

# CO<sub>2</sub> Quota Attribution Effects On the European Electricity System

Smart Energy Systems International Conference 2020



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Article

### CO<sub>2</sub> quota attribution effects on the European electricity system comprised of self-centred actors

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Abstract

Anthropogenic climate change confronts our electricity systems with new challenges which require us to rethink fundamental concepts of collaboration. Strong benefits and synergies arise when interlinking electricity systems and grids across borders. Countries can both collaborate by extending interconnection capacities, varying their degree of self-sufficiency and by trading emission certificates, or equivalently attributing the burden of emission reductions in different ways among our assets. We investigate a new future European electricity system in a bottom-up approach. The primary source of emission neutral electricity is coming from different variable renewable energy sources, but it also includes current and planned nuclear, coal, lignite and gas fueled power plants. We show that different CO<sub>2</sub> emission attributions have an immense effect on the required local CO<sub>2</sub> prices. Furthermore, we investigate how this influences the technology mix in the individual countries. Previous economists argue that it may be conceivably simpler to get everyone on board of the energy transition if a common emission price is negotiated. A cost optimal allocation of emissions, represented by a single European carbon price, leads to the placement of the majority of carbon emitting production capacity in a land through central Europe, and thus to highly uneven carbon emissions, because the emitting generation is rewarded from many countries and unrelated to a loss. We conclude that it is significantly easier for certain countries to decarbonise than electricity production than for others. The difficulty in the specific country depends strongly on how emission allowances are allocated in Europe. A deep collaboration between the countries leads both to a lowered total system cost and, perhaps more even importantly, to CO<sub>2</sub> emissions and required CO<sub>2</sub> prices that are much more equal between the European partners.

1. Introduction

In pursuance of mitigating anthropogenic climate change, in particular limiting the increase of the global mean temperature of the Earth to 2 °C or below, it is of fundamental importance to reduce the emissions of carbon dioxide (CO<sub>2</sub>). Action must be drastic and facilitated in the near term. In the most prominent emission reduction agreement, the Paris Agreement from 2015 [1], the countries pledge to “aim to reach global peaking of greenhouse gas emissions as soon as possible”. This agreement has, to date, been ratified by 189 countries. In Europe, the commitment has been significantly strengthened. The European Union (EU) aims to make Europe climate neutral in 2050 and has in 2019 committed to the European Green Deal [2]. For Europe to be a front runner in climate change mitigation, the European power system, with its large contribution to emissions, must undergo a suitable shift towards green generation. To realize the announced transition, clear local boundaries on emission levels must be negotiated.

Other studies have proven that high penetrations of renewables, with their continuously decreasing costs, are the most promising solution to reduce emissions [3]. But the European countries are inherently different. A difference that is [4] both to clear differences in technology choices in the individual countries and is [5] has been shown to have the capability of leading to strong carbon leakage inside Europe – Tindie et al. discuss, in their recent Preprint submitted to XXX August 26, 2020

Common & Trade

The European countries all agree that CO<sub>2</sub> emissions need to be decreased. The dividing question is who has to contribute by how much.

The field of energy system planning hence branch including the human aspect by taking into account cultural and political factors. We suggest to consider, and perhaps more to rethink, fundamental concepts of value creation. The energy transition in Europe can be both cost-effective and more efficient if synergies between the individual actors can be fully explored. A fundamental necessity for this is collaboration.

We believe that open modelling leads to better research, policy advice and energy politics. We advise and develop open energy models. This prevents energy models from becoming black boxes that are not open to critical input by future researchers. Combined with open data, this enables reproducibility, openness, quality, transparency, and stability in the energy modelling community and provides the largest benefits for society.



# Motivation

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- Most agree that our electricity system should be decarbonised
- The countries have very different systems
- Need for self-sufficiency

# Motivation

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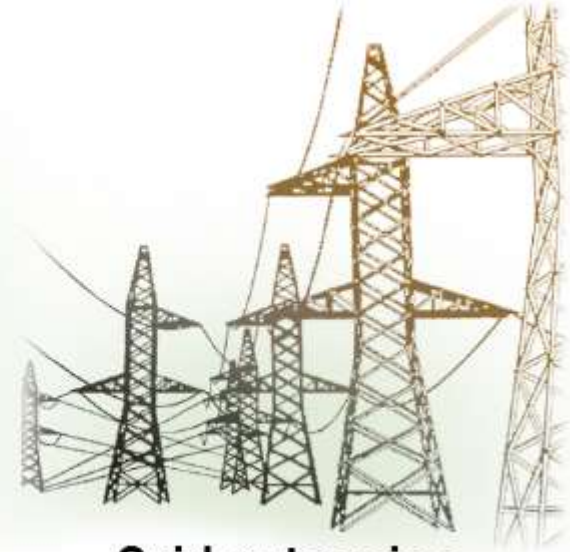
Is it time to rethink collaboration?



Emission attribution

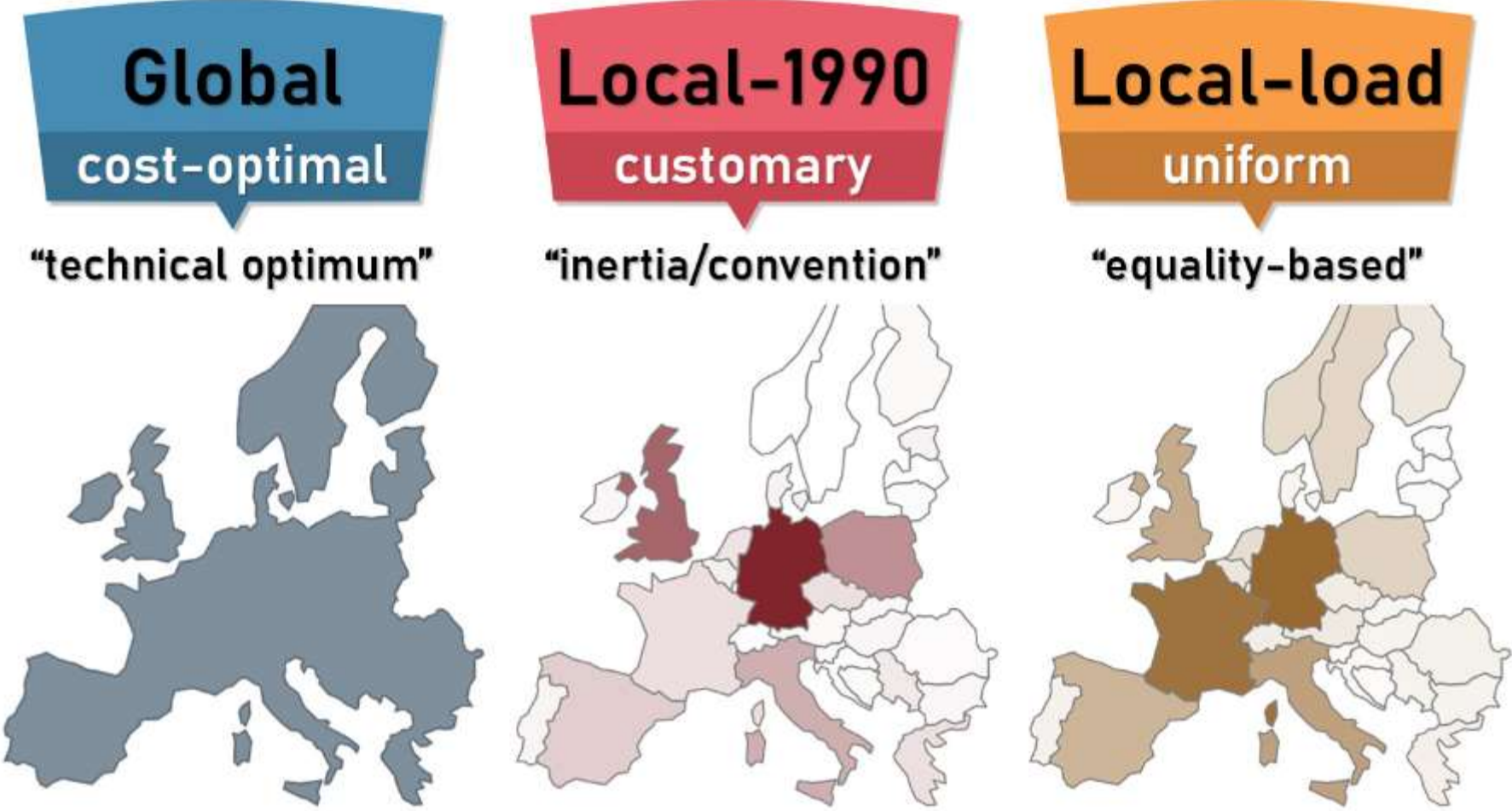


Generation autonomy



Grid extension

# Considered emission attribution schemes



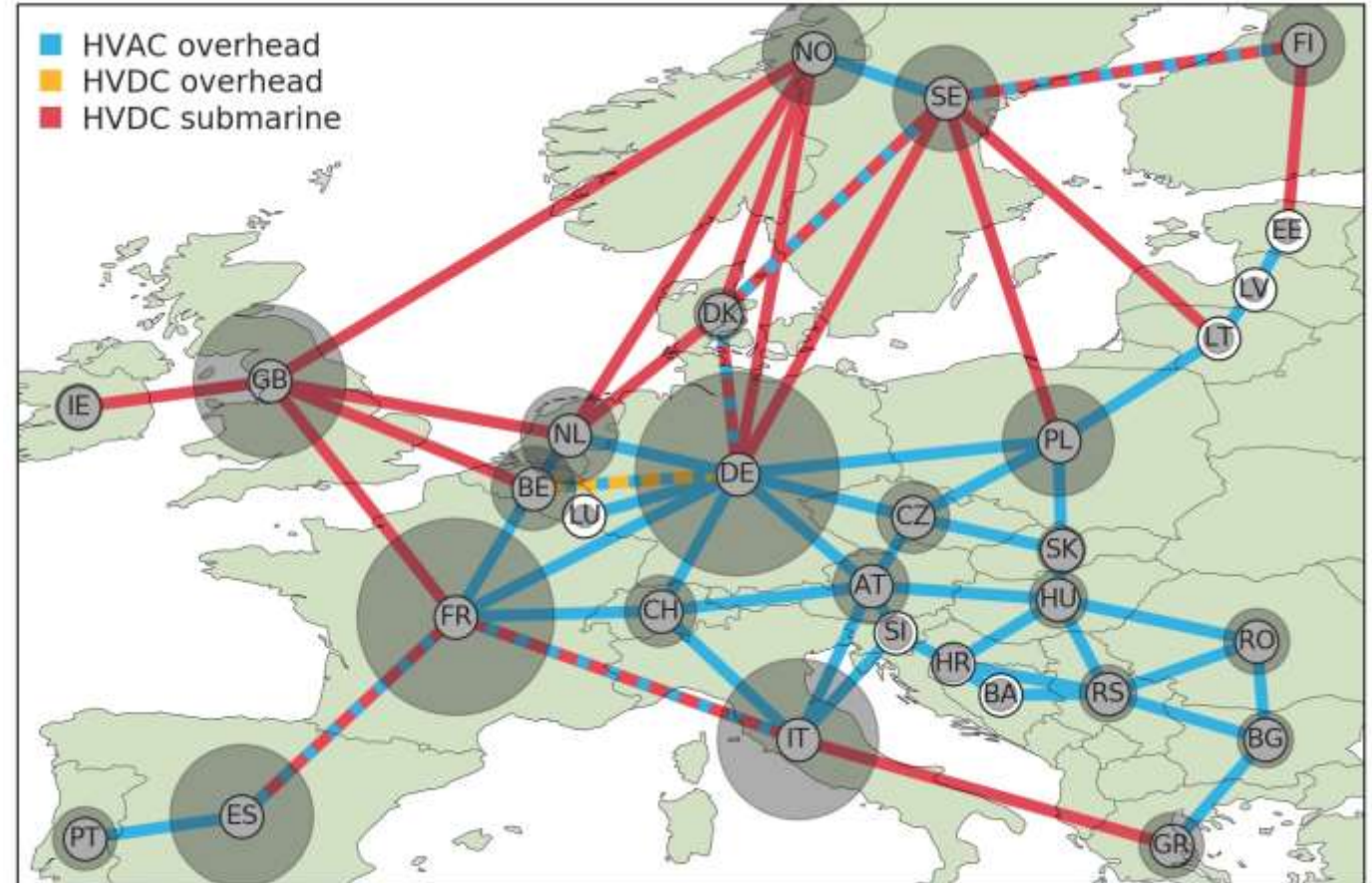
# Table of contents

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- Our modelling approach
- Results
- Conclusions & Outlook

# Modelling framework

- PyPSA\* model of the electricity system
- One node per country
- Cross-border transmission lines
- Brownfield approach



\* <https://github.com/PyPSA>

# Methodology

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Objective function:

$$\min \left( \sum_n \text{generation costs} + \text{storage costs} + \text{transmission costs} + \sum_{n,t} \text{variable costs} \right)$$

Subject to several constraints, including:

$$\text{generation} + \text{balance} = \text{demand} \leftrightarrow \lambda_{n,t} \quad \forall n, t$$

$$\sum \text{emissions} \leq \text{CAP}_{CO_2} \leftrightarrow \mu_{CO_2}$$

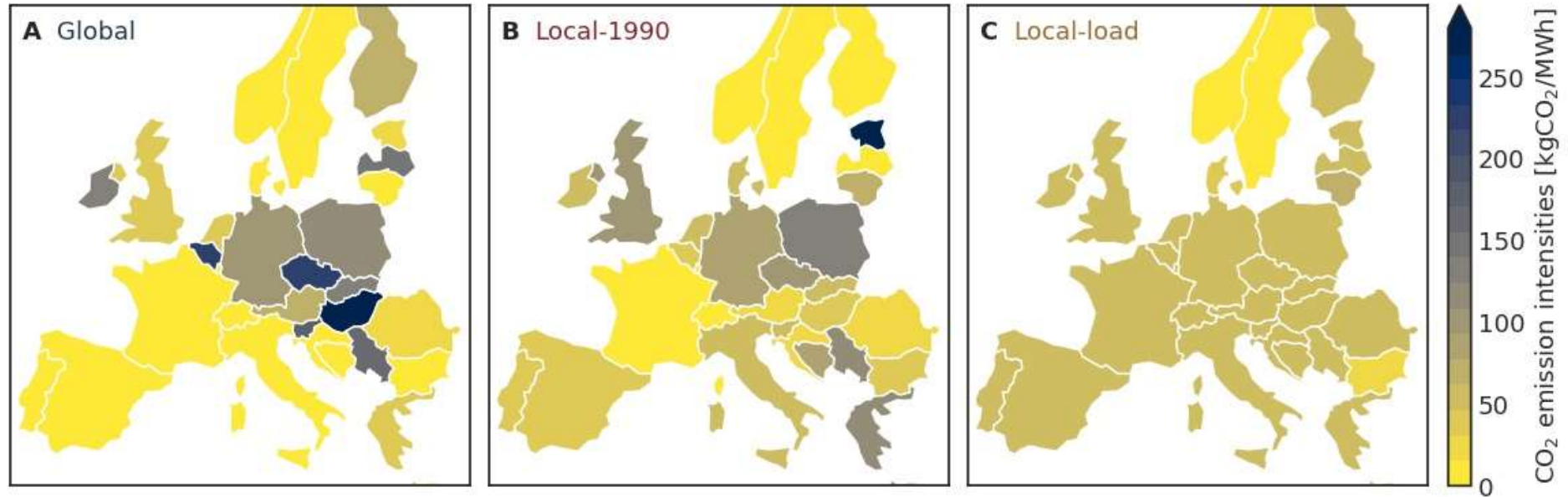
Main assumptions: perfect foresight, perfect competition, long-term market equilibrium.



# Near-future scenarios

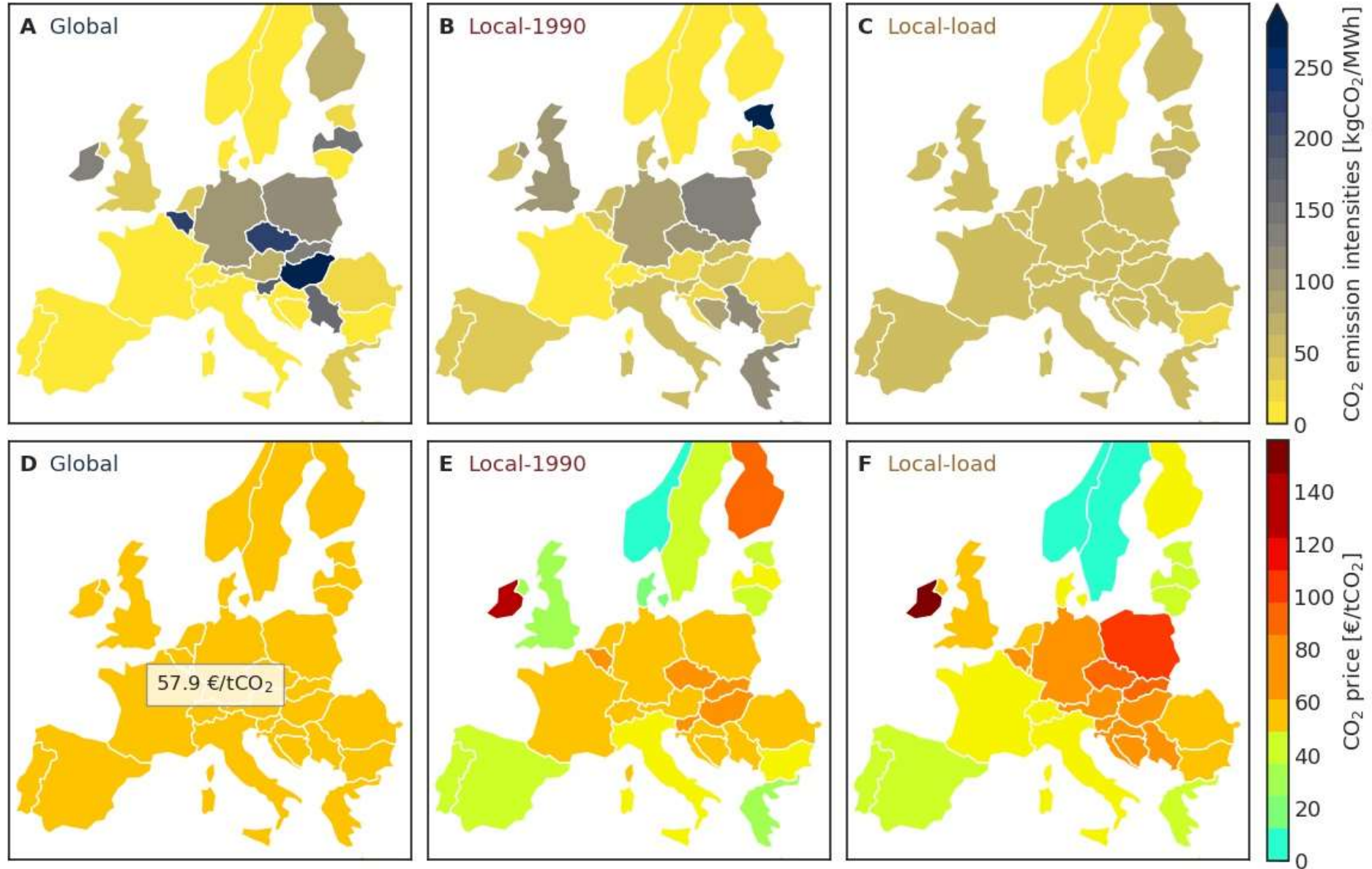
- 15% of 1990 electricity generation related emissions
- Planned cross-border transmission capacities
- All countries are highly self-sufficient
- Comparing different emission attribution schemes

# Emission attributions



2030 transmission expansion projection. On average, fully self-sufficient countries.

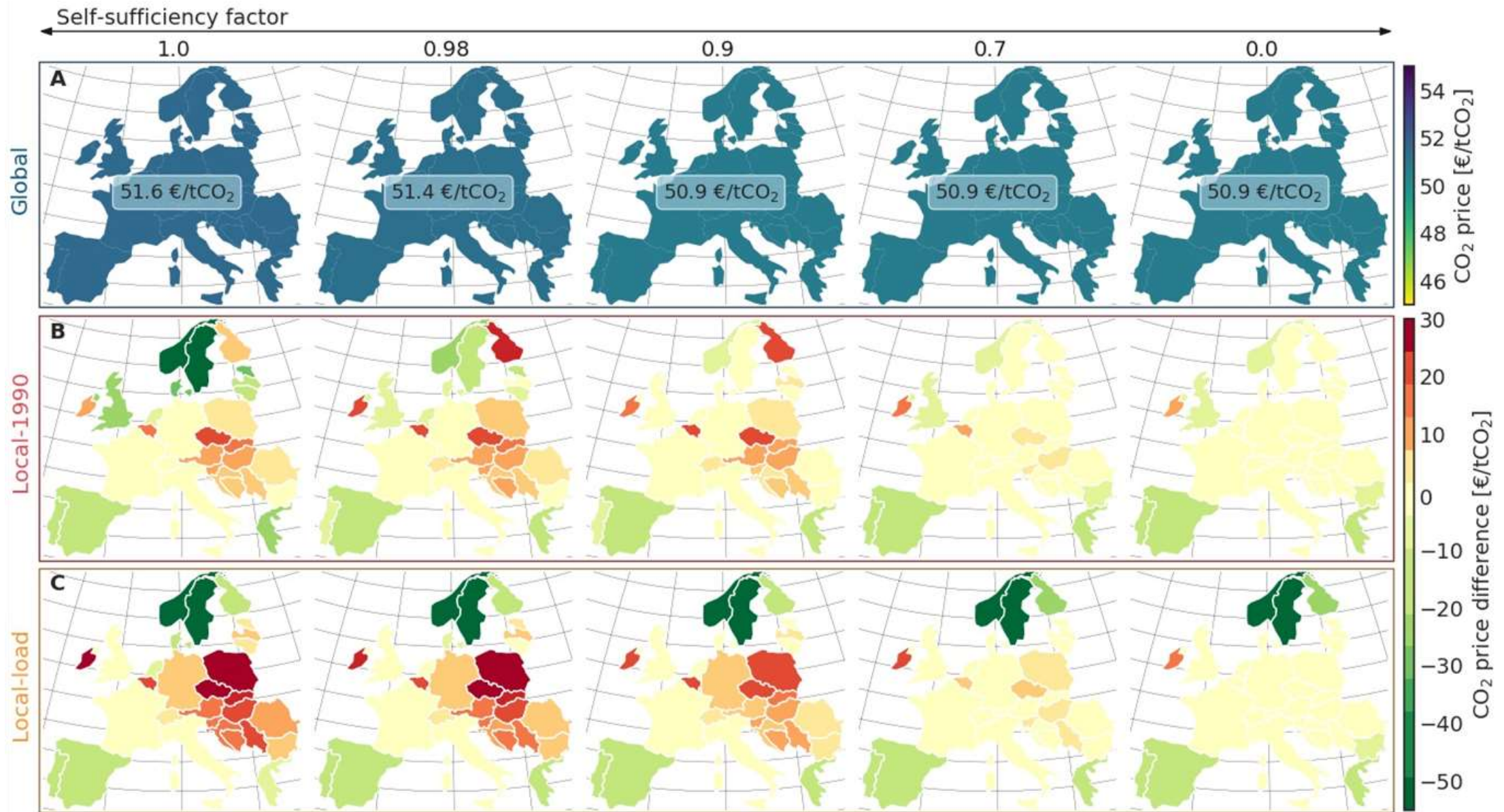
# Required emission prices



# Full collaboration

- 15% of electricity generation related emissions
- ~~No cross-border grid extension~~ → **Cross-border grid extension**
- ~~All countries are highly self-sufficient~~ → **Relax self-sufficiency requirement**
- Comparing different emission attribution schemes

# Emission prices



# Conclusions

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- We analysed the effects of collaboration by
  - country specific emission allowance distributions
  - cross border transmission extension
  - self-sufficiency requirement relaxation
- We found that stronger collaboration leads to
  - lower total system cost
  - more similar CO<sub>2</sub> emission prices
  - stronger dependence on others in terms of security of supply
- A middle way is possible: 70-90% self-sufficiency leads to most benefits

# Outlook

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- Investigate what causes high CO<sub>2</sub> prices in the individual countries
- Include a cross-sector coupling
  - Broader coverage
  - Synergies
  - Different transition speeds in different countries and sectors



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