ML for Emissions Monitoring

Reporting and Verification of Corporate GHG emissions

Lecturer: Dr Kasia Tokarska

Lecture Outline

In this lecture you will learn about:

1. Emissions accounting methods:
- GHG Protocol; Scope 1, 2, 3 emissions
- What's the problem: Challenges with estimating Scope 1,2 , 3 emissions

2. Methods & Applications:
- Overview of traditional emission estimation methods
- Overview of machine learning methods to estimate of Scope 1,2,3, emissions

3. Challenges and Future Directions
- Recommendations for selecting machine learning methods [interactive activity]

Physical Risks

Wildfires

Heatwaves

Hurricanes

Drought

Sea level rise

Flooding

Reducing emissions lowers physical risks

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Transition risks

Policy

Regulation

Liability

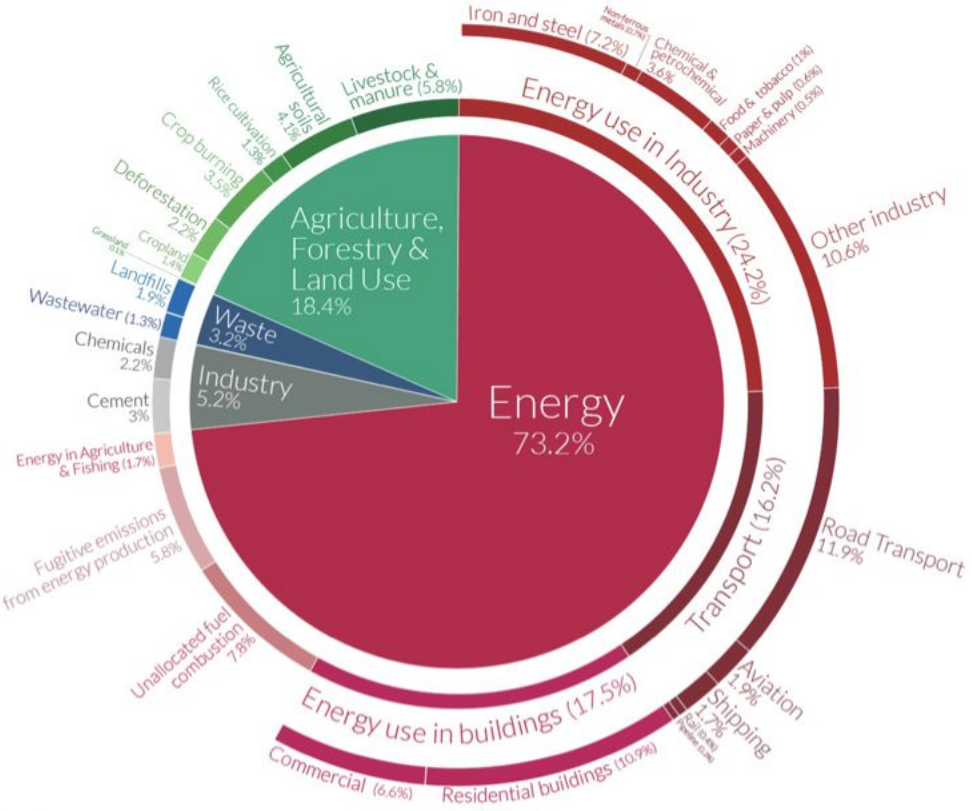
Market

Reputation

Technology

Reducing emissions lowers transition risks

Greenhouse gas emissions by sector



OurWorldinData.org – Research and data to make progress against the world's largest problems.
Source: Climate Watch, the World Resources Institute (2020).

Figure source: Our World in Data, 2016

Scope 1, 2, 3 Emissions

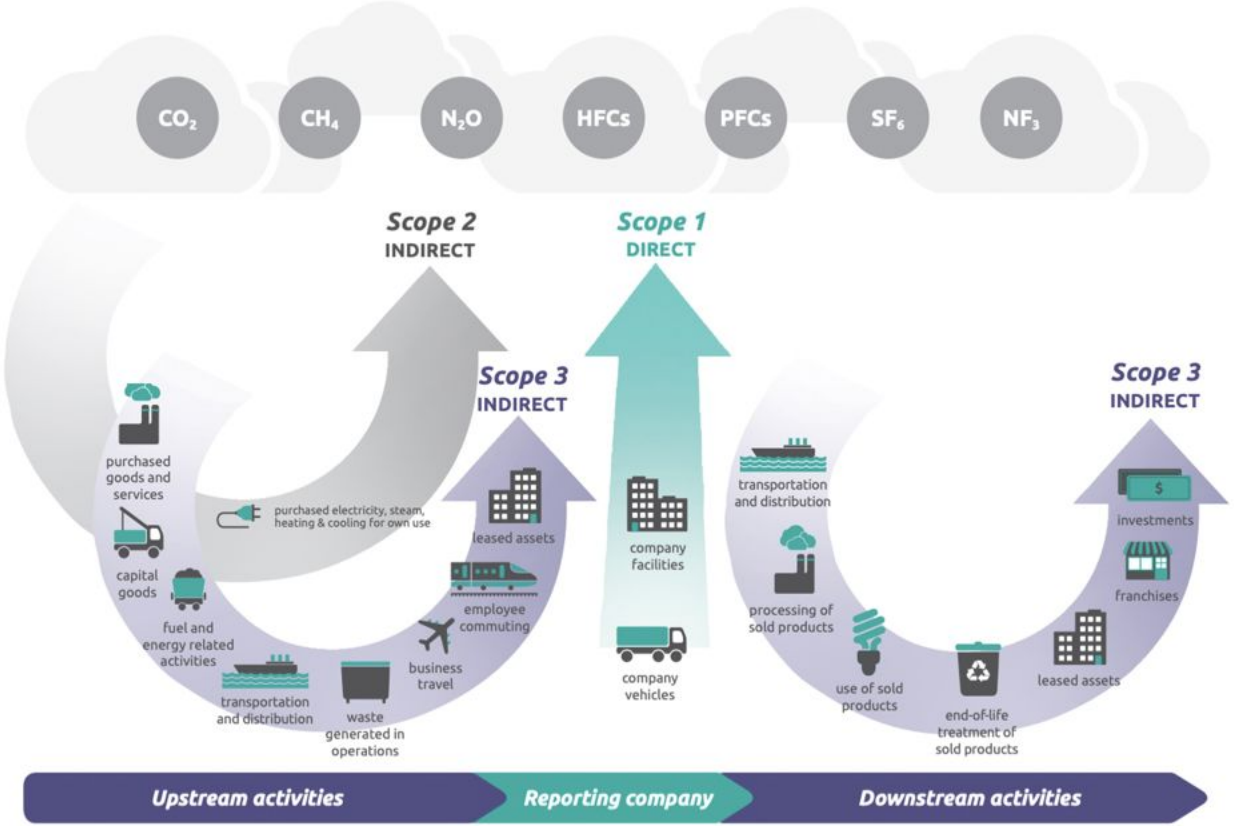


Figure source: GHG protocol. Figure 1.1.

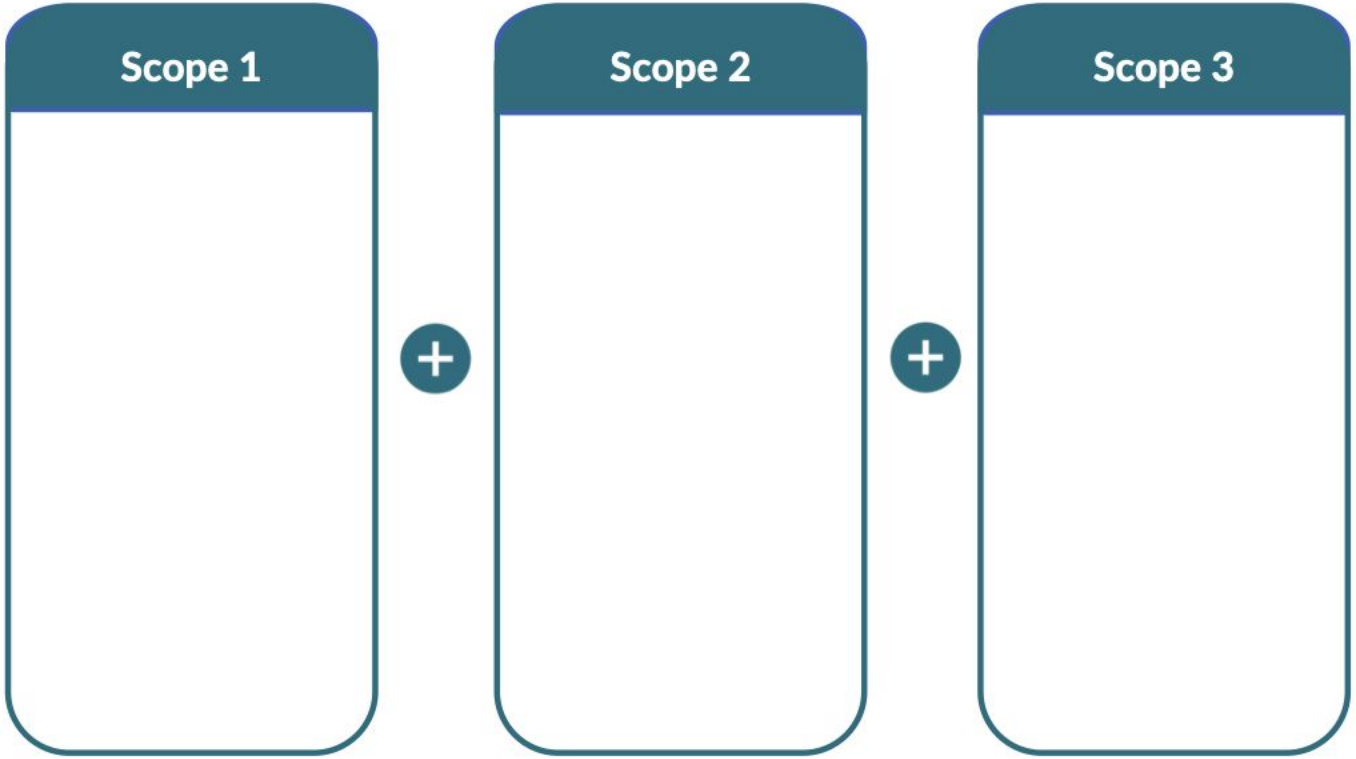
Scope 1, 2, 3 Emissions

Emissions type	*Scope*	*Definition*	*Examples*
Direct emissions	Scope 1	Emissions from operations that are owned or controlled by the reporting company	Emissions from combustion in owned or controlled boilers, furnaces, vehicles, etc.; emissions from chemical production in owned or controlled process equipment
Indirect emissions	Scope 2	Emissions from the generation of purchased or acquired electricity, steam, heating, or cooling consumed by the reporting company	Use of purchased electricity, steam, heating, or cooling
	Scope 3	All indirect emissions (not included in scope 2) that occur in the value chain of the reporting company, including both upstream and downstream emissions	Production of purchased products, transportation of purchased products, or use of sold products

Figure source: GHG protocol.

Example of GHG accounting

Imagine you are running an ice-cream company "*EarthlySweets*" distributing ice cream to different supermarkets



Example of GHG accounting

Imagine you are running an ice-cream company "*EarthlySweets*" distributing ice cream to different supermarkets

Scope 1

Running five fleet vehicles (distribution and transportation of ice cream)

Heating office spaces using on-site boilers

Emissions from the refrigeration equipment used to keep the ice cream cold

Total:
26,600 kg CO_{2e} /year

+

Scope 2

+

Scope 3

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Scope 2

Electricity use: 20,000 kWh/year

Includes:
- lighting,
- air conditioning of office spaces,
- energy used for keeping the ice-cream cool (ice-cream storage

Total:
8,000 kg of CO_{2e}

+

Scope 3

Example of GHG accounting

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Scope 3

Business travel (e.g., flights to ice cream conferences)

Emissions from employee commuting to office

Emissions from the production and transportation of the raw ingredients used to make the ice cream.

Total:
1150,333 kg of CO_{2e}.

Scope 1 emissions of one company are Scope 3 emissions of another company

	Extraction, processing and transport	Power generation	Transmission & distribution	End user consumption
	Emissions associated with extraction	Emissions from combustion of fuels in power generation	Power losses & consumption of power by utility (10% of total generated power)	Consumption of power by end user (90% of total generated power)
Mining / extraction company	**Scope 1** ($5\ tCO_2e$)	**Scope 3 (use of sold products)** ($100\ tCO_2e$)	-	-
Power generator	**Scope 3 (fuel- and energy-related activities)** ($5\ tCO_2e$)	**Scope 1** ($100\ tCO_2e$)	-	-
Utility	**Scope 3 (fuel- and energy-related activities)** ($10\% * 5\ tCO_2e = 0.5\ tCO_2e$)	(reported as scope 2)	**Scope 2** ($10\% * 100\ tCO_2e = 10\ tCO_2e$)	**Scope 3 (fuel- and energy-related activities)** ($4.5\ tCO_2e + 90\ tCO_2e = 94.5\ tCO_2e$)
End user	**Scope 3 (fuel- and energy-related activities)** ($90\% * 5\ tCO_2e = 4.5\ tCO_2e$)	(reported as scope 2)	**Scope 3 (fuel- and energy-related activities)** ($0.5\ tCO_2e + 10\ tCO_2e = 10.5\ tCO_2e$)	**Scope 2** ($90\% * 100\ tCO_2e = 90\ tCO_2e$)

Source: Supplement to the Reference Guide for the GRESB Infrastructure Asset Performance Component Guidance on Scope 3 Greenhouse Gas Emissions Reporting

Scope 3 emissions tend to be most under-reported

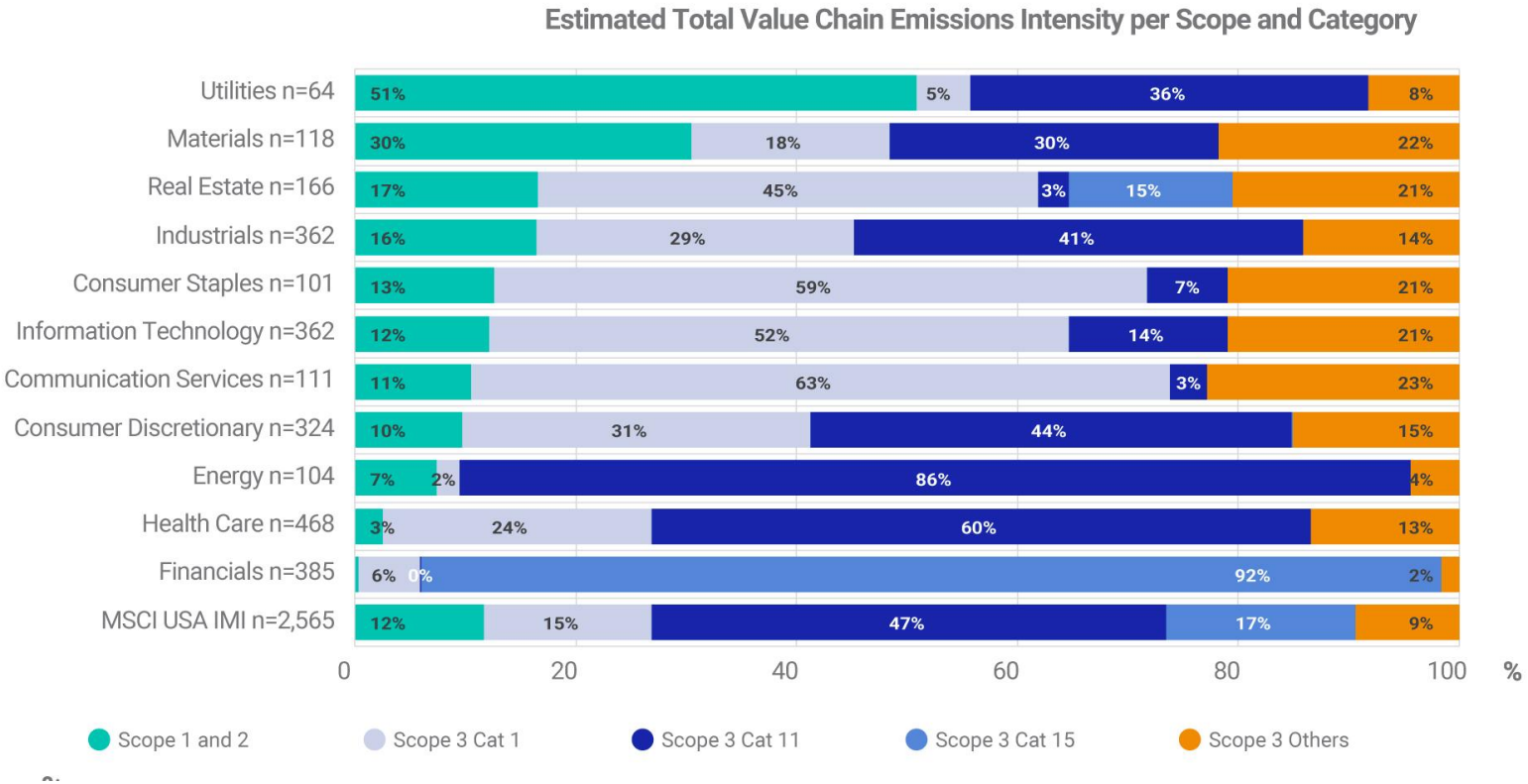


Figure source: MSCI

Traditional methods of emission accounting

Example of calculating emissions from purchased goods and services

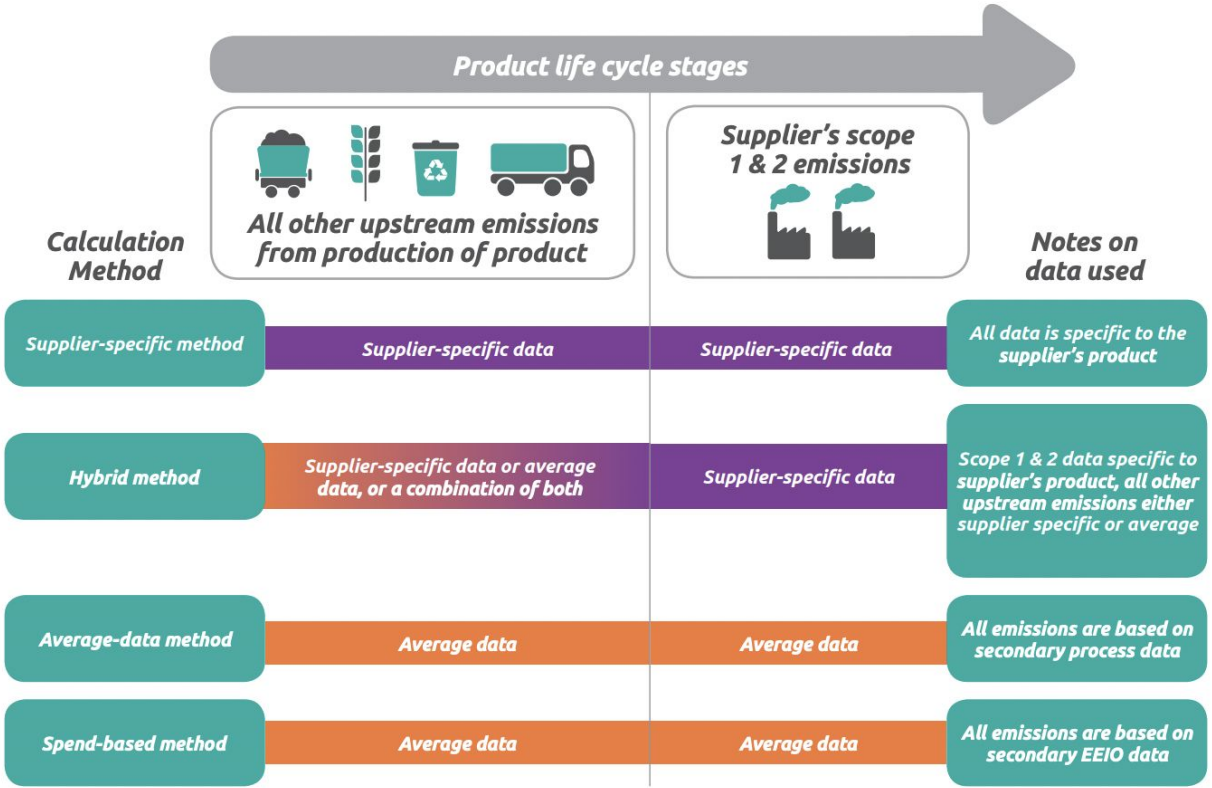
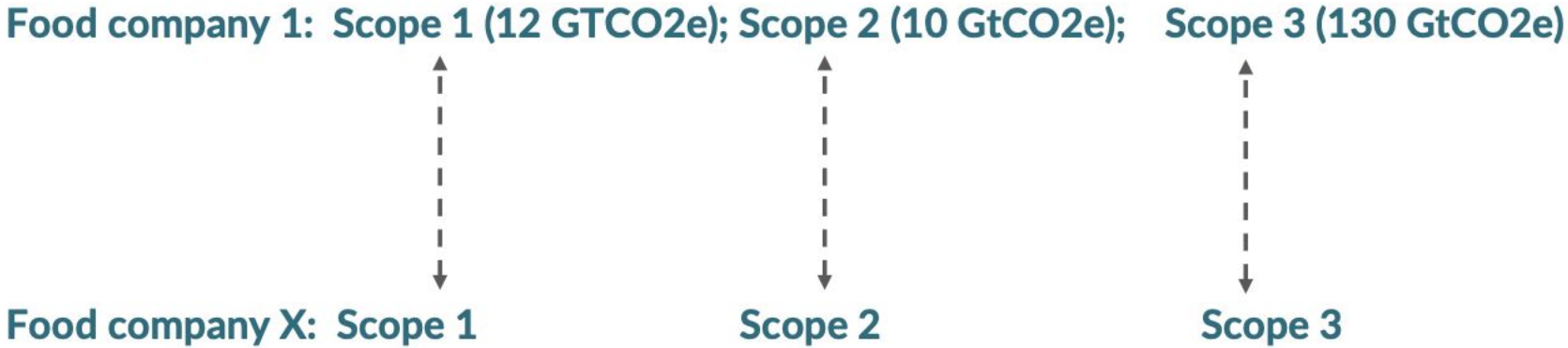


Figure source: GHG protocol.

ML for emission estimates

The idea is to make use of already reported emissions from industries in various sectors (e.g., CDP Database) and make inference on emissions for unknown company X in a given sector.



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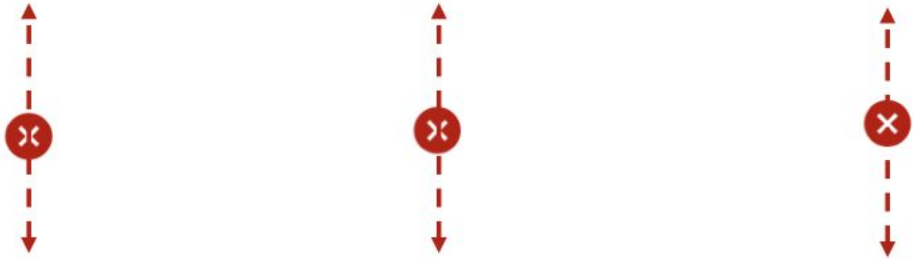
Large international company

Food company 1: Scope 1 (12 GTCO2e); Scope 2 (10 GtCO2e); Scope 3 (130 GtCO2e)



Food company X: Scope 1 **Scope 2** **Scope 3**

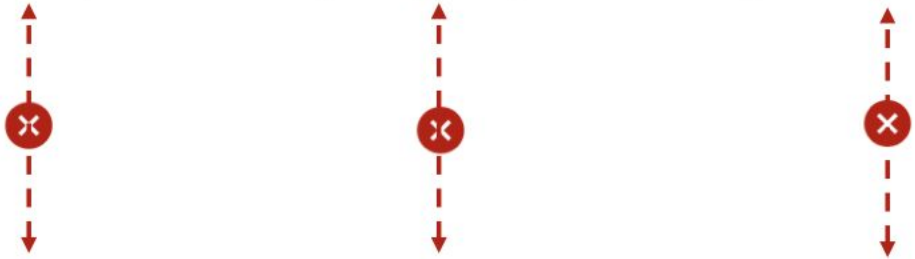
Small family-owned store

ML for emission estimates

The idea is to make use of already reported emissions from industries in various sectors (e.g., CDP Database) and make inference on emissions for unknown company X in a given sector.

Large international company in California, USA

Food company 1: Scope 1 (12 GTCO2e); Scope 2 (10 GtCO2e); Scope 3 (130 GtCO2e)



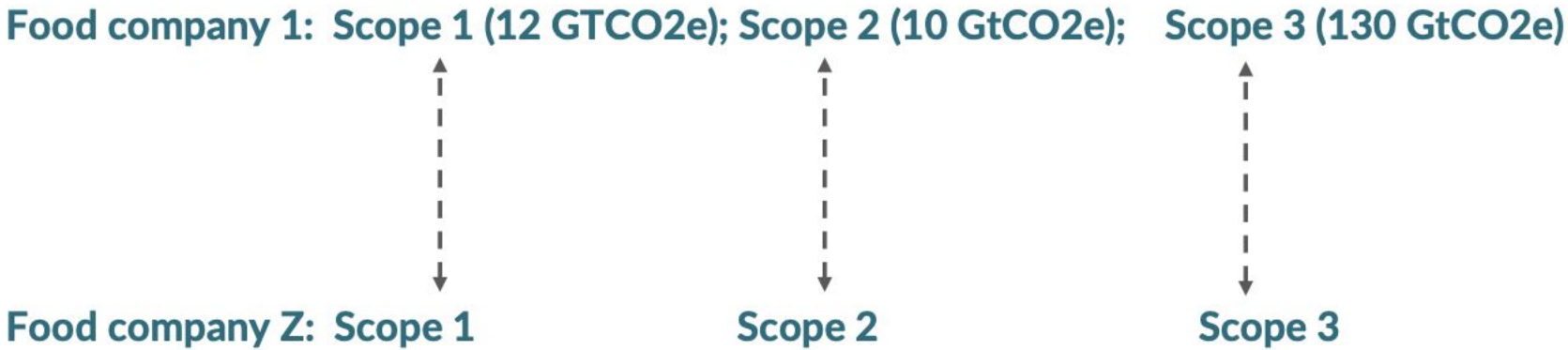
Food company X: Scope 1 **Scope 2** **Scope 3**

Small family-owned store in Finland

ML for emission estimates

The idea is to make use of already reported emissions from industries in various sectors (e.g., CDP Database) and make inference on emissions for unknown company X in a given sector.

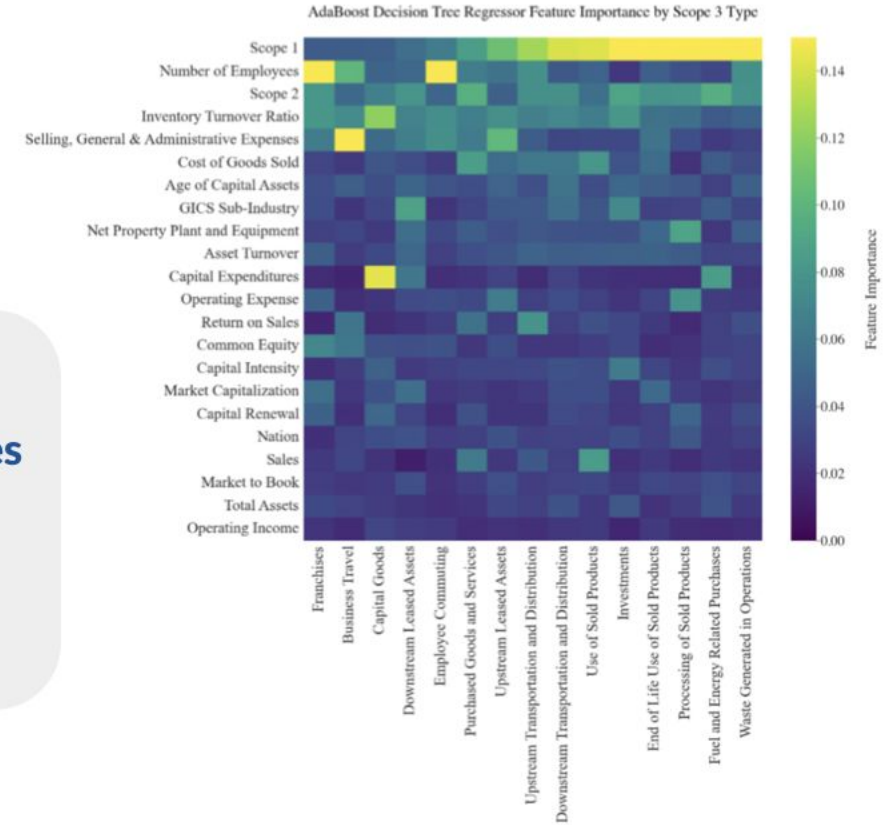
For more accurate predictions, some methods **make use of additional attributes** such as: country of the headquarters, number of employees, company revenue/size, etc.



Caution: **Data may be biased** towards certain types of companies and some sectors that report emissions.

Scope 3: Boosting methods

Features important for predicting each category of Scope 3 emissions may differ



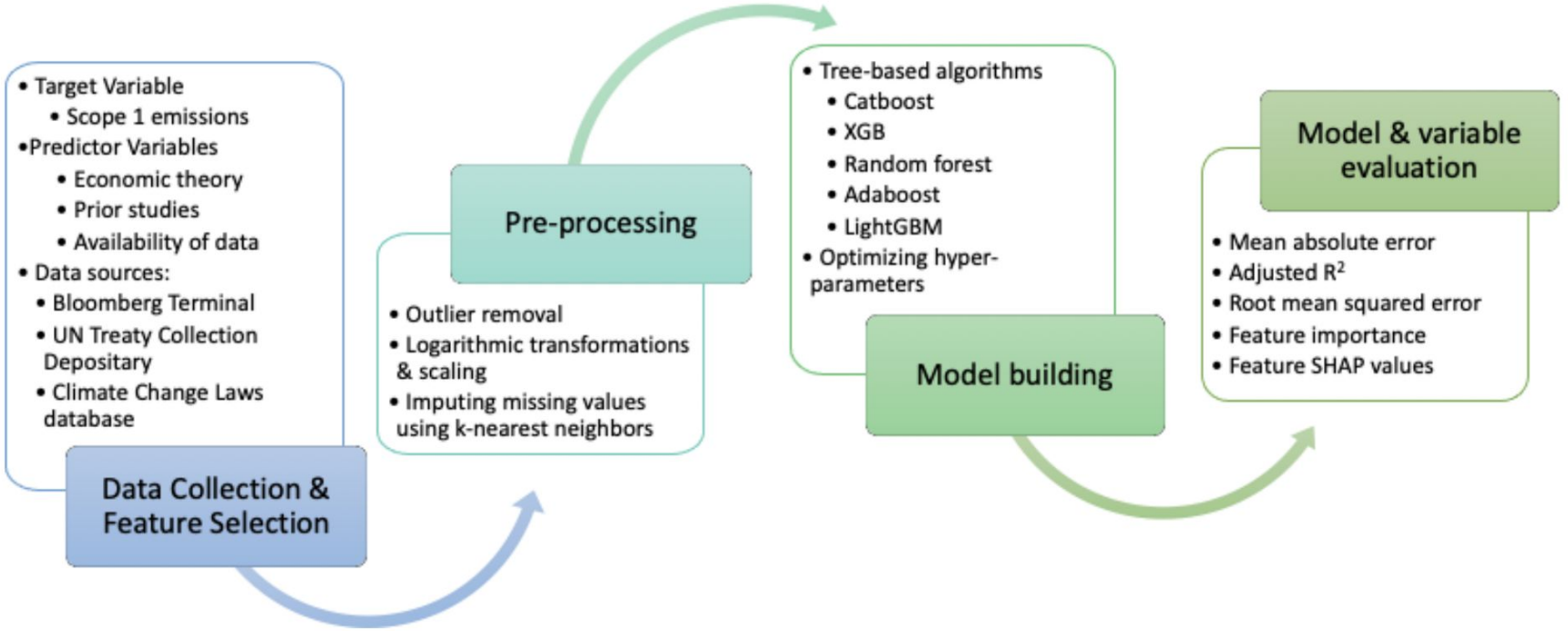
Questions:

Does it make sense to use different features for each individual Scope 3 category?

What are the pros and cons of doing that?

Source: Serafeim, George, and Gladys Vélez Caicedo. "Machine Learning Models for Prediction of Scope 3 Carbon Emissions." Harvard Business School Working Paper, No. 22-080, June 2022.

Scope 1: Tree based ML methods



Source: Hadziosmanovic et al. 2021. Estimating Corporate Scope 1 Emissions Using Tree-Based Machine Learning Methods

Opportunities and challenges of using ML for emissions inference

What are the main benefits of the presented methods (and others)?

What are the main drawbacks of these methods?

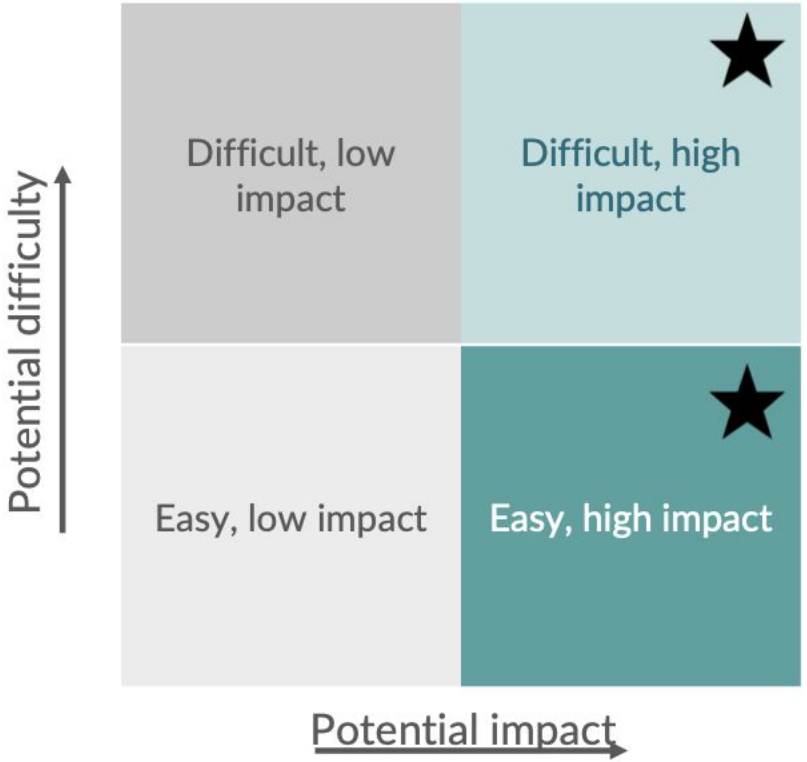
Is there something missing that would need to be accounted for?

Can we trust inferences of emissions using ML?

What are the alternatives?

Recommendations for selecting ML models

What are additional dimensions that need to be considered in evaluating the methods not shown here?



Emission data landscape

Where do I find emission data?

CDP database: https://www.cdp.net/en/data

GHG Protocol (Methodology): https://ghgprotocol.org/scope-3-calculation-guidance-2

Science based targets: https://sciencebasedtargets.org/

Interesting papers discussed in this lecture:

Serafeim, George, and Gladys Vélez Caicedo. "Machine Learning Models for Prediction of Scope 3 Carbon Emissions." Harvard Business School Working Paper, No. 22-080, June 2022. https://papers.ssrn.com/sol3/papers.cfm?abstract_id=4149874

Han et al. 2021. Estimation of Corporate Greenhouse Gas Emissions via Machine Learning https://www.climatechange.ai/papers/icml2021/4

Hadziosmanovic et al. 2021. Estimating Corporate Scope 1 Emissions Using Tree-Based Machine Learning Methods https://s3.us-east-1.amazonaws.com/climate-change-ai/papers/neurips2022/56/paper.pdf

And many more!