Technische Universität Braunschweig

Institut für Werkzeugmaschinen und Fertigungstechnik

Quantifying additionality of renewable energy supply options – decision making support for electricity consumers

Malte Schäfer | 28.04.2023

Work in progress | Presentation for Scope 2 Workshop @ DTU

About me

CV

Since 2018:
- PhD student
  @ TU Braunschweig

Before:
- R&D engineer
  @ automotive industry
- BSc & MSc in
  mechanical engineering

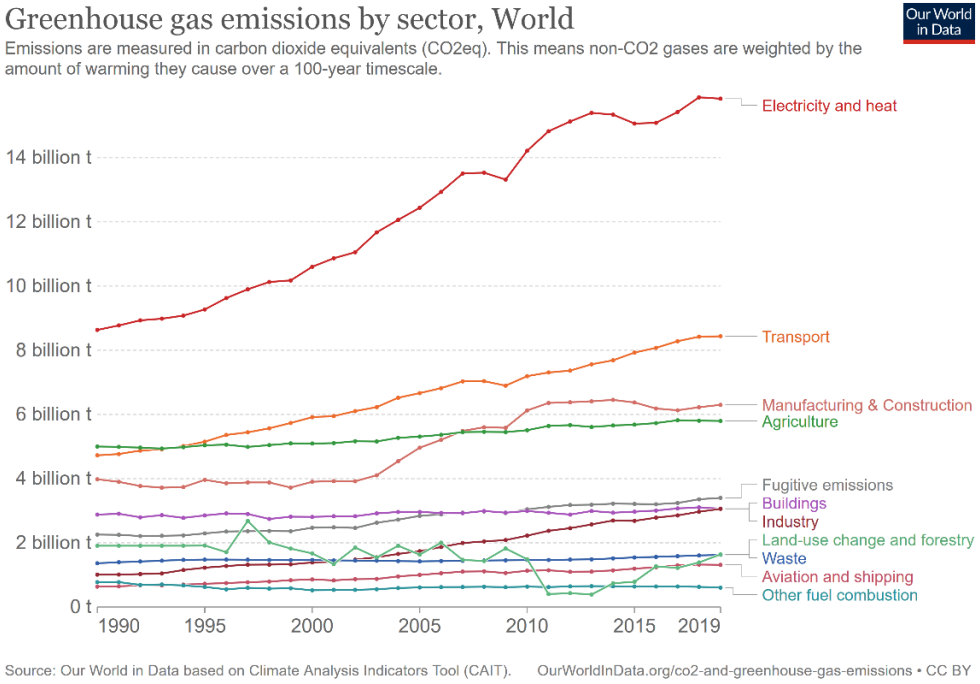
Dissertation topic

„Decision support for companies to reduce electricity-related emissions“
(working title)

Agenda

1. Background, motivation, research question
2. State of research, fundamentals
3. Proposed methodology
4. Exemplary results, limitations
5. Summary, discussion

Reducing electricity-related emissions is the goal



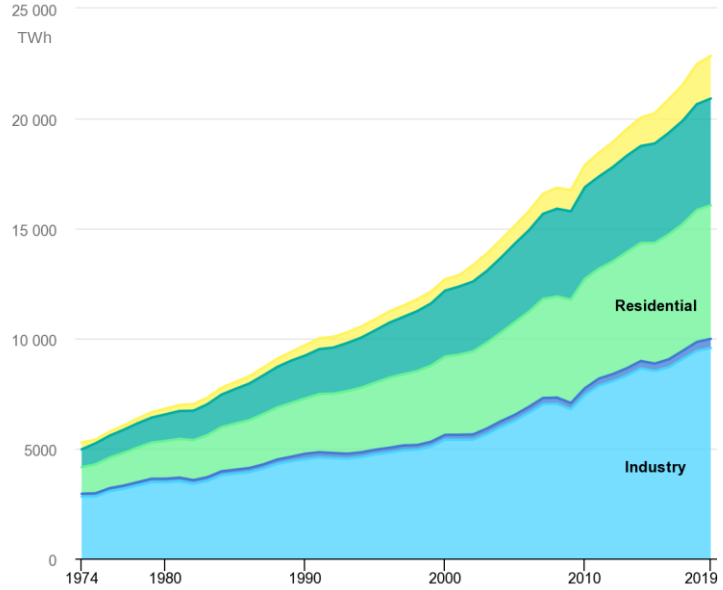
Electricity-related emissions:

- Largest share
- Increasing

Goal:
Reduce electricity-related emissions (ERE)

Electricity consuming industry is the target audience

World electricity final consumption by sector, 1974-2019



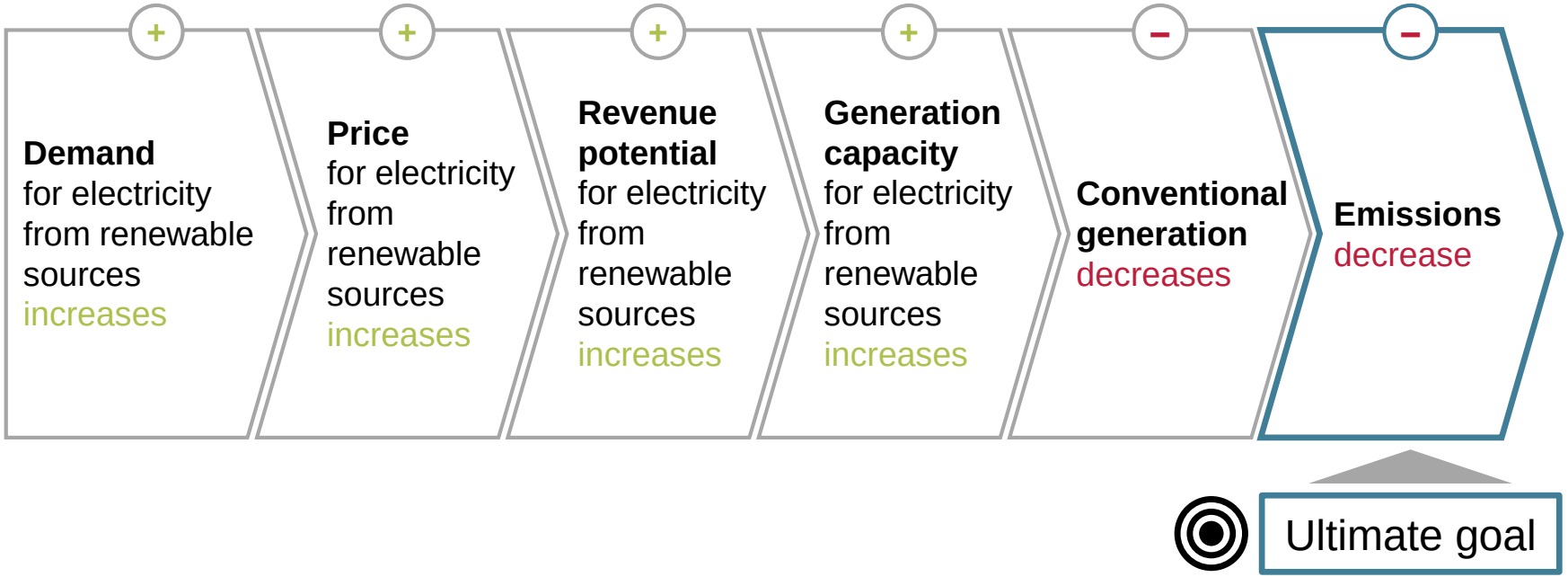
IEA

Perspective:
How to reduce ERE from the perspective of the electricity consumer (primarily industry)

Industry consumes most of the electricity

ERE: electricity related emissions

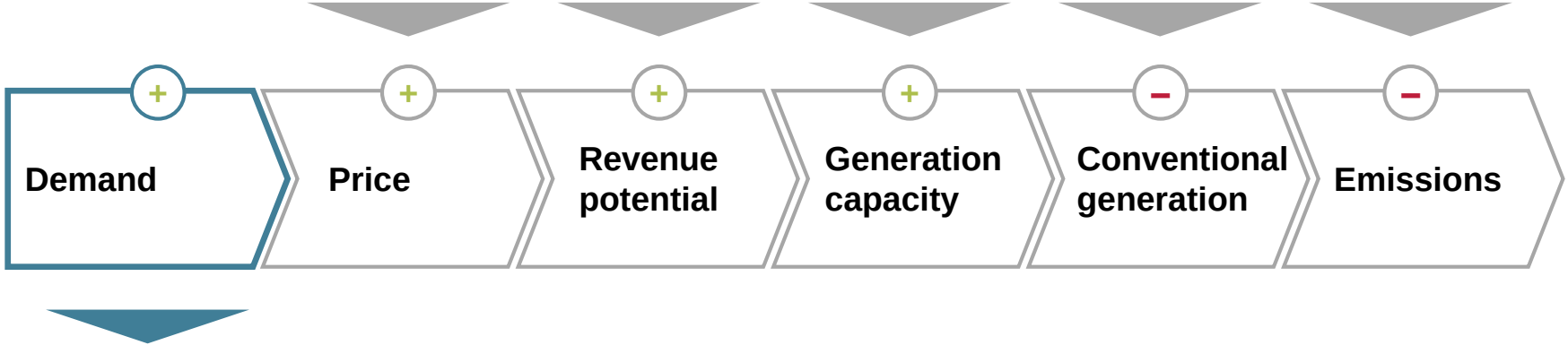
Demand for renewables can reduce emissions



Demand pull is the emission reduction lever of the industry

Also exist

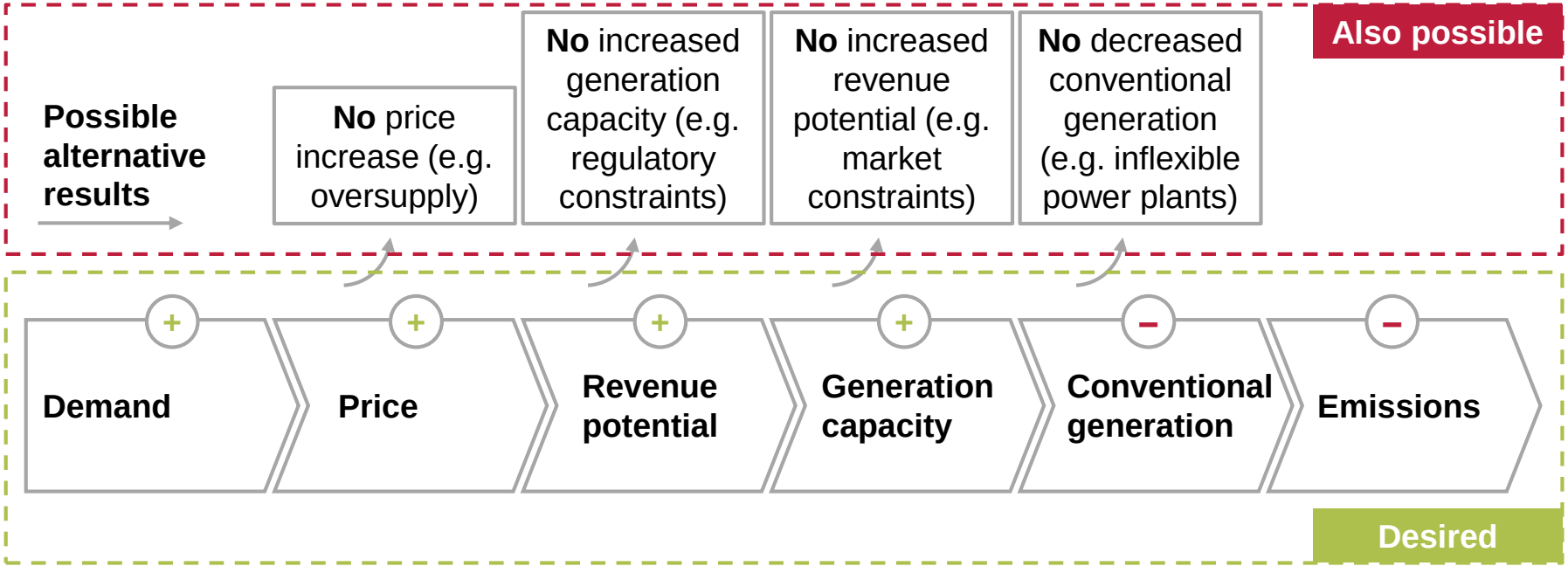
Other emission reduction levers (besides demand pull),
such as regulatory measures (e.g. feed-in tariffs)



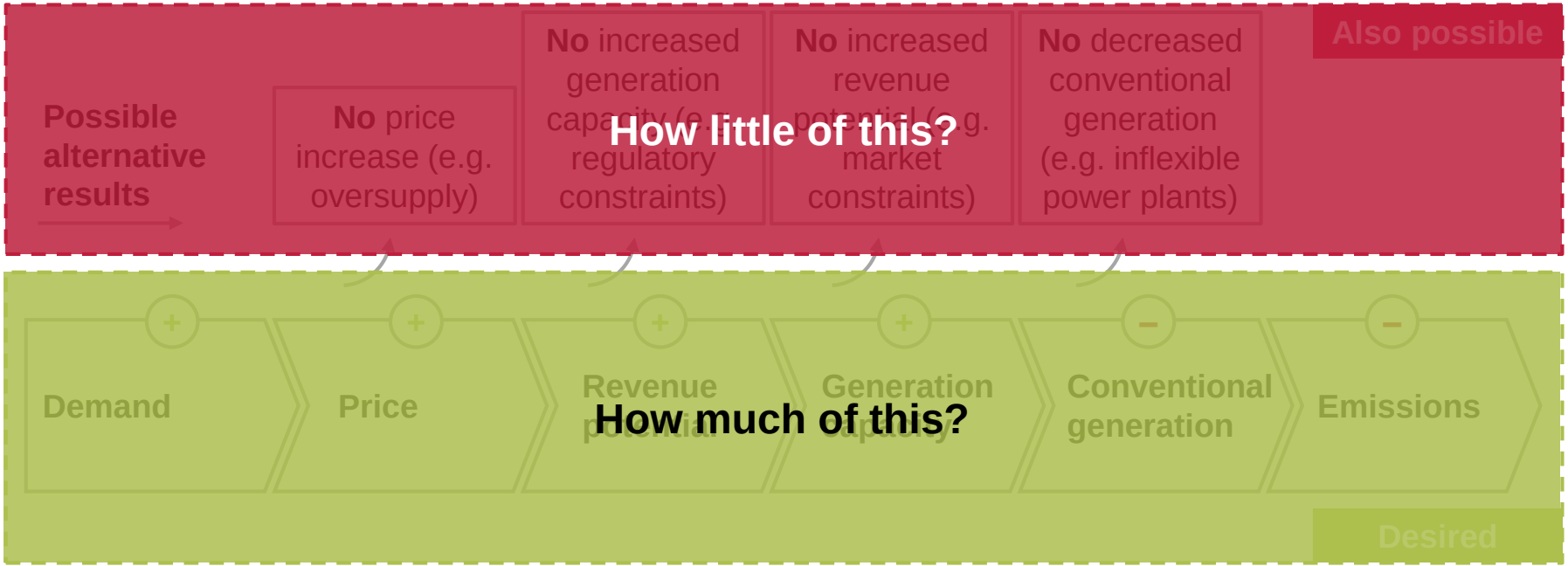
Primary emission reduction lever in the hands of (industrial) consumers,
and the only reason why market-based accounting exists.

Of interest

Demand pull lever is not guaranteed to yield desired results

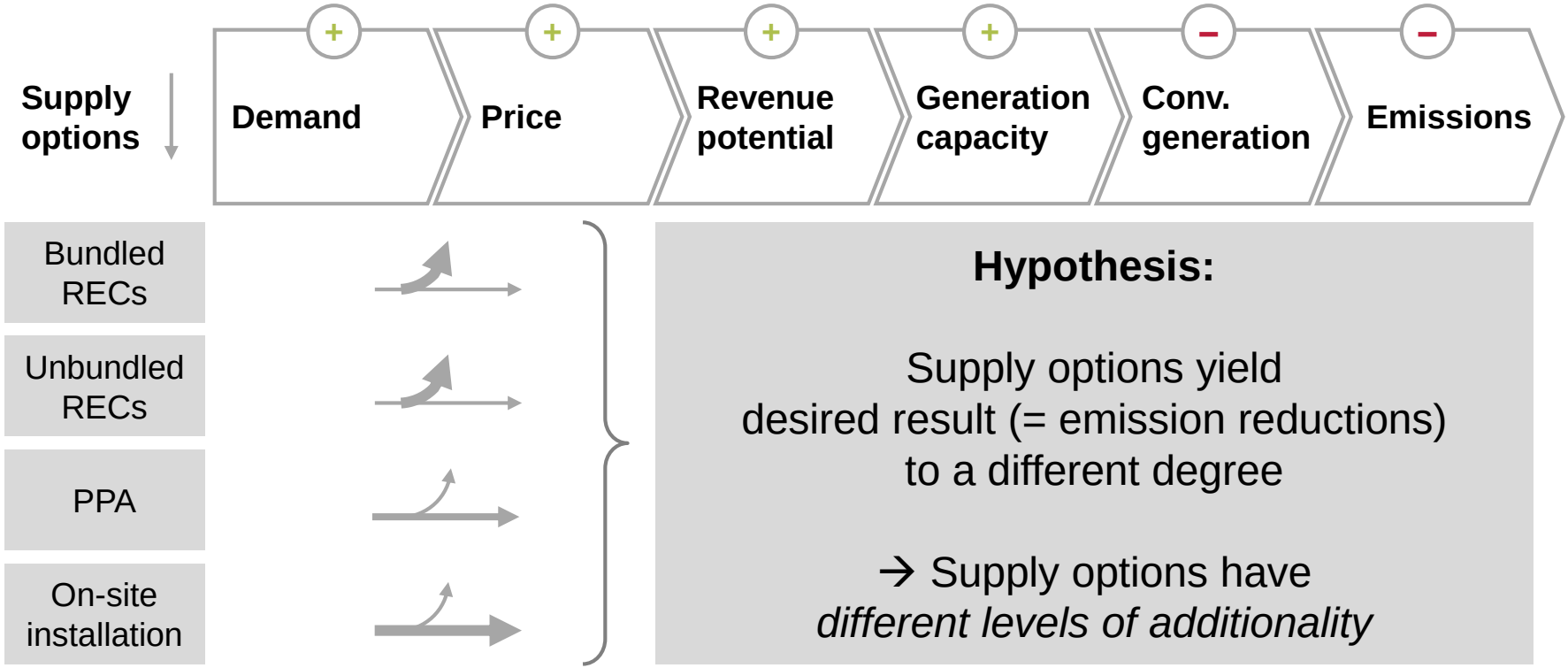


Additionality indicates desired results achievement level



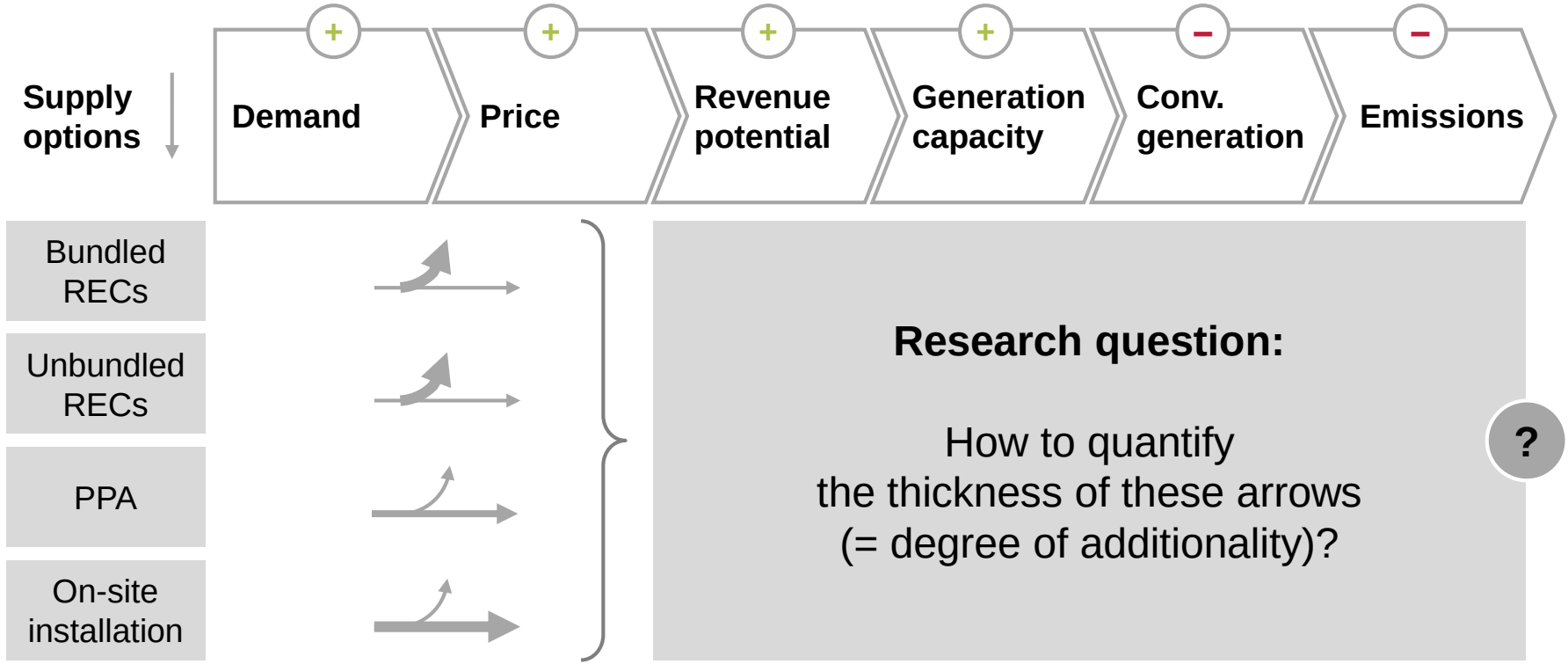
Additionality: to which degree does demand pull result in emission reductions?

Additionality level varies between supply options



REC: renewable energy certificate
PPA: power purchase agreement

Research question: how to quantify additionality?



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State of research (not exhaustive)

Gillenwater 2012:
What is Additionality?
(Part 1, 2, 3)
→ Definition of additionality (independent from RE)

Gillenwater 2008:
Redefining RECs (Part 1, 2)
→ RECs provide little/no additionality

Gillenwater (et al.) 2013/2014:
Wind energy and additionality
→ RECs do not influence wind energy investments (=no additionality)

Brander et al. 2018:
Creative accounting
→ Market-based accounting misleading, no additionality from RECs

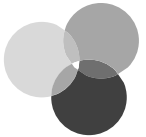
Bjørn et al. 2022:
RECs threaten integrity of SBTs
→ Little/no additionality from RECs

Ongoing literature review by Bjørn & Brander

+ more references

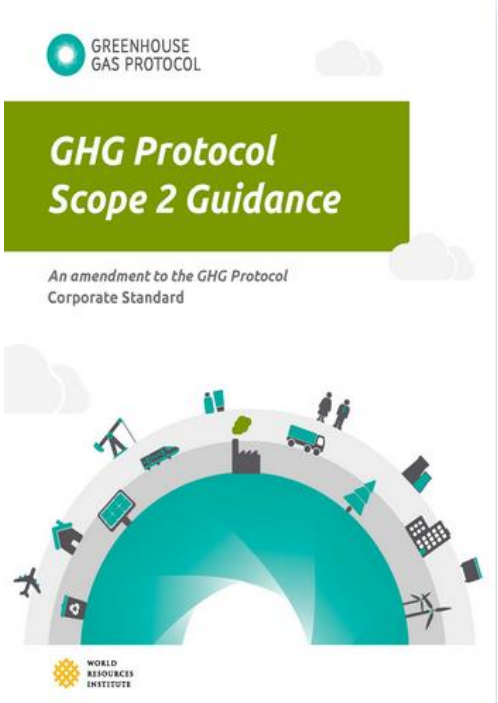
Research gap

Approach that combines the following aspects:
- Quantification of additionality – not just binary/qualitative
- Applied to multiple supply options (RECs, PPA etc.) – not just one
- Consumer focus (demand pull) – not e.g. policy



REC: renewable energy certificate
PPA: power purchase agreement
SBT: science based target

Scope 2 Guidance does not (yet) require additionality

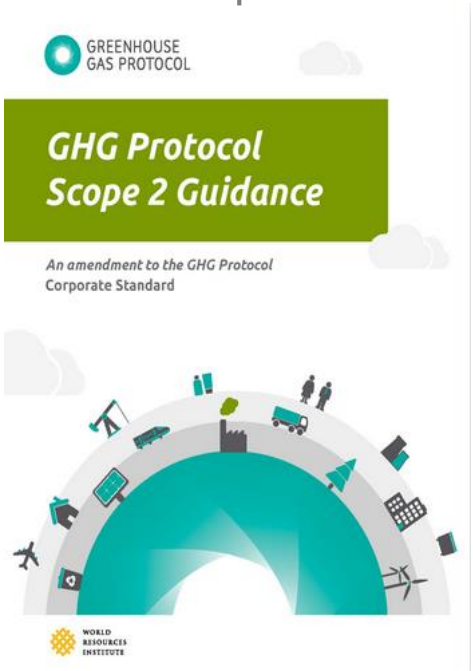


GHG Protocol

*This guidance **does not require** that contractual instruments claimed in the market-based method fulfil criteria such as offset "additionality" […].*

Industry is **unlikely to consider additionality** when choosing a supply option as of now.

Scope 2 Guidance provides two accounting methods



GHG Protocol

Accounting methods

Location-based

*[B]ased on GHG emissions emitted by the generators from which the reporter **contractually purchases** electricity […].*

Market-based

*[B]ased on average energy generation emission factors for defined **geographic locations** […].*

GHG: greenhouse gas

Multiple supply options for industrial electricity consumers

	Supply Option	Description	
	Unbundled RECs	Separate purchase of electricity and RECs from multiple suppliers (e.g. utility, trader, spot market).	Many detail specifications possible.
	Bundled RECs	Combined purchase of electricity and RECs from one supplier (e.g. utility).	
	PPA	Long term supply contract with project partner for delivery of electricity & RECs from one specific RE installation.	
	On-site installation	RE installation installed on-site (behind meter) with own money, for own-consumption (and potentially grid feed-in).	
	More supply options exist		

REC: renewable energy certificate
PPA: power purchase agreement

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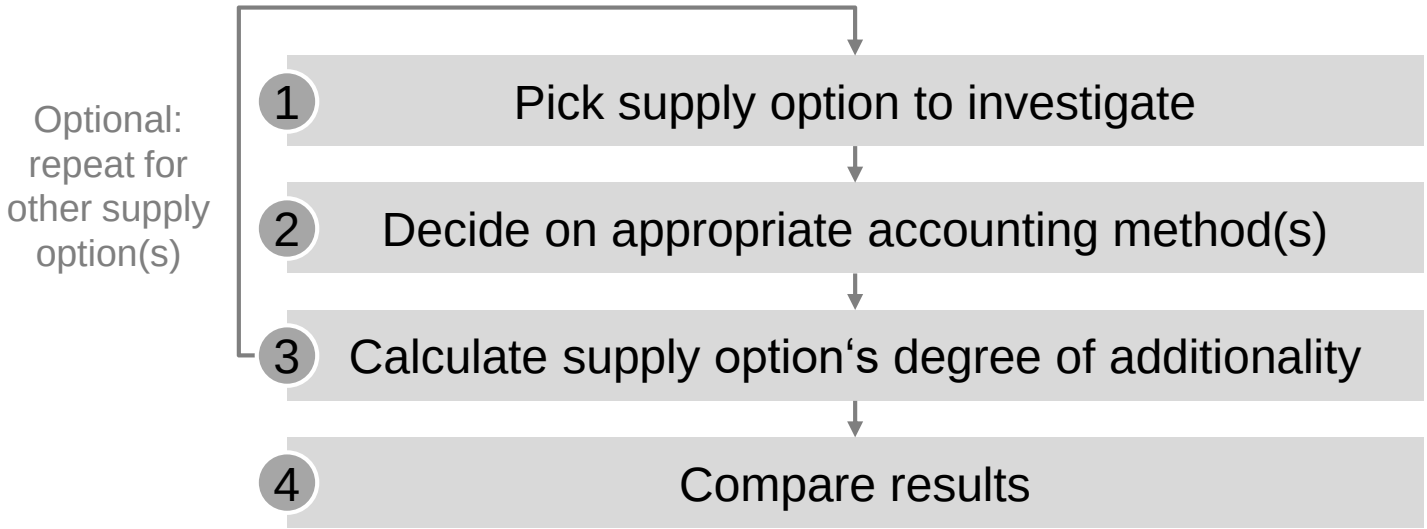
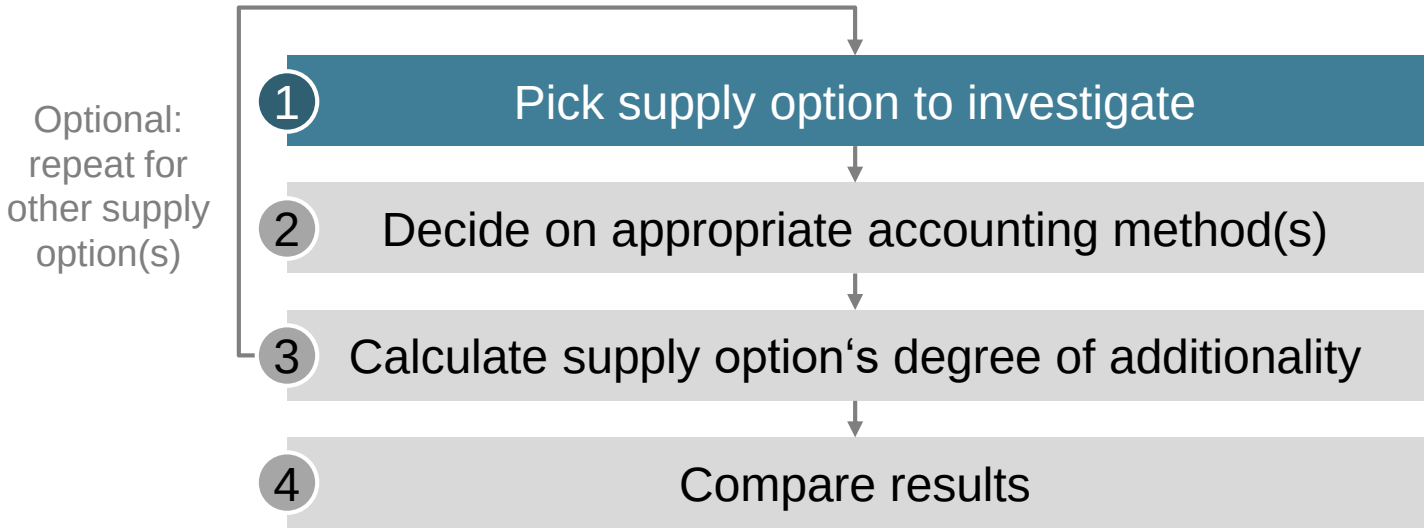
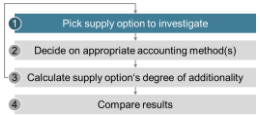
Overview of the proposed 4-step methodology



Step 1: pick supply option



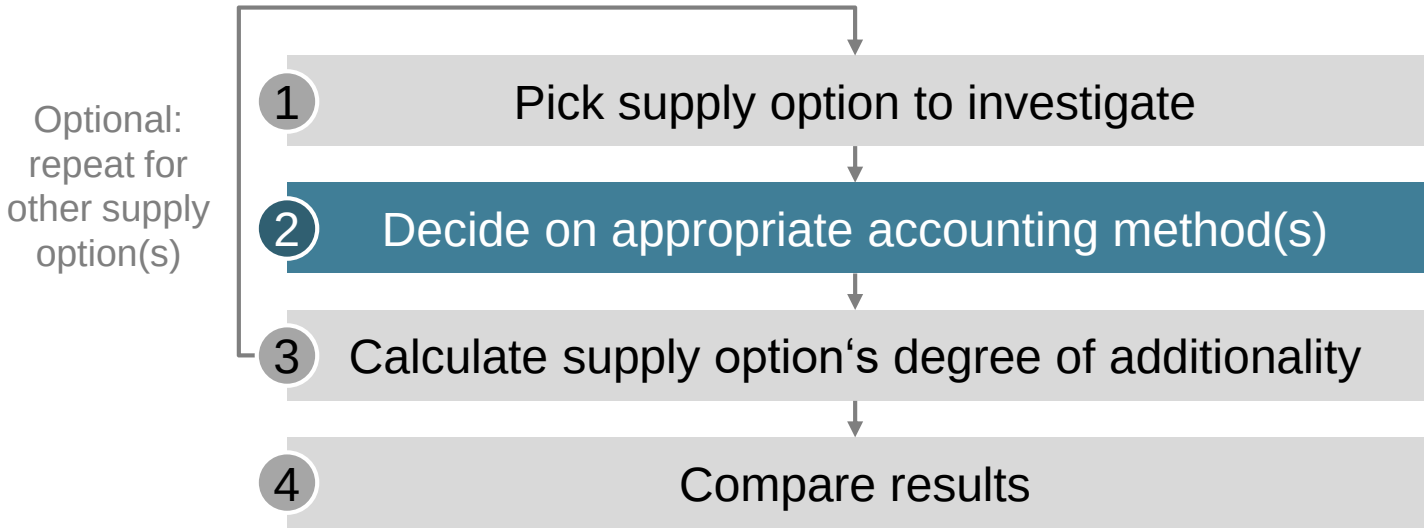
Step 1: pick supply option – e.g. PPA



Supply Option	Description
Unbundled RECs	Separate purchase of electricity and RECs from multiple suppliers (e.g. utility, trader, spot market).
Bundled RECs	Combined purchase of electricity and RECs from one supplier (e.g. utility).
PPA	**Long term supply contract with project partner for delivery of electricity & RECs from one specific RE installation.**
On-site installation	RE installation installed on-site (behind meter) with own money, for own-consumption (and potentially grid feed-in).

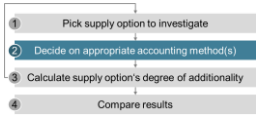
REC: renewable energy certificate
PPA: power purchase agreement

Step 2: decide on accounting method(s)



Step 2: decide on accounting method(s) based on market price

MP: market price
LCOE: life cycle cost of electricity
(LCOE: technology-specific, and thus differs between supply options)



Start

MP > LCOE?

yes

Apply location-based accounting only

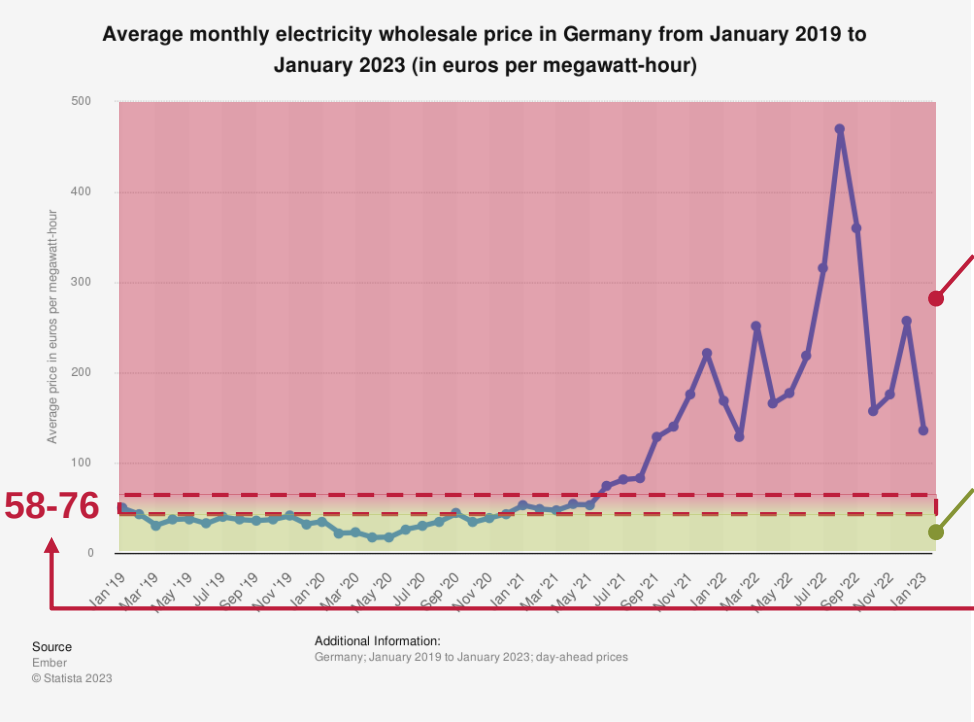
RE expansion not primarily demand-driven
→ **No additionality**

no

Apply both location-based and market-based accounting

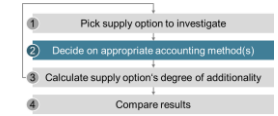
RE expansion primarily demand-driven
→ **Some additionality**

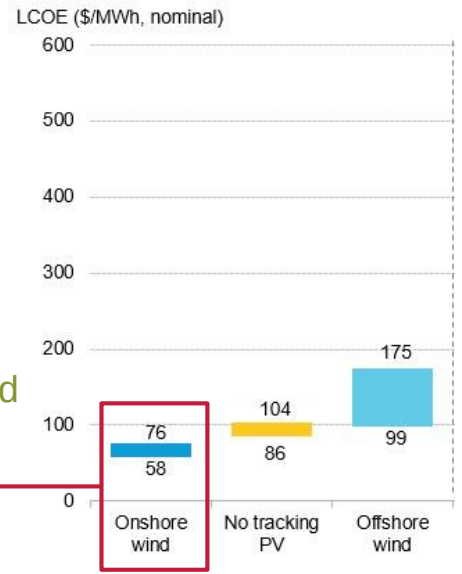
Exemplary comparison of MP and LCOE for onshore wind



MP > LCOE: Location-based accounting

MP < LCOE: Market- and location-based accounting



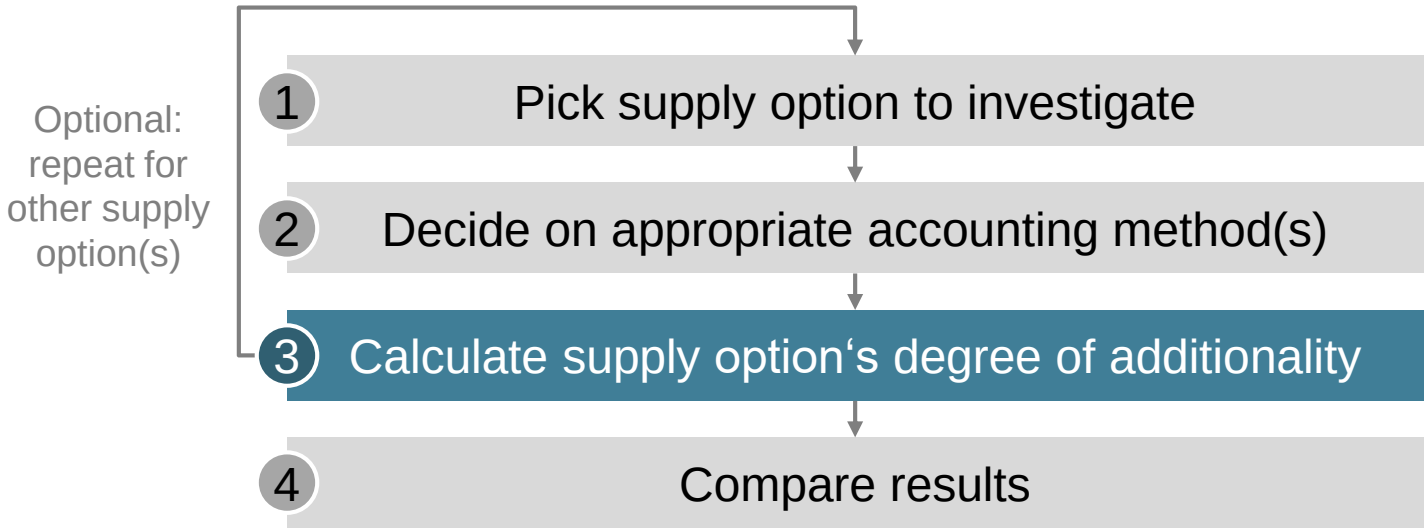


Statista, based on Ember

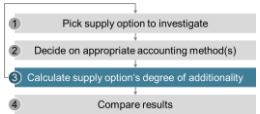
Wind Europe, based on BNEF, cropped

MP: market price
LCOE: life cycle cost of electricity

Step 3: calculate degree of additionality



Additionality applies only to market-based accounting



MP > LCOE?

yes

Apply location-based accounting only

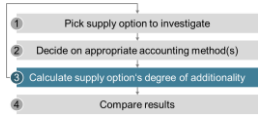
no

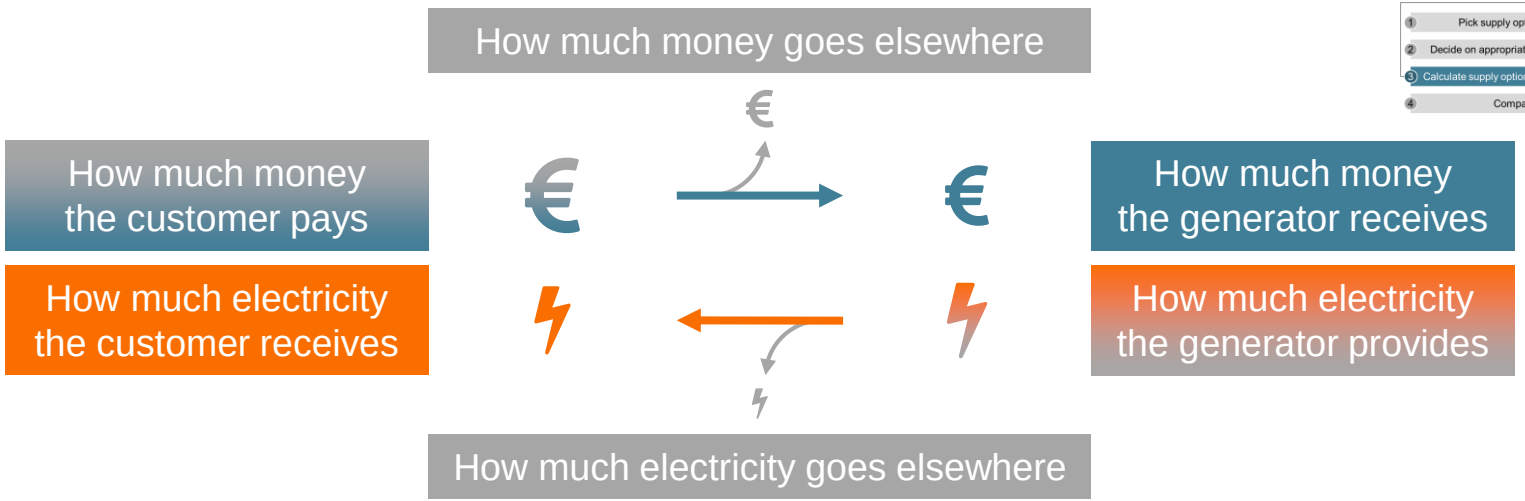
Apply both location-based and market-based accounting

Additionality only relevant here

MP: market price
LCOE: life cycle cost of electricity

AM measures additionality from monetary flows





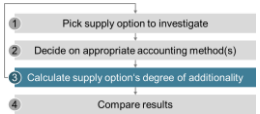
Additionality metric (AM):
Indicator for the degree of additionality of a supply option

$$AM = \frac{€}{kWh} = \frac{\text{How much money the generator receives}}{\text{How much electricity the customer receives}}$$

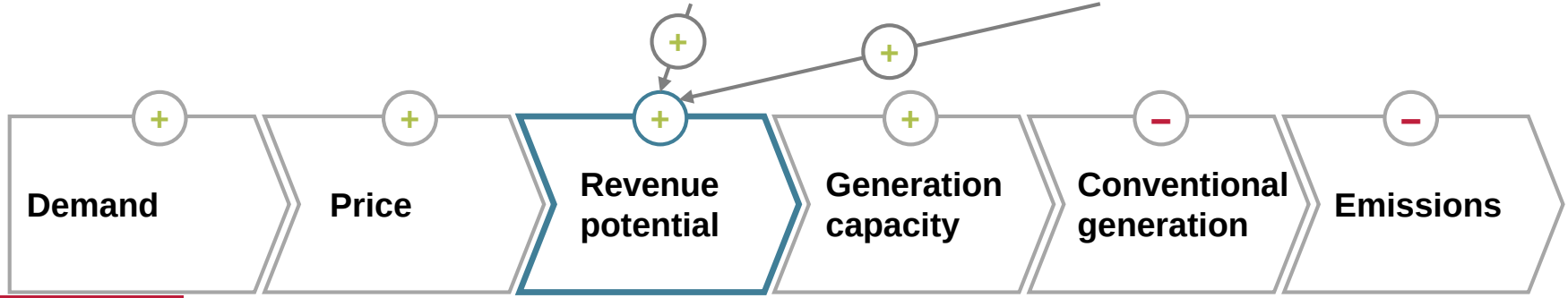
Contract duration influences the revenue potential

$$AM = \frac{€}{} \times \frac{}{} = \frac{\text{How much money the generator receives}}{\text{How much electricity the customer receives}} \times \frac{\text{How long the contract duration is}}{\text{How long the installation lasts}}$$

$$\frac{€}{kWh} \times \frac{a}{a}$$

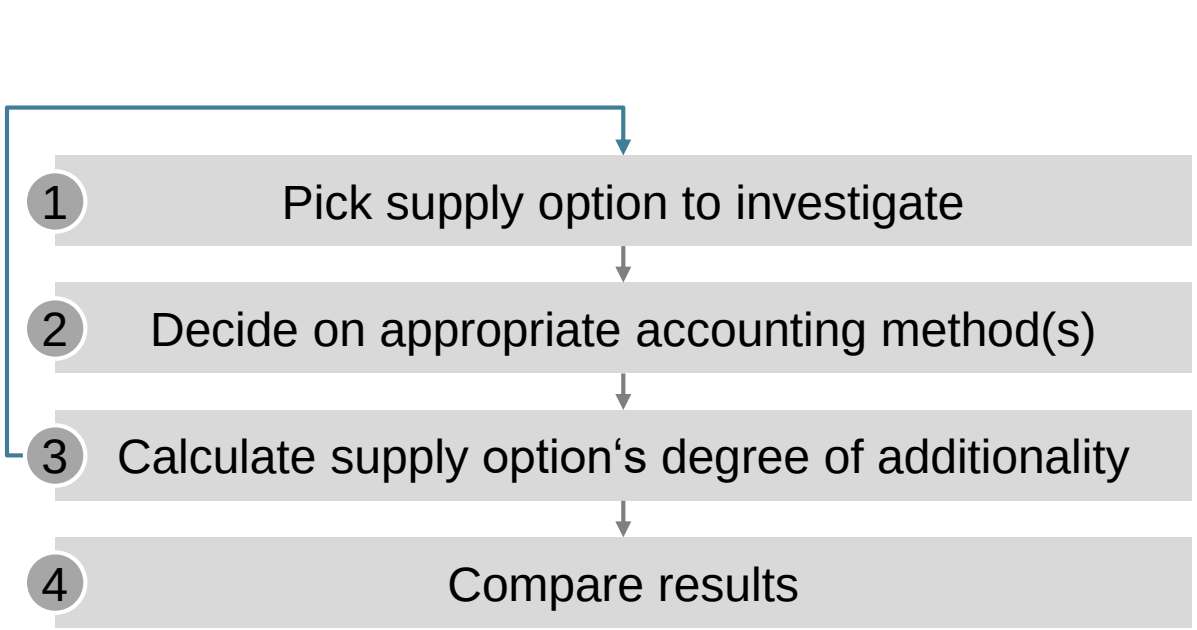


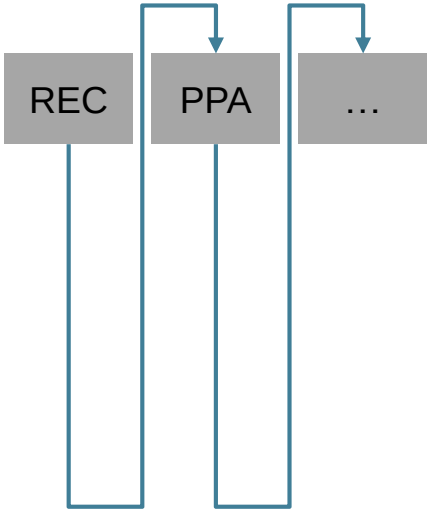
How much? For how long?



Optional step: redo steps 1-3 for other supply option(s)

Optional: repeat for other supply option(s)

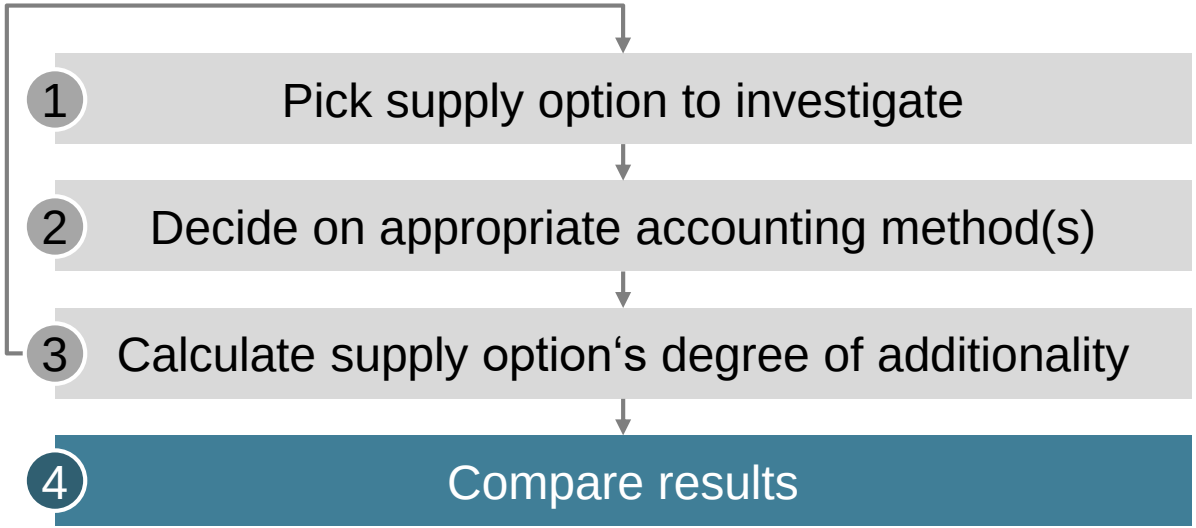




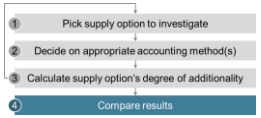
REC: renewable energy certificate
PPA: power purchase agreement

Step 4: compare results

Optional: repeat for other supply option(s)



Results indicate supply options‘ degree of additionality



	Supply Option	MP > LCOE?	Accounting	AM
	Unbundled RECs	yes		No additionality
	Bundled RECs	yes		No additionality
	PPA	no		0.09 €/kWh
	On-site installation	no		0.15 €/kWh

Supply option with highest degree of additionality

Fictional results

MP: market price
LCOE: life cycle cost of electricity
AM: additionality metric
REC: renewable energy certificate
PPA: power purchase agreement

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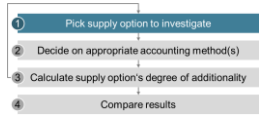
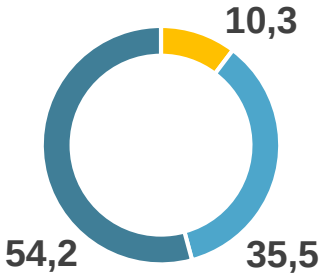
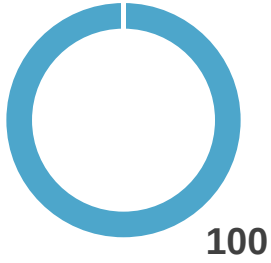
Case study: comparing bundled RECs & PPA



	Bundled RECs	PPA
	naturstrom Energie mit Zukunft	Energy Brainpool PPA-Preismonitor
Contract duration	2 years (+current)	5 years (+current)
Price	0.205 €/kWh	0.103 €/kWh



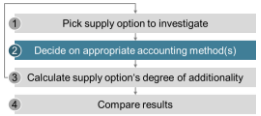


Excluding taxes, fees etc.

PV: photovoltaics
REC: renewable energy certificate
PPA: power purchase agreement

Market price fluctuations influence accounting choice

MP > LCOE?



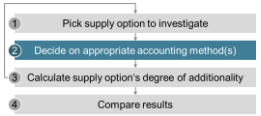
	MP	Bundled RECs	PPA	Accounting
LCOE		0.205 €/kWh	0.103 €/kWh	
Monthly ø (04/2023)	0.100 €/kWh	no	no	
Annual ø (04/2022 - 04/2023)	0.215 €/kWh	yes	yes	

For both supply options

MP: market price
LCOE: life cycle cost of electricity
REC: renewable energy certificate
PPA: power purchase agreement

Case study example relies on monthly average market prices

MP > LCOE?

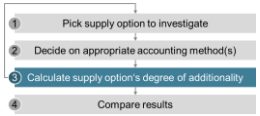


		Bundled RECs	PPA	
	LCOE	0.205 €/kWh	0.103 €/kWh	
	MP			**Accounting**
Monthly ø (04/2023)	0.100 €/kWh	no	no	
Annual ø (04/2022 - 04/2023)	0.215 €/kWh	yes	yes	

MP: market price
LCOE: life cycle cost of electricity
REC: renewable energy certificate
PPA: power purchase agreement

AM for both supply options are calculated

$$AM = \frac{€}{kWh} \times \frac{\text{time}}{\text{time}} = \frac{\text{How much money the generator receives}}{\text{How much electricity the customer receives}} \times \frac{\text{How long the contract duration is}}{\text{How long the installation lasts}}$$



Bundled RECs

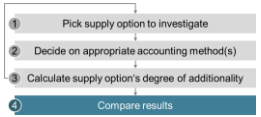
$$AM_{\text{bundled}} = \frac{€}{kWh} \times \frac{\text{time}}{\text{time}} = \frac{0.205\ \frac{€}{kWh} \times 100{,}000\ kWh}{100{,}000\ kWh} \times \frac{2\ a}{25\ a} = 0.0164\ \frac{€}{kWh}$$

PPA

$$AM_{\text{PPA}} = \frac{€}{kWh} \times \frac{\text{time}}{\text{time}} = \frac{0.103\ \frac{€}{kWh} \times 100{,}000\ kWh}{100{,}000\ kWh} \times \frac{5\ a}{25\ a} = 0.0206\ \frac{€}{kWh}$$

AM: additionality metric
REC: renewable energy certificate
PPA: power purchase agreement

PPA yields a higher degree of additionality than bundled RECs



	Supply Option	MP > LCOE?	Accounting	AM
	Bundled RECs	no		0.0164 €/kWh
	PPA	no		0.0206 €/kWh

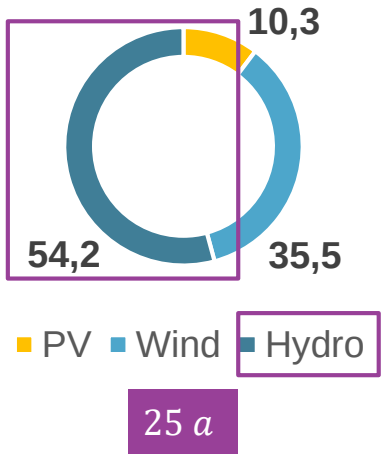
Supply option with highest degree of additionality

MP: market price
LCOE: life cycle cost of electricity
AM: additionality metric
REC: renewable energy certificate
PPA: power purchase agreement

The exemplary results rely on simplified assumptions

Simplifications

Hydro plants have a lifetime > 25 years



PPAs are not viable for 100,000 kWh/a

PPA

100,000 kWh

Location-based accounting was left out

PV: photovoltaics
PPA: power purchase agreement

The methodology has some limitations

Money to producer ≠ LCOE

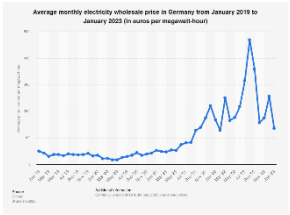
To generator

0.103 €/kWh

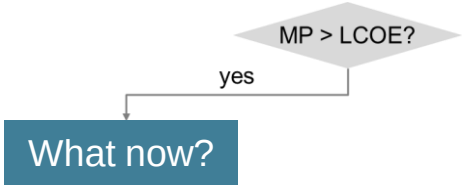
LCOE

? €/kWh

Unclear how to handle MP & LCOE dynamics

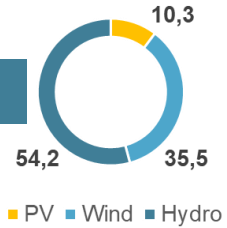


No additionallity incentive for MP > LCOE



Does not account for generator age

Quite old



Feed-in tariffs not covered

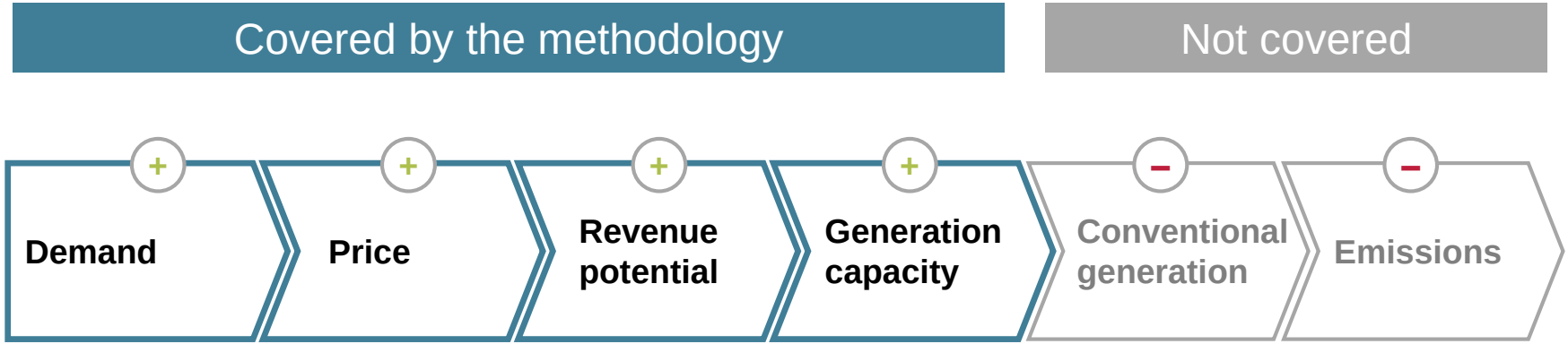
How much money the generator receives

How much money other generators receive (e.g. feed-in tariffs paid by all customers)

Does not discount monetary flows

MP: market price
LCOE: life cycle cost of electricity
PV: photovoltaics

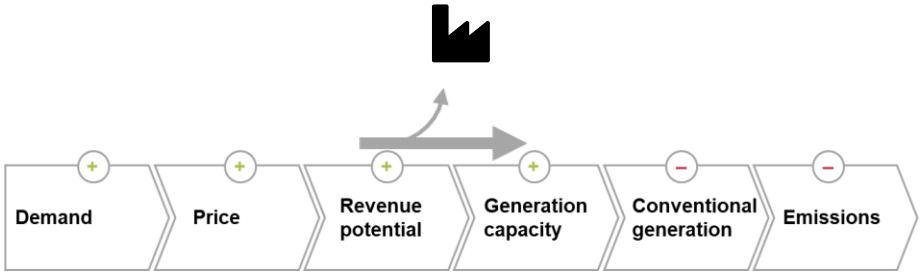
Final limitation: partial coverage of the causal chain

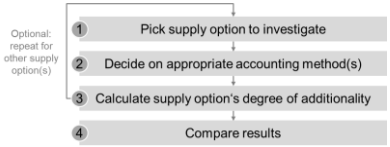


Agenda

1. Background, motivation, research question
2. State of research, fundamentals
3. Proposed methodology
4. Exemplary results, limitations
5. Summary, discussion

Summary





$$AM = \frac{€}{} \times \frac{}{} = \frac{\text{How much money the generator receives}}{\text{How much electricity the customer receives}} \times \frac{\text{How long the contract duration is}}{\text{How long the installation lasts}}$$

To support decision making in industry…

…related to how demand for electricity can lead to lower emissions than now…

…I propose a 4 step methodology to quantify additionality…

…that relies on monetary flows and contract duration.

Discussion and open questions

Do the results make sense?
Do the results match our intuitions?
Are the results suitable for decision making?
Are the results self explanatory?

What is missing from the methodology?
What does the methodology get wrong?
Does the methodology contain superfluous aspects?

Are there related approaches I should look at?
Does something like this already exist?

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Quantifying additionality of renewable energy supply options – decision making support for electricity consumers

Malte Schäfer | 28.04.2023

Work in progress | Presentation for Scope 2 Workshop @ DTU