up with a large set of articles. It may make it difficult for you to review all of them. In this case, you may choose to employ a sampling process. If you use a sampling process (selecting a subset of all articles), you should document the sampling process (why and how).

↑ Step 2: Research Methodology Specific Practices

Data Analysis and Statistics

▼ What is a Data Analysis and Statistics?

Unlike quantitative energy modelling, a method that relies on data analysis and basic statistics is far less sophisticated. These models often rely on univariate or multivariate analysis of variables associated with the energy or environmental footprint of cryptocurrencies.

Think about a very simple model (such as the South Pole model), in this case rather than focusing on the energy consumption of the whole network, you only focus on a specific problem while utilising simple statistics.

Tasks

- [ ] Check if any of the recommendations from quantitative energy modelling apply to your model
- [ ] Apply a more rigorous form of data analysis
- [ ] Adhere to the Ten Simple Rules for Effective Statistical Practice

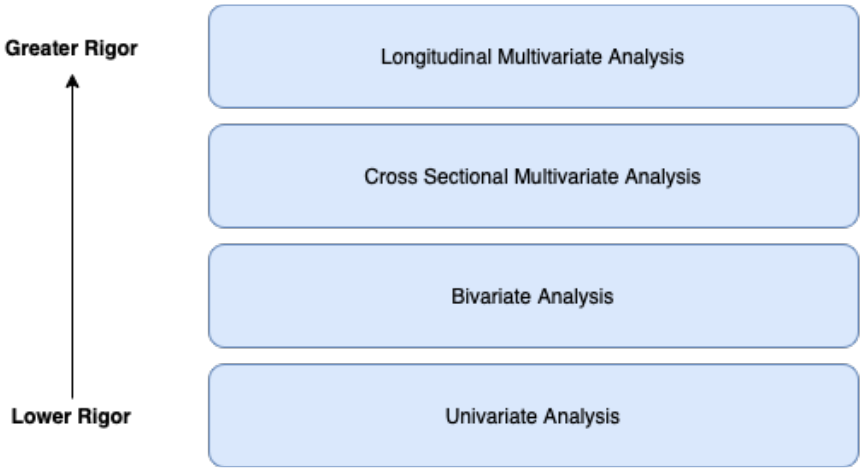
Check if any of the recommendations from quantitative energy modelling apply to your model

It is difficult to segment quantitative energy models from simple statistical models if you include one or more economic, technical and social variables in your statistical models. Thus it is important that you review all the guidelines in quantitative energy modelling and check if they apply to your model.

- [ ] Document which of the guidelines from quantitative energy modelling apply to your model, if none, document why.

Select a Rigorous Type of Review

If possible, we recommend that you use a more rigorous type of statistical model



▼ Not sure what each of these categories means?

Start by reading the literature review section in Savocool et al. (2018)

Adhere to the Ten Simple Rules for Effective Statistical Practice

We recommend that you read these guidelines designed by researchers at Carnegie Mellon University (along with researchers from Johns Hopkins, Harvard University, and UC Berkeley). The ten simple rules are:

- [ ] Ensure that your statistical methods enable data to answer scientific questions
- [ ] Account for noise in your data
- [ ] Ensure data collection is informed by intended statistical method
- [ ] Examine the quality of the data
- [ ] Contextualise the statistical method in the scientific context of your problem rather than treating the analysis as a set of computations
- [ ] Keep it simple (Occam's razor)
- [ ] Provide assessments of variability
- [ ] Check and document your assumptions
- [ ] Where applicable, replicate your analysis
- [ ] Ensure that your analysis is reproducible

↑ Step 2: Research Methodology Specific Practices

Case Studies

▼ What is a case study?

Case studies allow us to take an in-depth look at a specific instance of a broader phenomenon.

In energy studies of Blockchain, these case studies are often specific to cryptocurrencies and their energy or environmental footprint. There is a wealth of literature on the selection and execution of case study analysis to ensure that the studies are of high relevance to the broader field.

Tasks

- [ ] Appropriate case selection
- [ ] Defining clear boundaries
- [ ] Acknowledge the uniqueness or generalisability

Appropriate case selection

There are different types of case selections such as typical, diverse, extreme, influential, most similar and most different. If you are not sure which type of case study is appropriate for your study, we strongly recommend you read Savocool et al. (2018) (Pages 30-32).

- [ ] Select an appropriate type for your case study (from the above-listed types)
- [ ] Collect an appropriate number of cases (it can be single or comparative)
- [ ] Document any spatial variations in your cases
- [ ] Document and account for any temporal variations

Define clear boundaries

It may be difficult to analyse a specific case in its entirety thus it is important to acknowledge the boundaries of your analysis. This may for example be temporal bounds (e.g. you only calculate energy consumption for Bitcoin for the past 4 months)

Acknowledge the uniqueness or generalisability

You may analyse a single PoS based cryptocurrency but your approach or your results may be informative for other assets or it could be so special that your analysis should not be used for any other currency. Thus we recommend that you explicitly acknowledge the uniqueness or generalisability of your chosen case.

↑ Step 2: Research Methodology Specific Practices

Experiments

▼ What is an experiment?

In some instances where it might be difficult to extract information from observation, it may be useful to conduct experiments.

In the Blockchain energy domain, these experiments are often done to calculate the energy consumption of a specific device and then use that information to generate measurements for a subset or the whole of the network.

Tasks

- [ ] If feasible, read the COBP Document by US DoD
- [ ] Ensure representative sample
- [ ] Appropriate choice of setting
- [ ] Review the guidelines for Case Study and adhere to applicable Guidelines

If feasible, read the COBP Document by US DoD

There is a wealth of literature on how to conduct an experiment in academia and beyond. We strongly recommend that you review one of the following documents before constructing your experiment:

- [ ] Code of Best Practice: Experimentation by Command and Control Research Program in DoD (Click here)
- [ ] Conducting experiments in information systems setting: GitLab Experimentation Best Practices (Click here)

Ensure representative sample

You should select an appropriate experiment object for your experimentation. If you are designing an experiment to analyse the performance and energy profile for mining Dogecoin, you should select a range of GPU devices that are popular for mining Dogecoin rather than just focusing on a single device.

▼ Confused?

No worries, you should review the guidelines related to the selection of an appropriate case study as that might help you better select an experiment object.

Appropriate choice of setting

The settings of the experiment should closely resemble that of the real-world object to ensure a reliable result. Specifically, look out for seasonality in your data.

Review the guidelines for Case Study and adhere to applicable Guidelines

You should review the guidelines for Case Study as that may apply to some experiments. If you think none of the suggestions in the case study apply to your experiments, you may skip this!