Carbon embedded in traded goods and leakage:
Flows, trends and implications

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Outline

Covering three main areas of work:

- Tackling carbon leakage
- Industrial supply chains: some implications for mitigation economics and policies
- Global embedded carbon flows (from Carbon Trust: Global Carbon Flows)

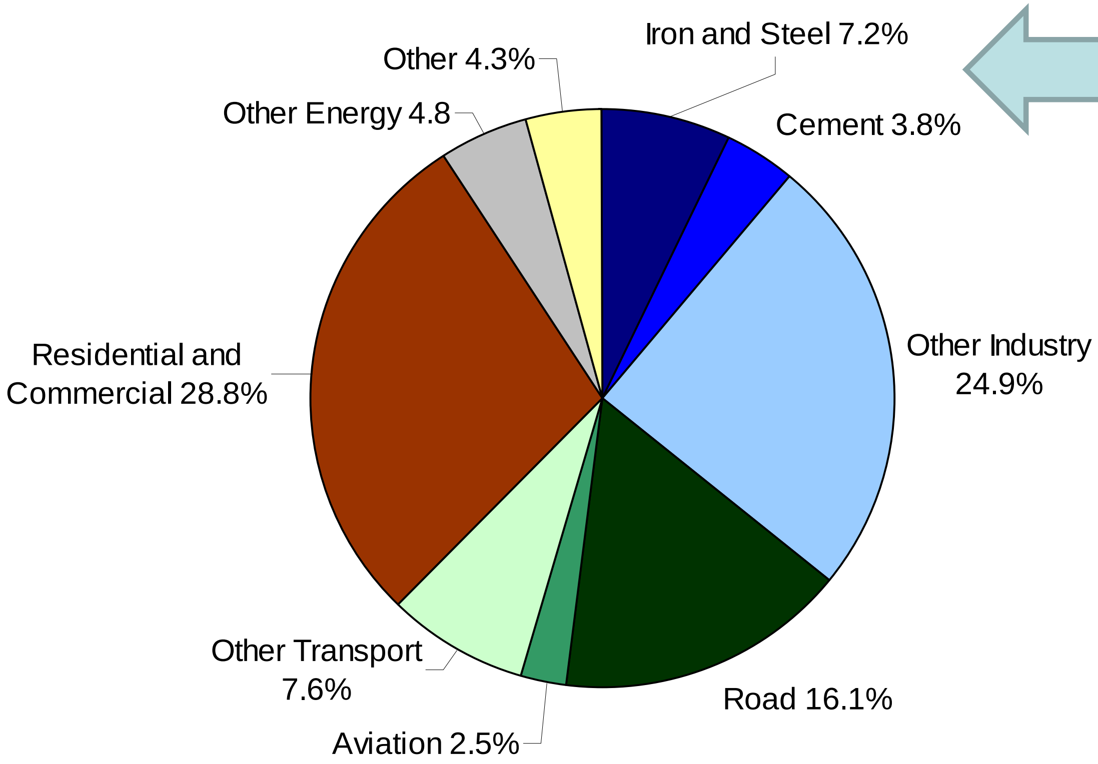
The core dilemma …

If damaging emissions are not incorporated in prices, then many standard assumptions about the welfare benefits of free markets and trade become questionable

- But what happens in a world of unequal carbon prices?

Manufacturing is potentially mobile and remains the biggest global emitting end-use sector

Much of the apparent progress in reducing OECD manufacturing consumption has been illusory, reflecting outsourcing particularly to China



PLUS process emissions that double steel and almost treble cement sector emissions

Global energy-related CO2 emissions, 2007

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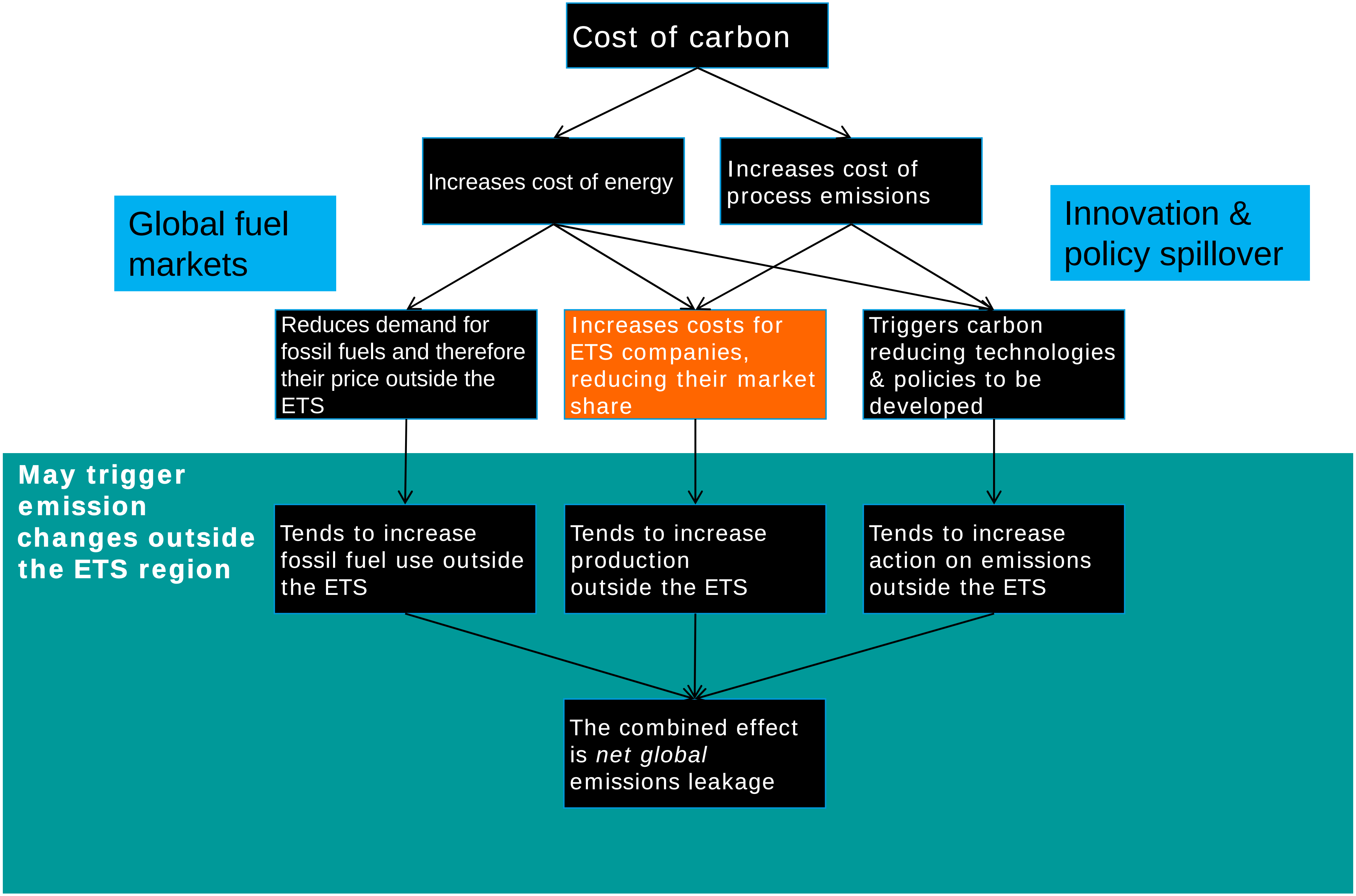
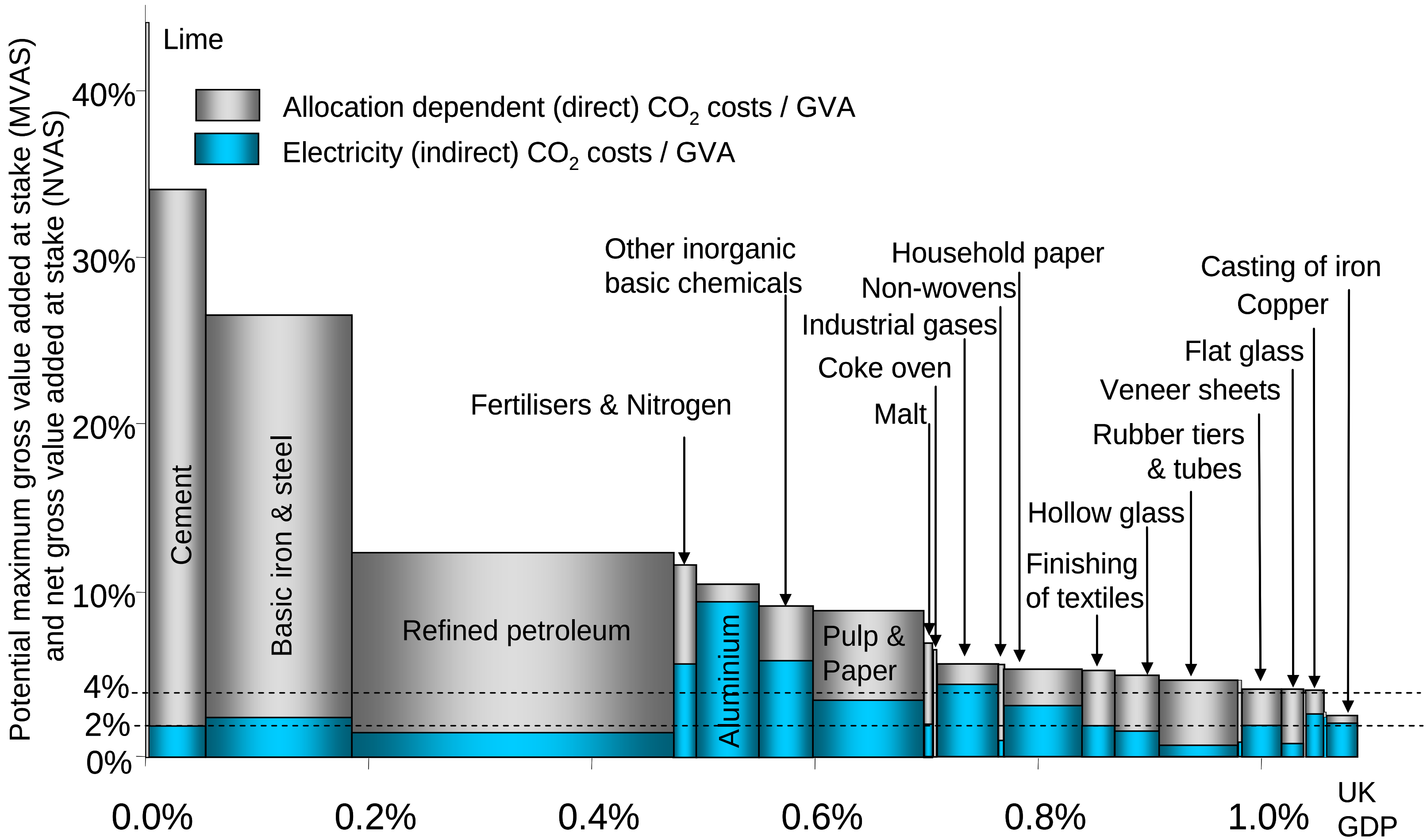
A cost of carbon can trigger external effects through three main channels – focus in this work is on central (industrial) channel



Within manufacturing, carbon emissions are *heavily concentrated* in a few primary production activities that contribute only a small share of value-added



Price increase assumption: CO_2 = €20/t CO_2; Electricity = €10/MWh

Sources: Climate Strategies: Hourcade et.al *(2007)*. *Differentiation and dynamics of EU ETS industrial competitiveness impacts*

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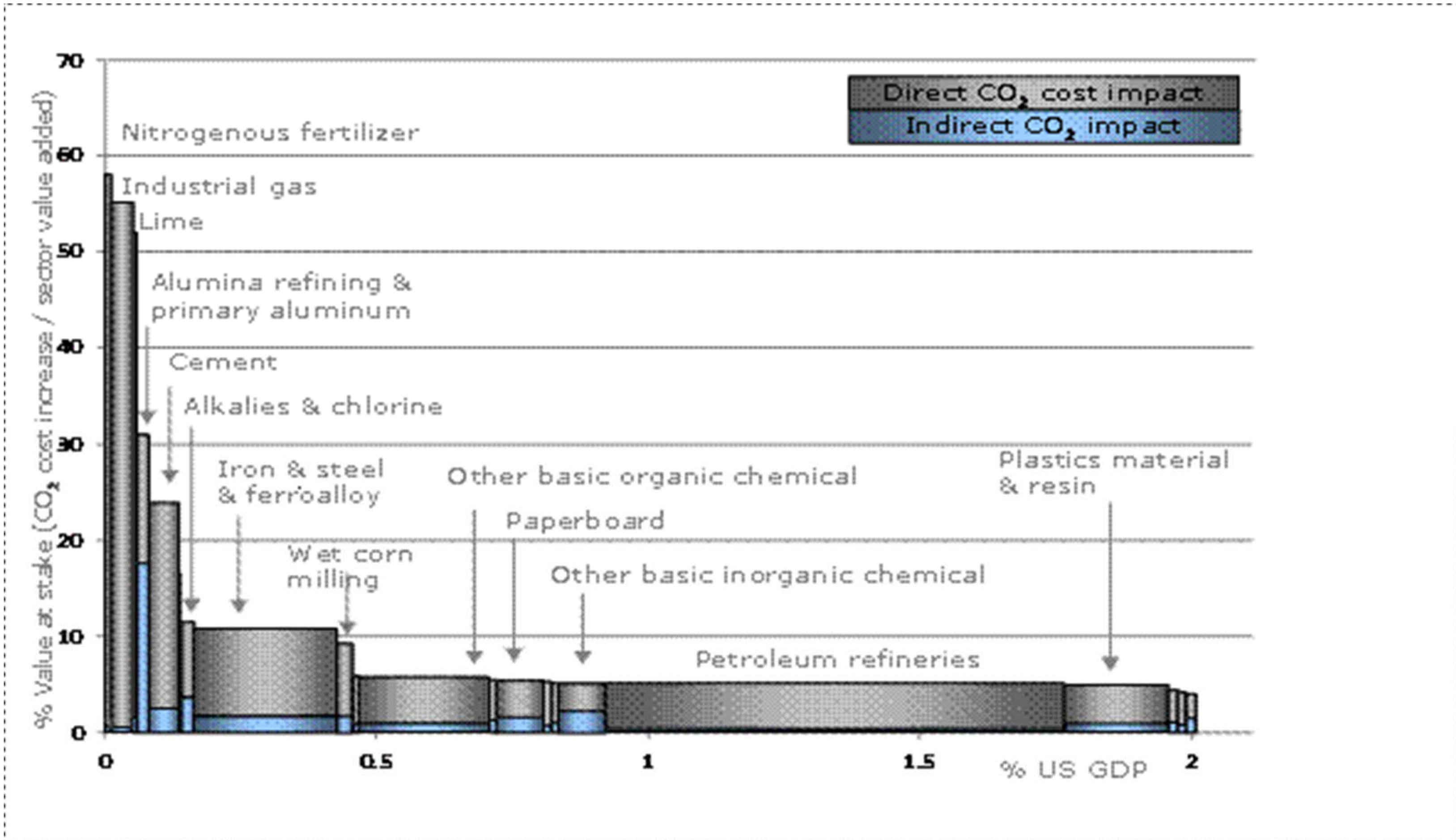
Similar degree of concentration evident in US industry

- Some sectoral differences, US economic structure closer to German, though Germany has higher % Value Added in the most cost-impacted sectors, US refining sector exceptionally large



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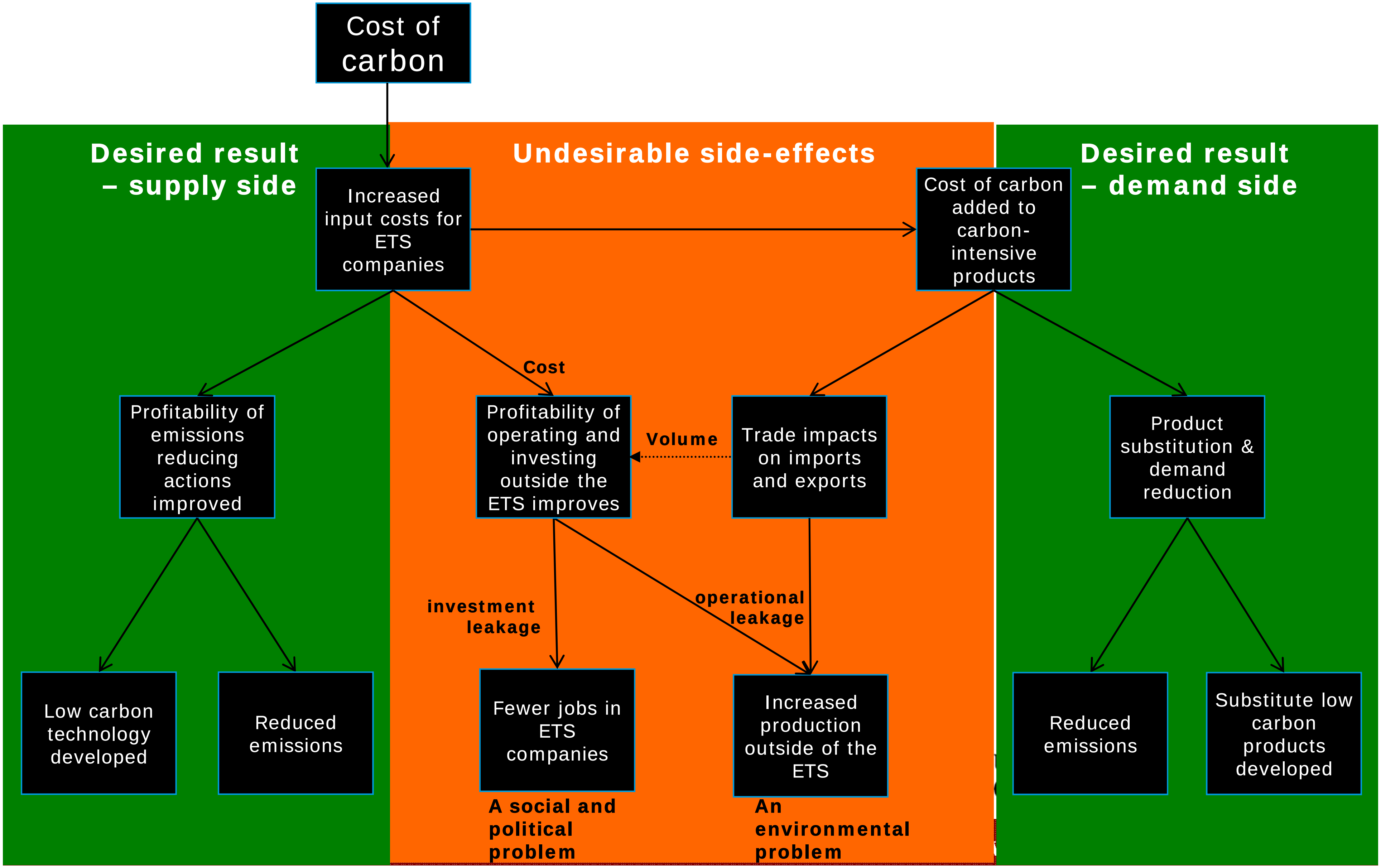
Pricing carbon has incentive effects on production and demand

Industrial carbon leakage – corresponding undesirable side effect of these incentives

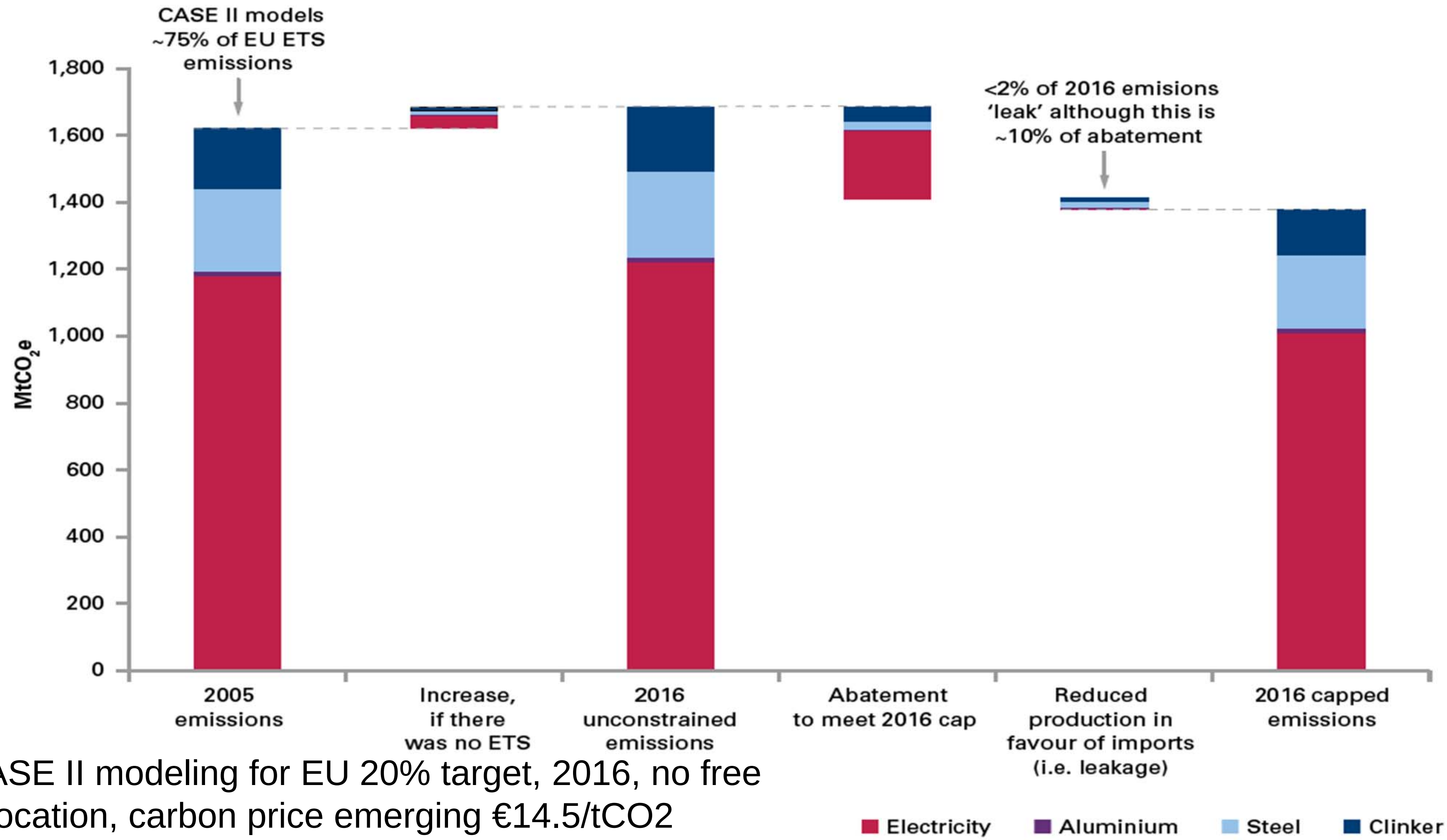


Models to quantify leakage effects

- Ideally, would represent in detail:
  - both sides of benefits (cleaner production and demand-side incentives)
  - both channels of leakage (production and investment impacts)
  - equilibrating effects in the wider economy, including revenues
- No model does all this in adequate detail, main choice seems to be:
  - **Detailed sectoral models,** representing supply chain and sector trade, can disentangle supply and demand-side benefits, but to date still have combined (aggregate) representation of leakage channels
    - (eg. CASE II)
  - **Aggregated trade models,** with no direct representation of supply chain (thus weak on supply chain and demand-side effects), aggregate leakage channels, but include wider equilibrating effects
    - (eg. EU DART model, RFF model)
- Main difference in results seems to be not in modelling the scale of industry leakage itself, but in assessing response measures

CASE modeling: Likely scale of leakage would not negate *overall* objective

- but without countermeasures may be significant for key sectors, led by steel,
- would increase for higher carbon prices / tougher targets
- has no benefit – only downsides, locally concentrated, making it politically potent



CASE II modeling for EU 20% target, 2016, no free allocation, carbon price emerging €14.5/tCO2

Source: Carbon Trust (2010): *Tackling Carbon Leakage: sector-specific solutions for a world of unequal carbon prices (data from Droege et al.)*

Responses: 'Level down', or 'At the border'?

Free allocation / exemption is not free

- Protecting energy intensive sectors inevitably requires the rest of the economy to 'work harder' to reach a given emissions target
- Free allocation or other compensation risks degrading the underlying incentives to decarbonise
- Such 'levelling down' will be most *effective* if it aligned with production and investment decisions – through allocation in proportion to output (output-based allocation) – which also makes it the most *costly:*
  - removes incentive to use the carbon intensive product more efficiently (ie. removes the right-hand half of Chart 3)
  - 'carbon intensive product' is primary step: eg. clinker, pig iron

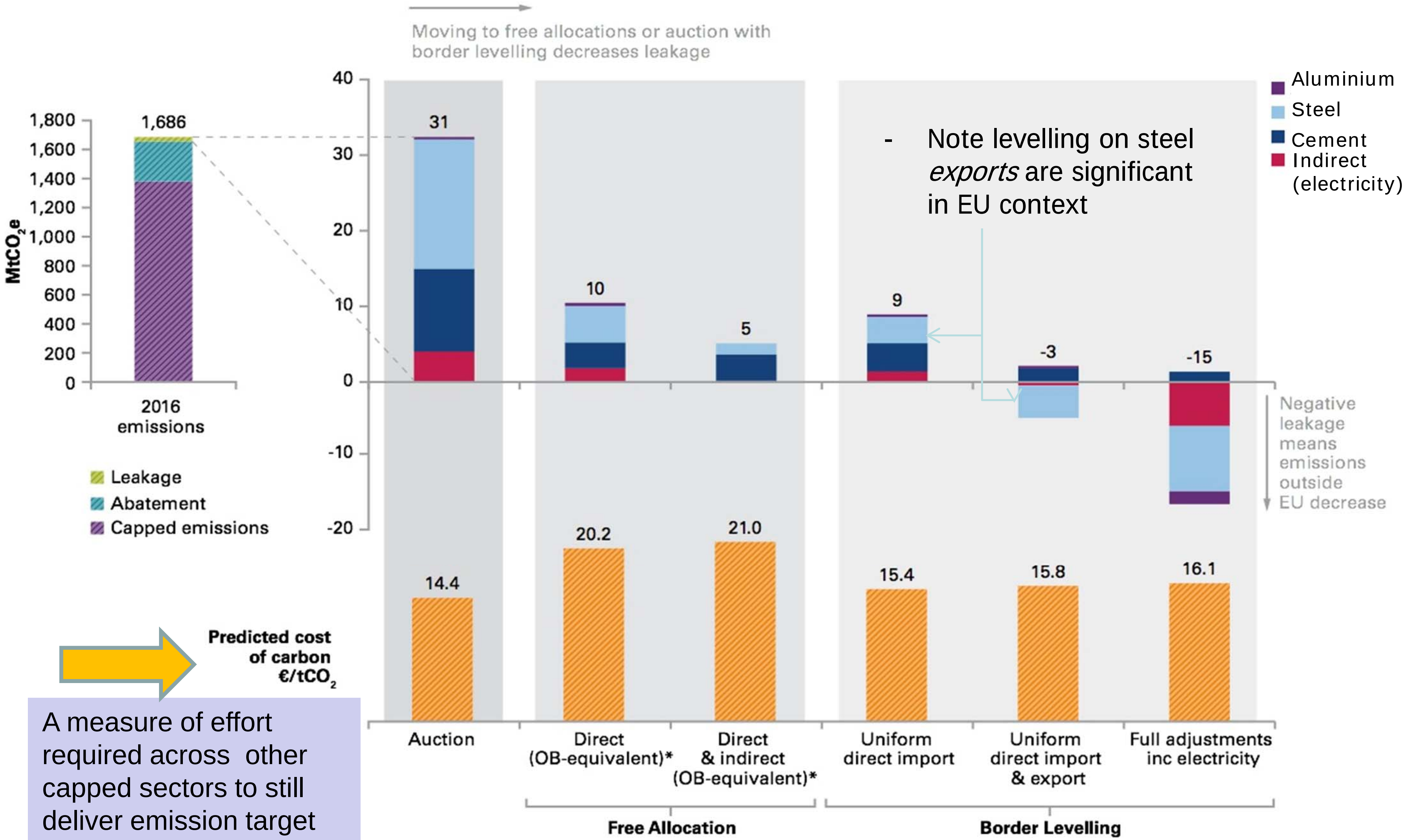
Border levelling preserves incentives

- Import adjustments (charging carbon on imports) enable the full incentive to be preserved domestically in meeting domestic goals
- Export reimbursement (of carbon costs) enable domestic producers to compete abroad without losing share to (potentially less efficient) foreign producers

But how big is the difference (and what is feasible?)

Border leveling is more effective and efficient, if feasible

- illustrated by modeling of steel, cement and aluminium in EU ETS Phase III



- Note levelling on steel *exports* are significant in EU context

A measure of effort required across other capped sectors to still deliver emission target

Source: Carbon Trust (2010): *Tackling Carbon Leakage: sector-specific solutions for a world of unequal carbon prices (data from Droege et al. using CASE II model)*

Words of caution – *type* of implementation matters

- **Fixed free allocation** with new entrant / closure rules (as in EU ETS)
  - May deter *investment leakage*, but do little to shield operational decisions & thus can risk windfall profits without necessarily stopping carbon leakage
  - Requires modeling to separate operational from investment decisions and to make assumptions about political risk in investment planning (v.complex)

- **Output-based allocation** should be more effective at tackling both windfall profits and leakage but need to apply it to carbon-intensive step in production amplifies losses:
  - takes out the incentive to use the primary product (eg. clinker) efficiently, hence deters radical process innovation or substitution through rest of production & consumption
  - Requires some modeling of production process & supply chain to capture these effects: the aggregate models do not do this

- **Feasible types of border leveling** are constrained by practical and legal considerations
  - Import adjustments are simplest for a *fixed benchmark* – eg. a fixed CO2 charge (or allowance requirement) per tonne of cement
  - Export adjustments can only be reasonably applied where the cost of carbon actually paid can be tracked through to specific exported products and reimbursed at the border
  - Legal and implementation complexities remain
- ***Global welfare*** impacts of border adjustments v.small given equilibrating effects (eg. Whalley).

Source: Climate Strategies (2009): Droege S. et al., *Tackling Carbon Leakage in a world of unequal carbon prices*, final report

Covering three main areas of work:

- Tackling carbon leakage
- Industrial supply chains: some implications for mitigation economics and policies
- Global embedded carbon flows (from Carbon Trust: Global Carbon Flows)

A simple world

Capital | Labour | Energy | Materials

↓

Manufacturing

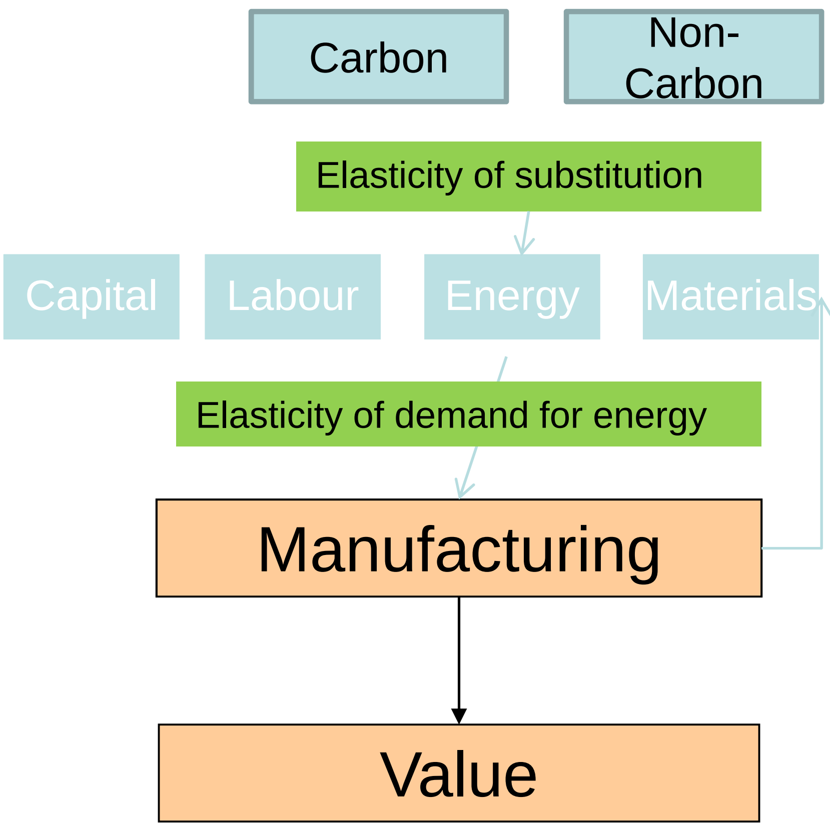
↓

Value

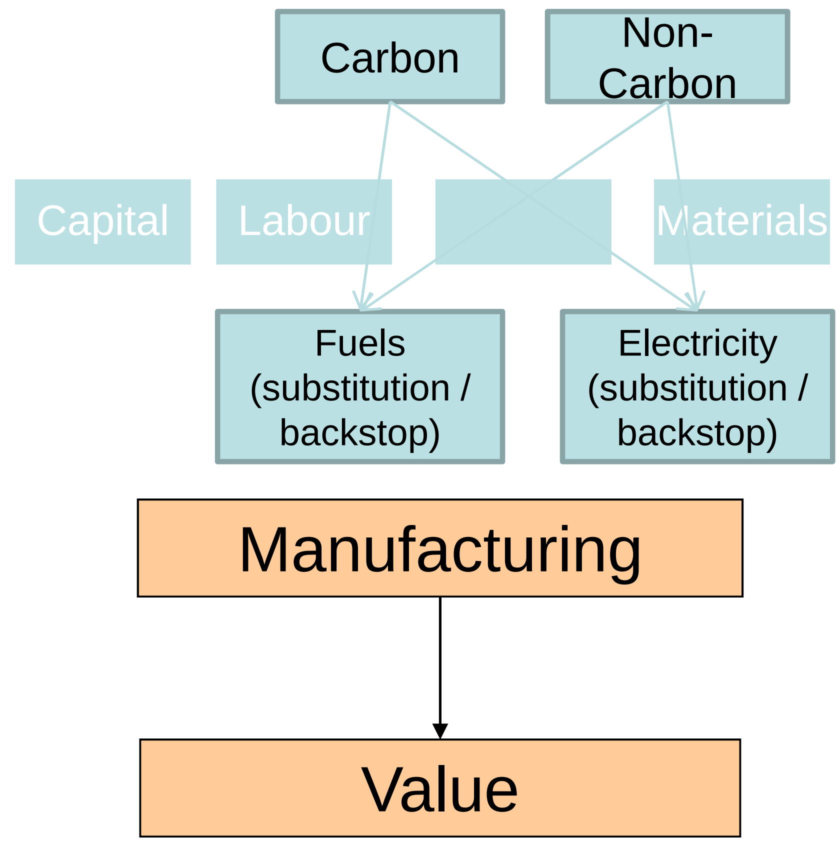
(manufactured goods)

Global abatement modeling has concentrated most on elaborating energy sector – not supply chains of industry / materials demand

Simple



More sophisticated



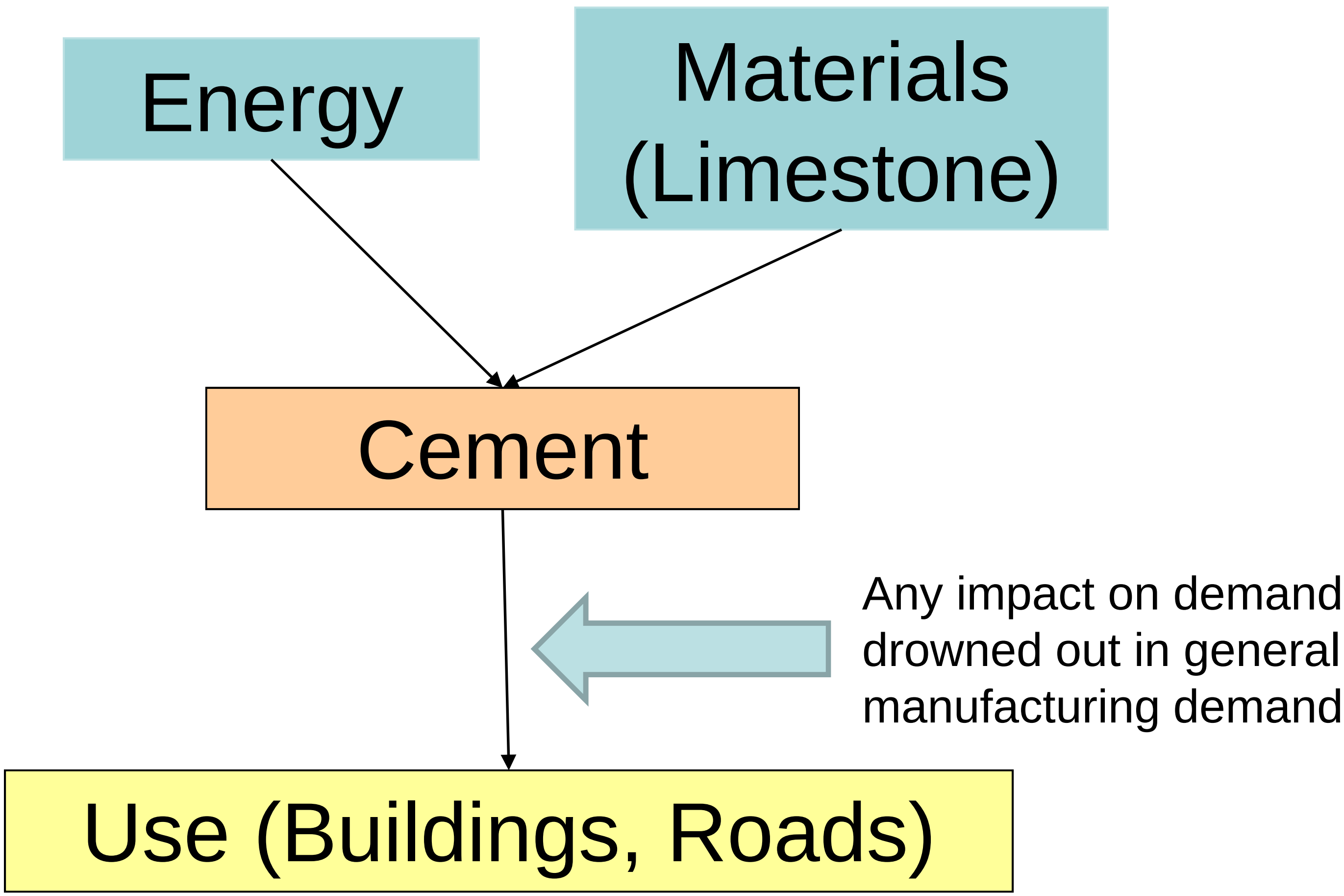
The process of global abatement modeling over past 20 years consists almost entirely of more sophisticated modeling of energy sector with elasticities and direct technology substitution in energy supply

This is a problem

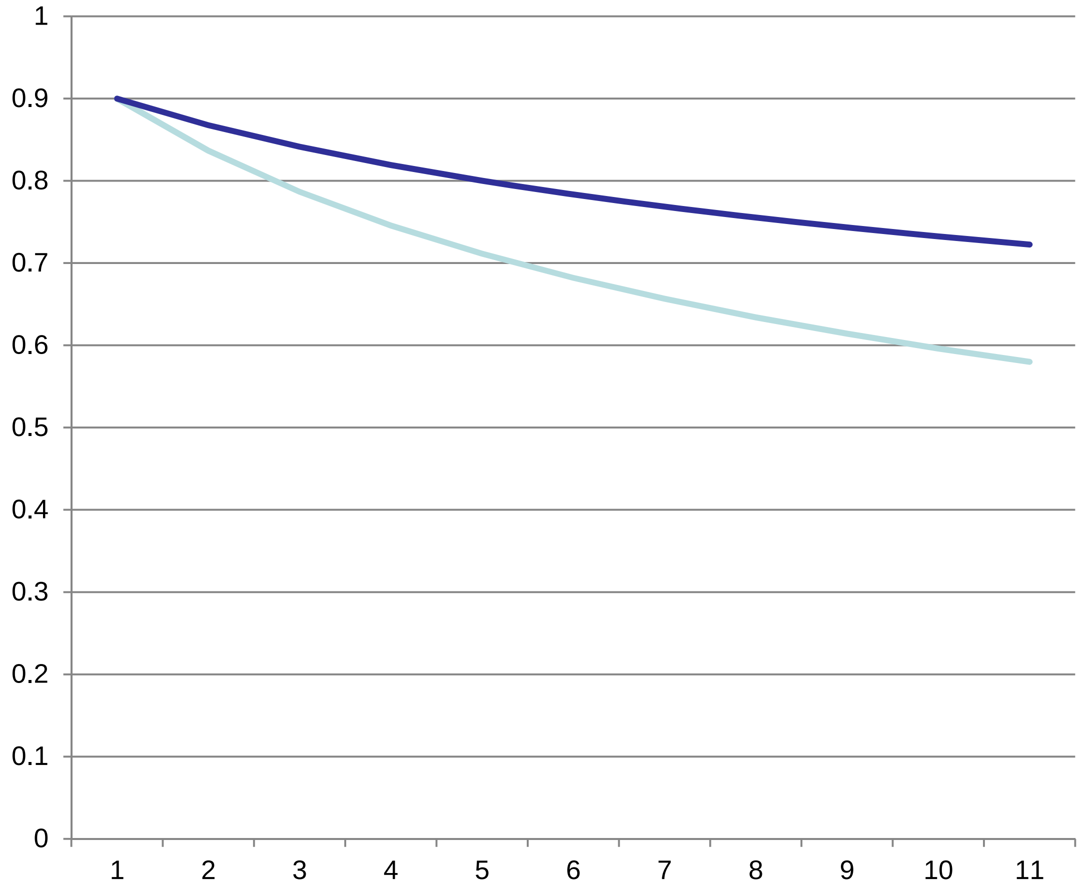
- *All* energy resources have problems (external costs) and limitations
- Climate change limits the most abundant fossil fuel (except for CCS, which itself carries problems and limitations)
- Exergy analysis points to a *huge* physical potential to improve efficiency with which we deliver the energy services we demand, particularly in transport and buildings
- But manufacturing has been seen as different – particularly in relation to core industrial production, and process emissions
- We have remarkably little understanding of how much energy services we *really* demand – *particularly* in manufacturing
- Global abatement assessments point to manufacturing and aviation as the Achilles' Heel of global decarbonisation

Energy demand in a simple manufacturing chain

- a representative view of most economic models (if we're lucky)



Impact of elasticity response (illustrative)



Emissions

Elasticity -0.2

Elasticity -0.4

Time, impact of restructuring and EU ETS ??

Trebling of carbon input costs

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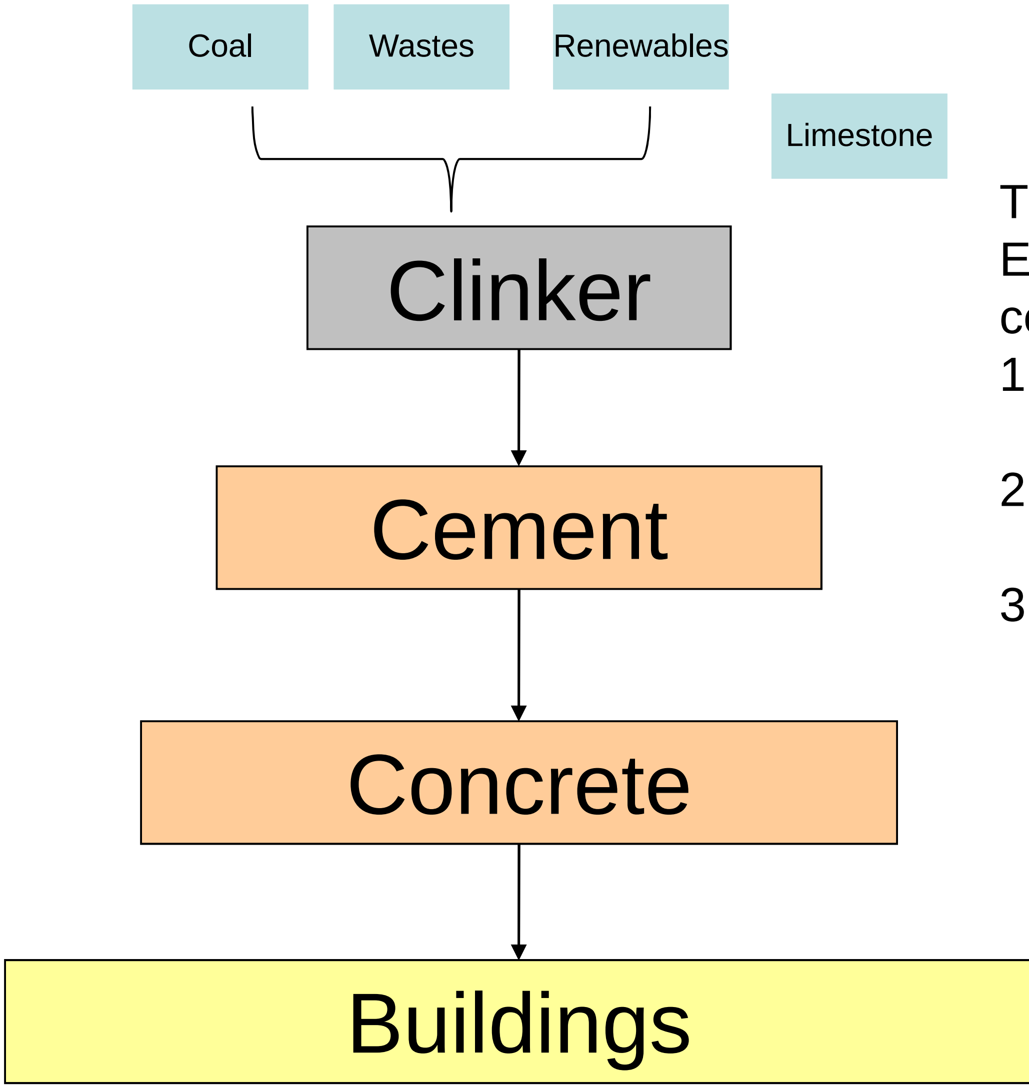
Cement Production Chain



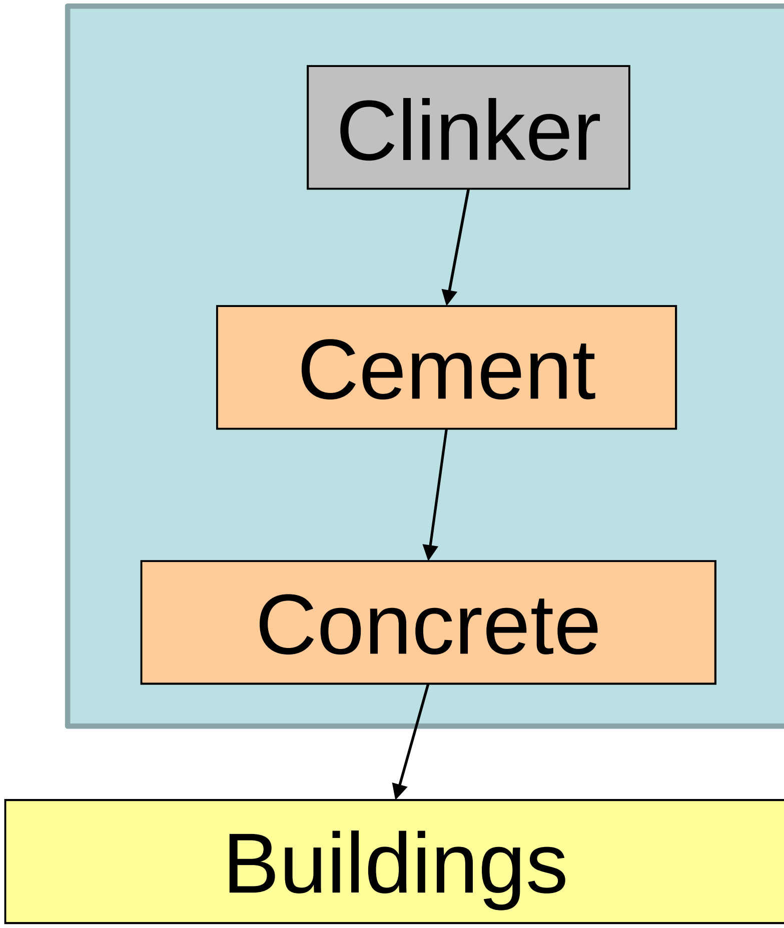
The ‘cement surprise’ in the EU ETS has been the ability of the cement sector to reduce emissions

1. Increased plant efficiency (but approaching limits)
2. Recycled and renewable fuels (tires, biomass)
3. Substitution of clinker by mixing other inputs to cement

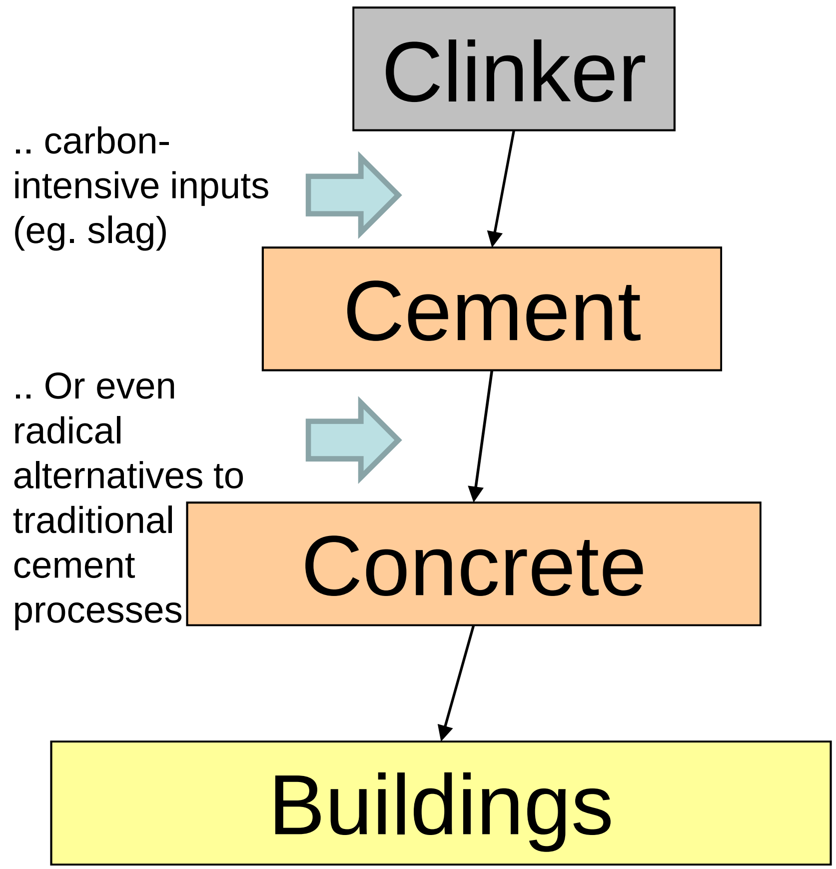
(2) and (3) are both *substitution processes*

Substitution within supply chain requires unbundling

Vertically integrated supply chain



Unbundled supply chain allows possibility of substitution ..

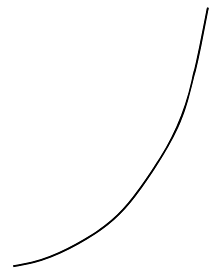


Elasticities assume a particular functional form that may represent efficiency but not substitution effects

Standard elasticity:

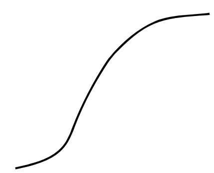
Emissions from cement (clinker) at cost Cck

$$E = constant \times Cck^{-\beta}$$

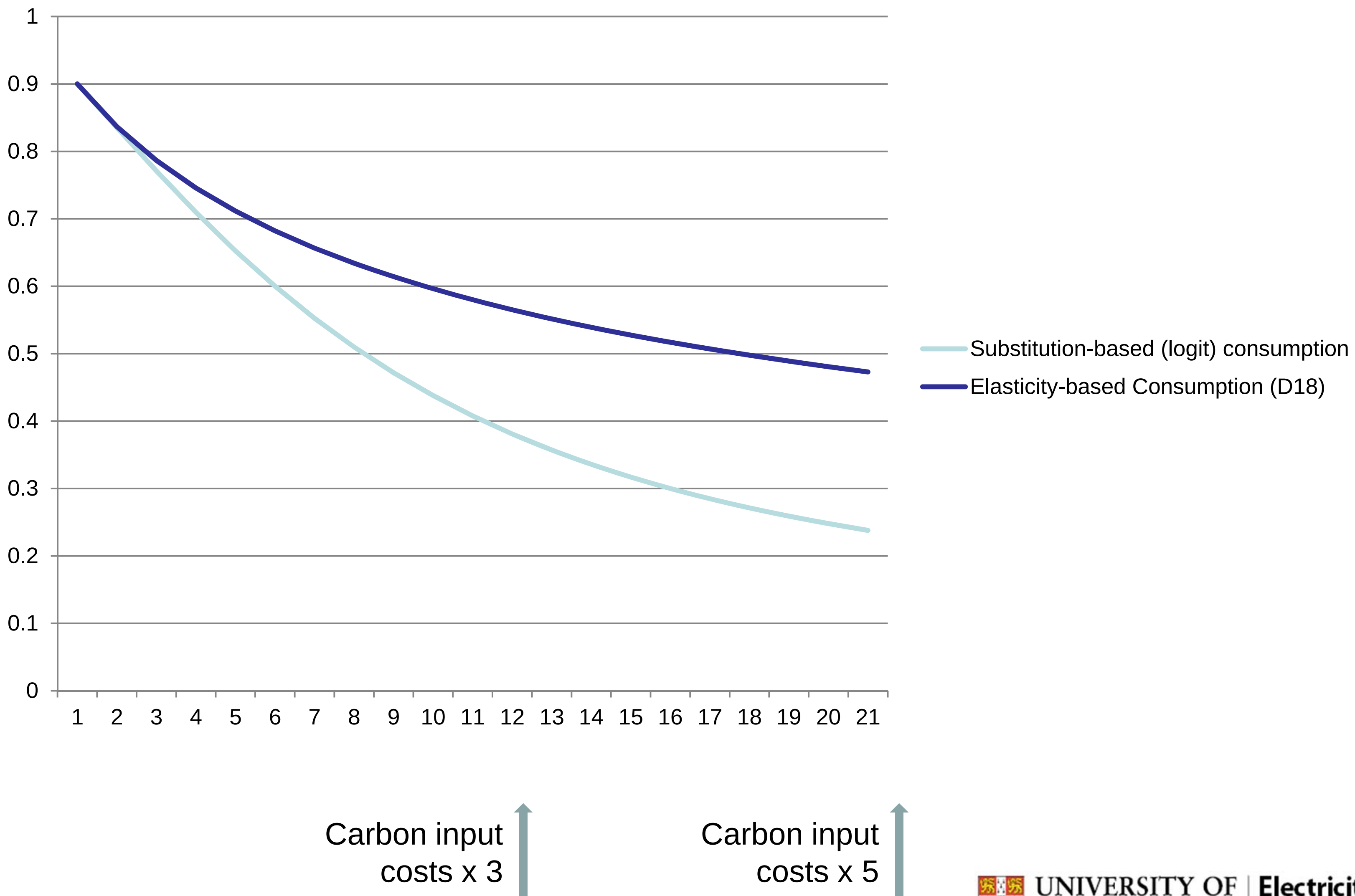


Logit substitution function
(Csub is cost of substitute)

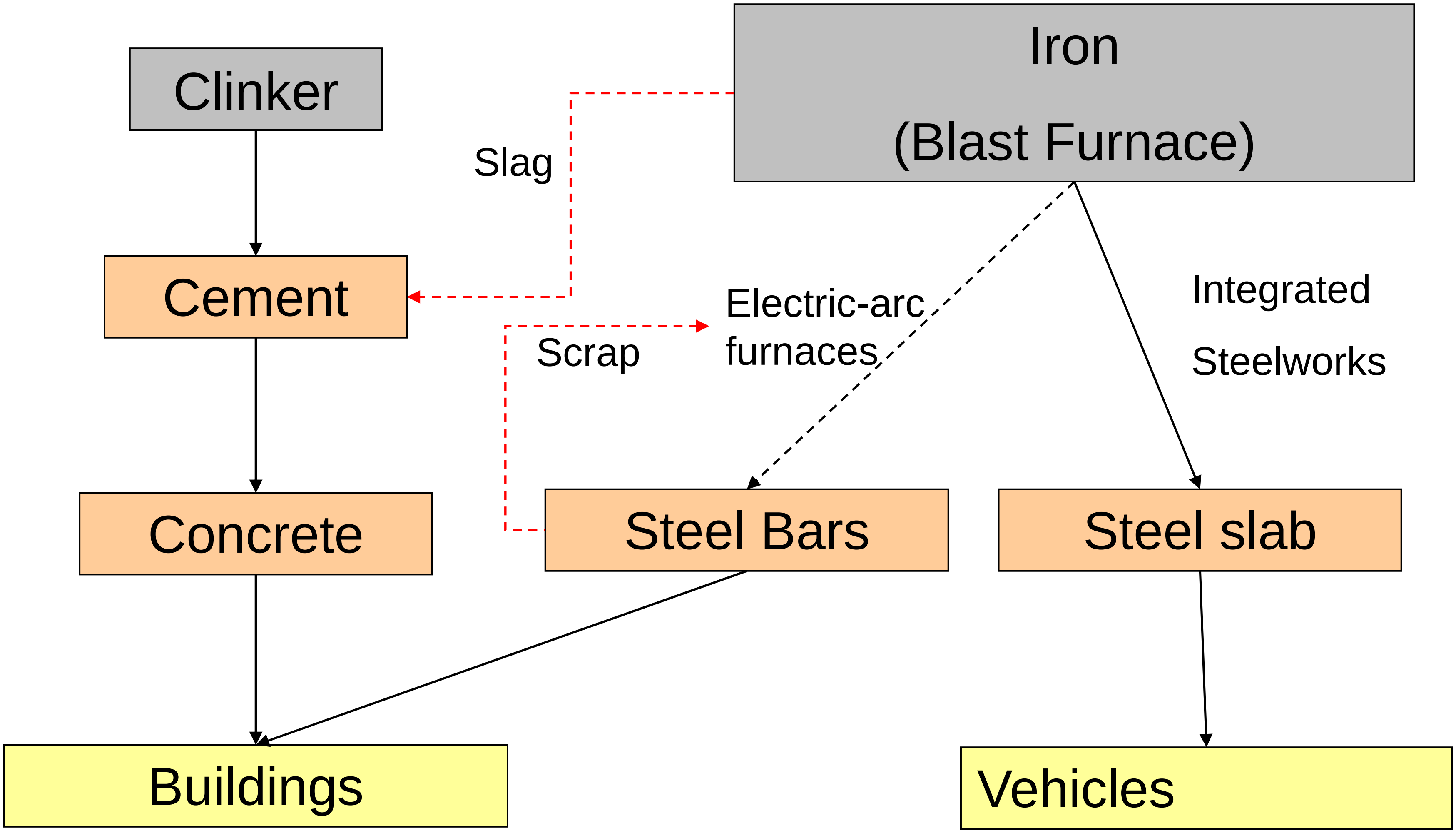
$$Sck = \frac{(Cck)^{-\eta 1}}{(Cck)^{-\eta 1} + (Csub)^{-\eta 1}}$$



At large cost difference, economics of efficiency (through elasticity) diverges fundamentally from substitution

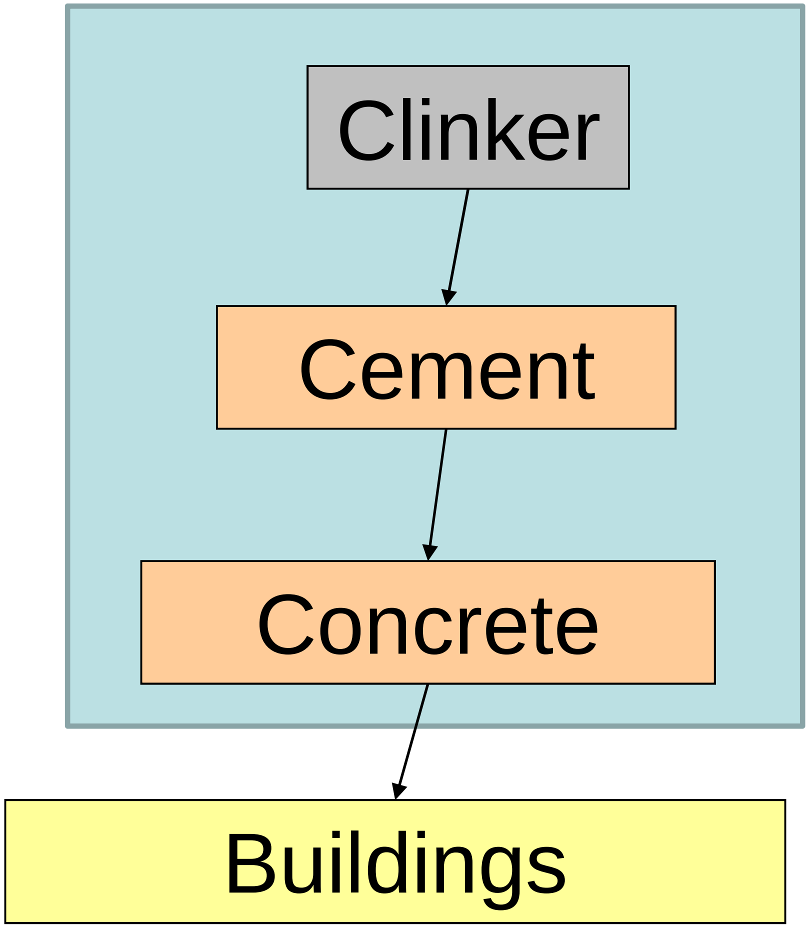


Cement and Iron Production Chain

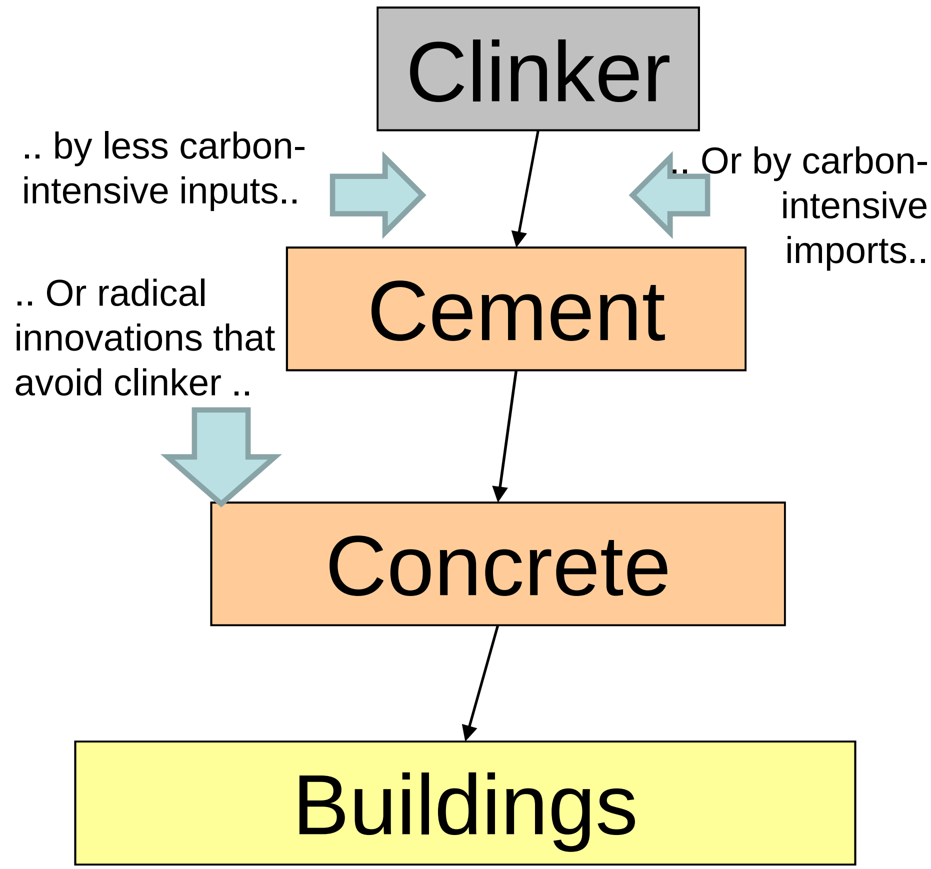


But with a carbon price, unbundling also introduces problem of import substitution / carbon leakage

Vertically integrated supply chain



Unbundled supply chain allows possibility of substitution ..



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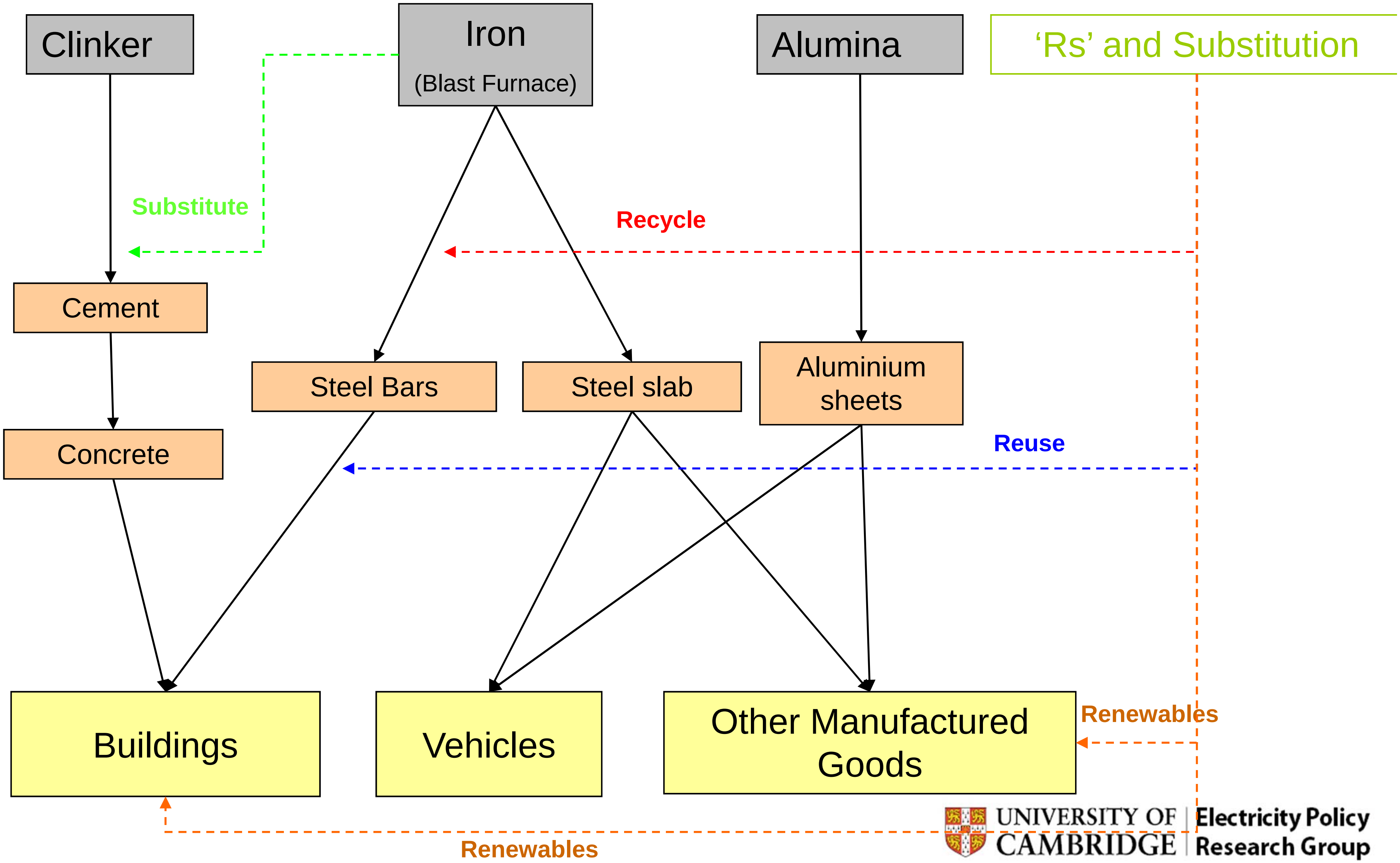
A complex world – which we need to understand much better before jumping to conclusions on mitigation costs or policies



.. in which the most efficient mitigation requires response to cumulative carbon at each step of supply chain

- Start with primary production emissions
- Track the carbon to the next step, add the carbon at the next step
- Include tracking any carbon *payment*
- Wherever a carbon price is applied, charge it on the *total carbon*, *minus the carbon already paid for*
- The approach can operate across borders in ways directly analogous to VAT: "carbon added information, instruments .."
- Creates an incentive for entities at each step to respond to full cost of embodied carbon; and for governments "upstream" to apply carbon charges themselves so as to keep the revenue: ".. and incentives"
- But how far along the supply chain downstream … ?

Covering three main areas of work:

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- Industrial supply chains: some implications for mitigation economics and policies
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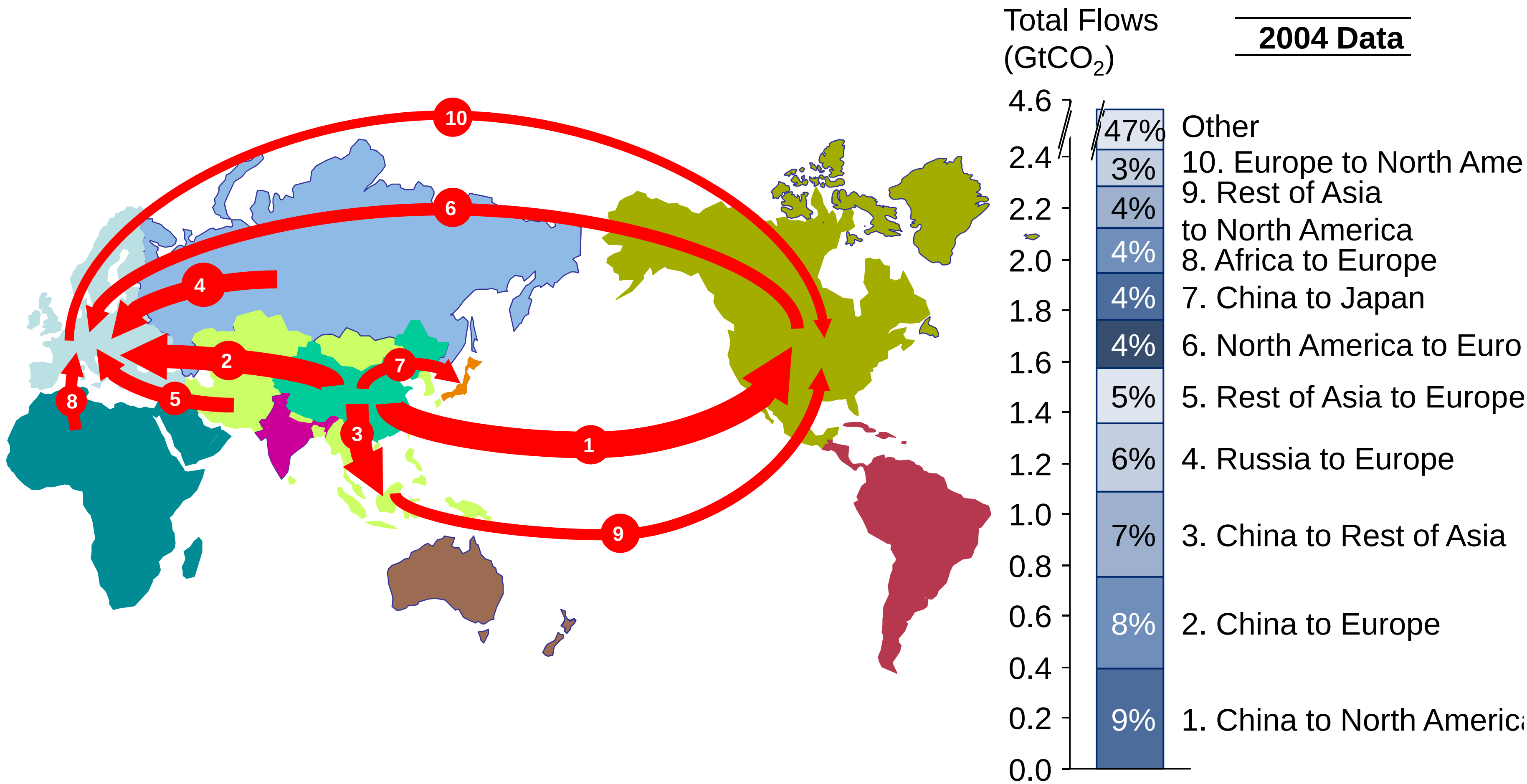
Figure 5: Top 10 regional flows of CO_2 embedded in goods and commodities



Note: Rest of Asia excludes China, Japan and India
Data includes flow of Scope 1-3 (direct, indirect and upstream) emissions arising in region of export that are embodied in trade flows to the region of import
Refer to Annex [B] for region definitions
Source: Carbon Trust Analysis; CICERO / SEI / CMU GTAP7 EEBT Model

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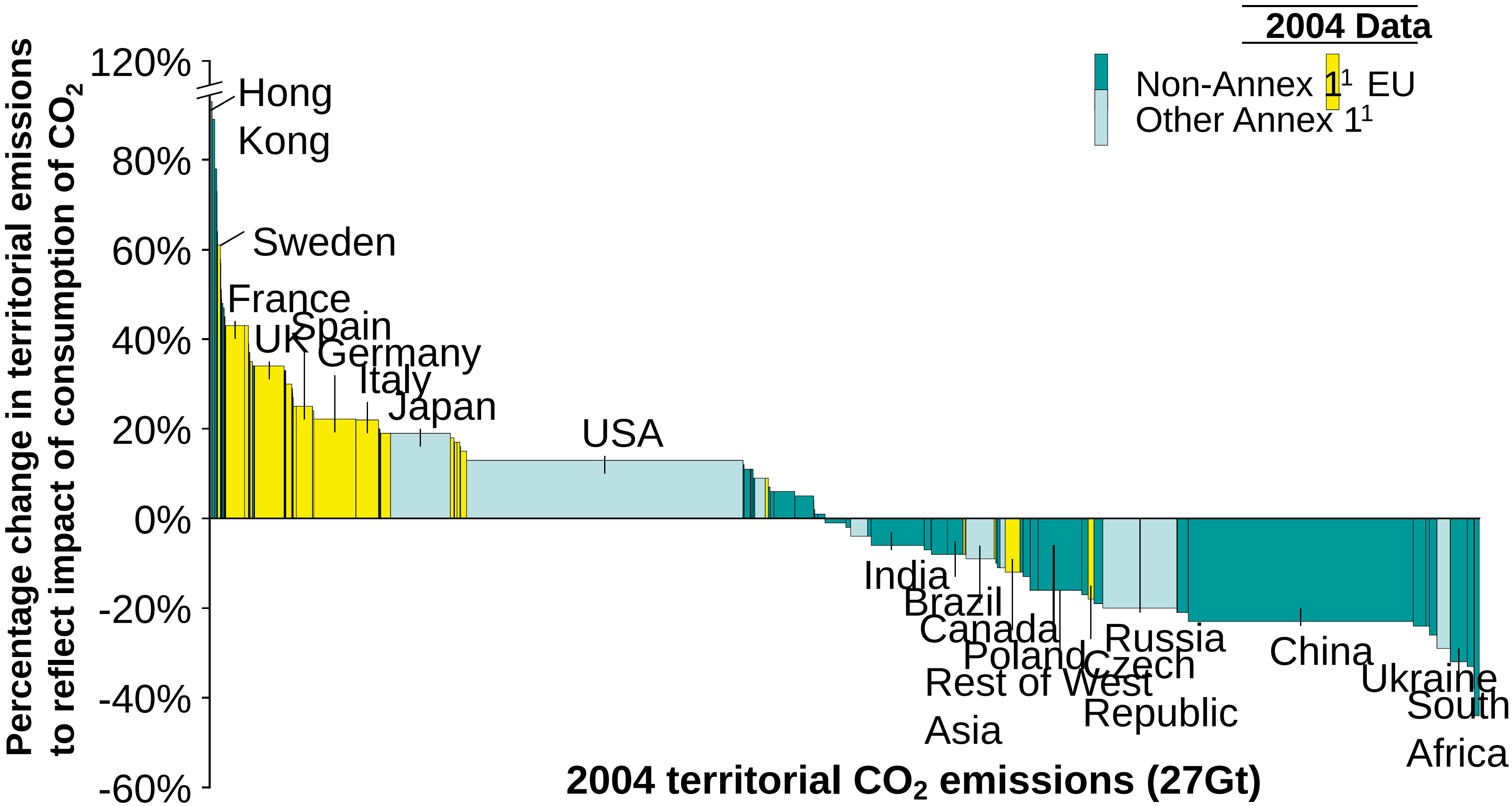
Figure 3: The impact of a consumption based view on emissions by country compared to production



1. Annex 1 to UNFCCC

Note 1: Includes CO_2 emissions from production, process, transport and household sources only (27Gt in 2004); excludes non-CO2 emissions, and emissions due to land-use change

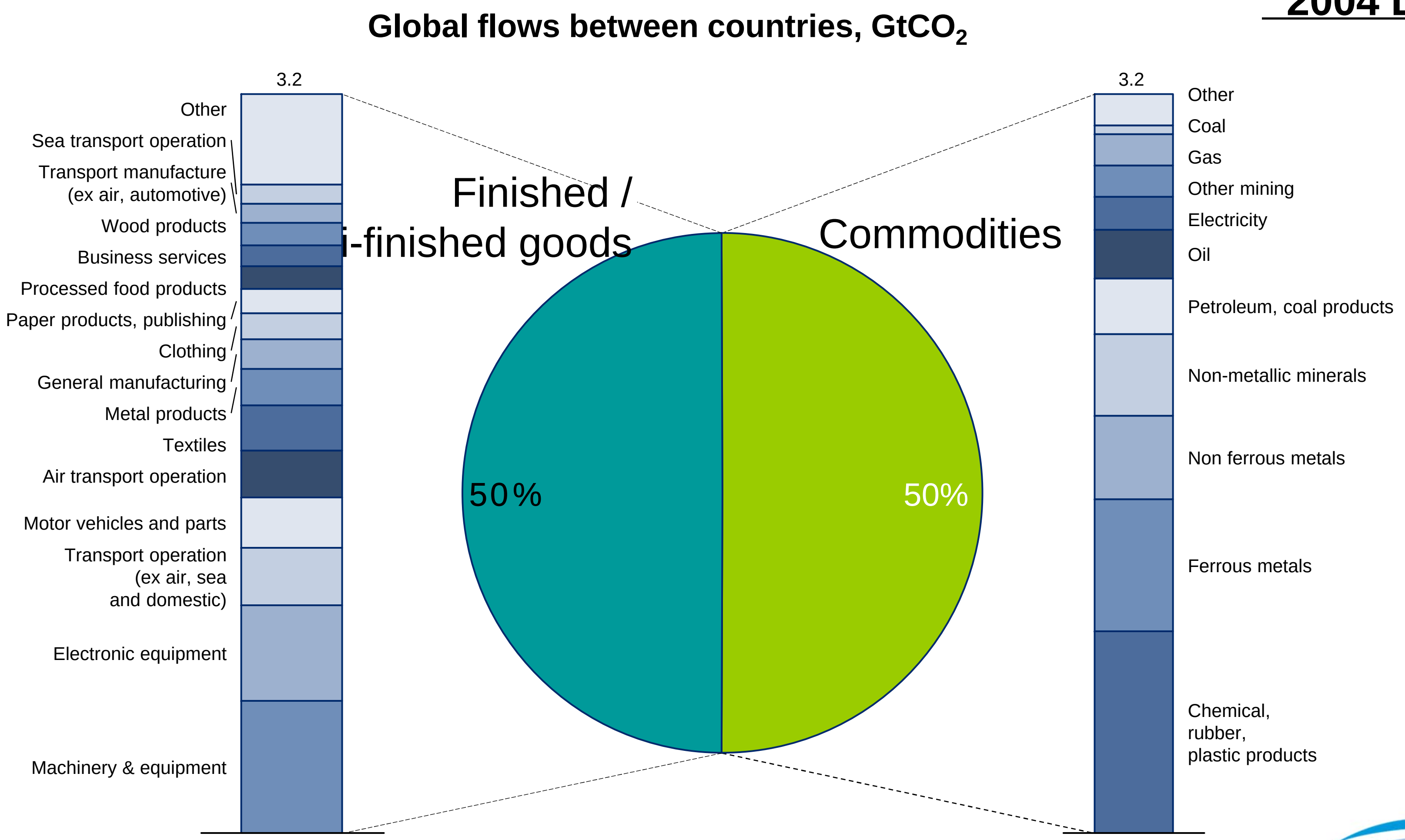
Note 2: Based on an MRIO (multi region input/output) model allocating emissions to regions of consumption

Source: Carbon Trust Analysis; CICERO / SEI / CMU GTAP7 MRIO Model (2004)

Might it be possible for policy to focus on bulk commodity trade whilst finished goods addressed through carbon labelling?

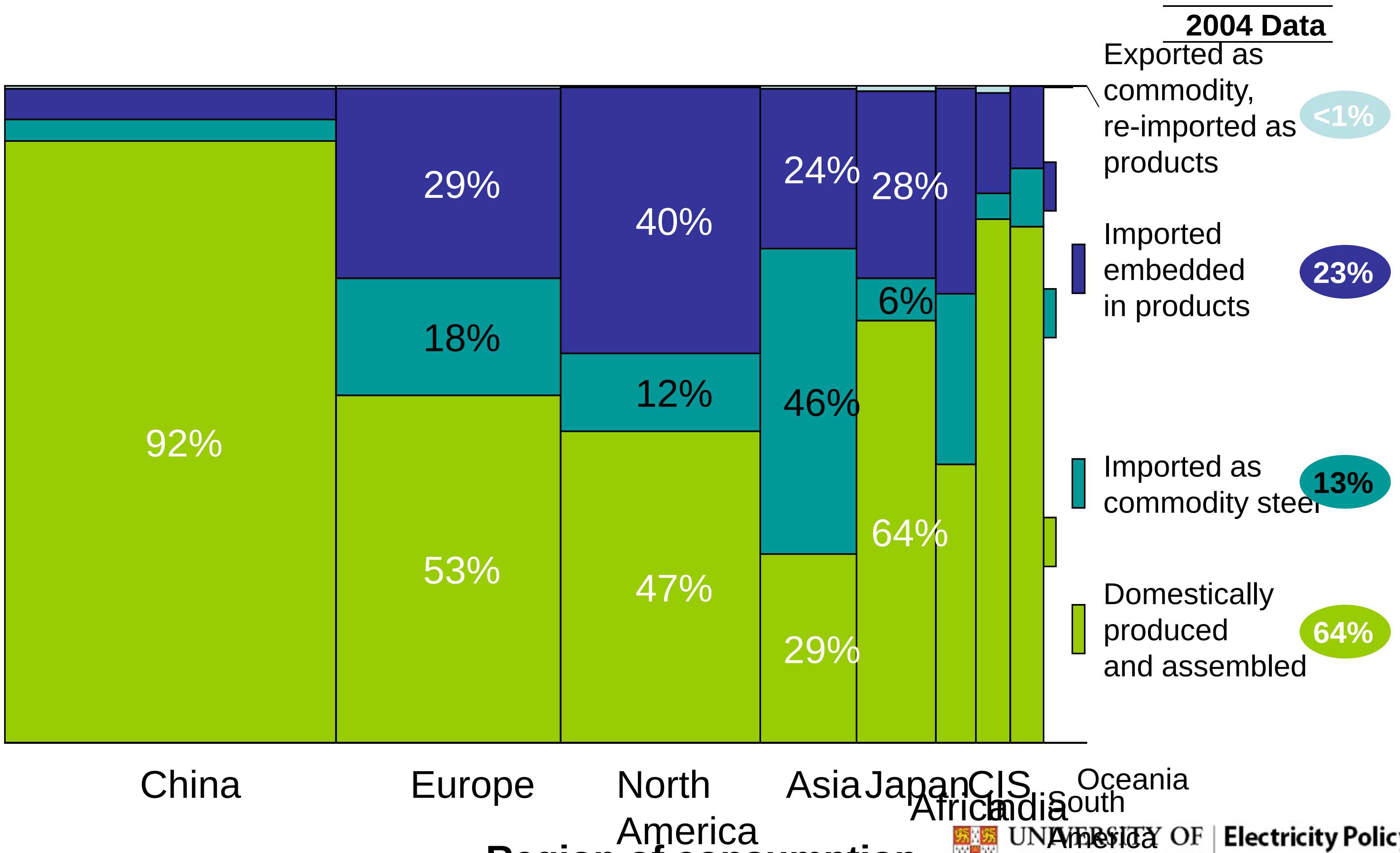
Embodied carbon flows evenly divided between commodities and goods in 2004

2004 Data



Source: Carbon Trust Analysis; CICERO / SEI / CMU GTAP7 EEBT Model (2004)

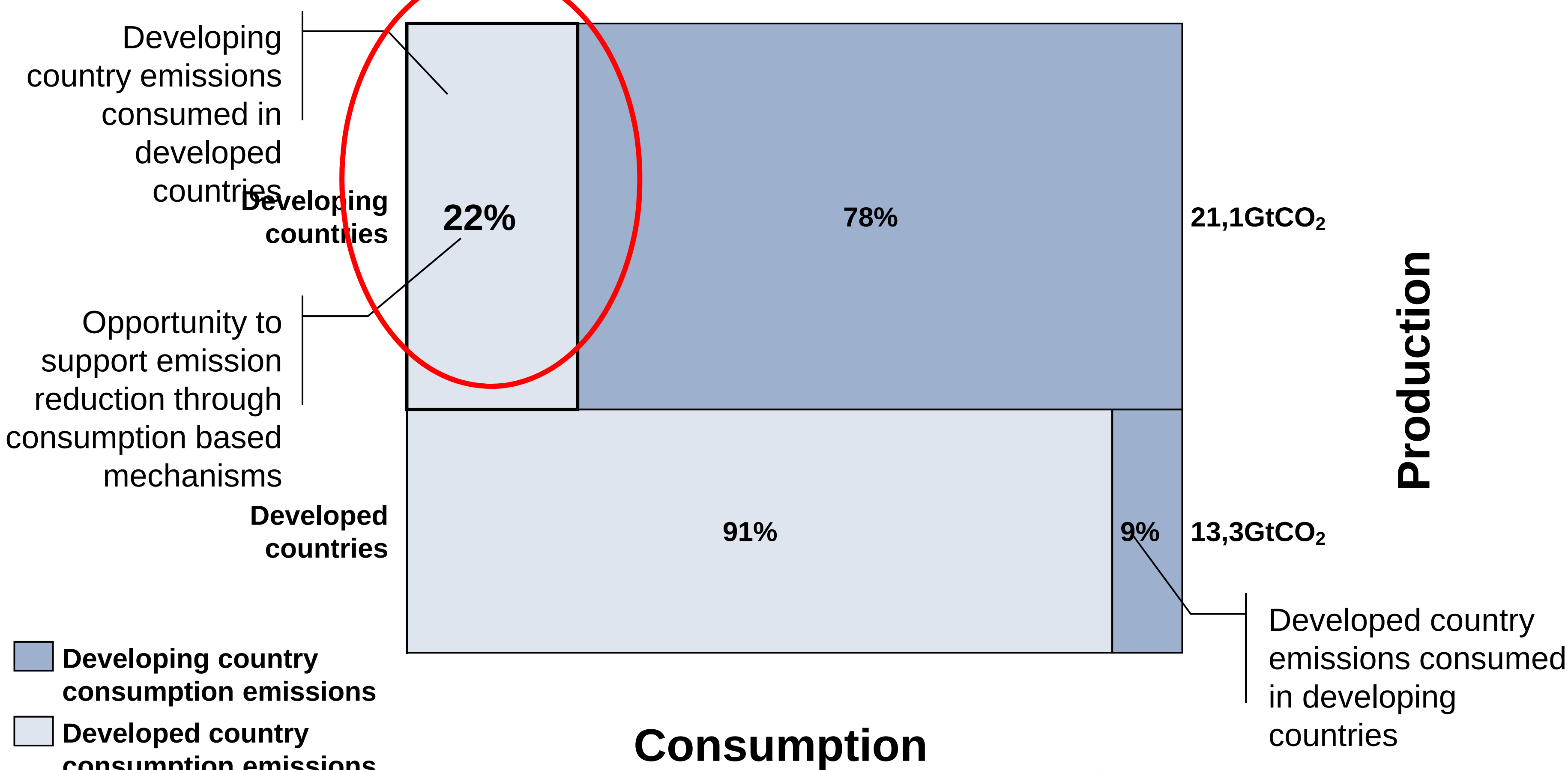
Figure 6: Domestic vs imported steel emissions by category of consumption



Note 1: Includes Scope 1 (direct) and Scope 2 emissions (indirect, allocated electricity)
Source: Carbon Trust Analysis; CICERO, SEI and CMU – GTAP7 EEBT & MRIO model

Consumption-based emissions approaches in developed countries can support wider global emissions reductions

2020 emissions, low end Copenhagen accord achievement



Note: Excludes household emissions (which occur in country of production, irrespective of production or consumptioni perspective)
Source: Carbon Trust Analysis; CICERO / SEI / CMU GTAP7 MRIO/EEBT Model (2004)

Conclusions

- A world of unequal carbon prices will inevitably raise trade issues of many forms
- Concerns about carbon leakage have already disrupted efforts to price carbon in several jurisdictions
- *Industrial* carbon leakage is very sector-specific issue – around half a dozen main industrial commodities
- A close analysis of supply chains and substitution possibilities underlines losses from relying on free allocation
- Combined with shrinking footprint of EU production-only emissions, will inevitably turn attention to consumption-based perspectives and associated border levelling
- This will form part of broader global debate on incremental moves towards consumption-based accounting
- More disaggregated and recent trade data compiled from a carbon as well as value-added perspective will be important going forward

Climate Strategies – international research network with link to UK Carbon Trust in ETS & competitiveness studies

Climate Strategies

- Sponsored research through an international network of academics, Secretariat hosted at Cambridge University
- Series of studies including ETS, competitiveness, auctioning, linking of schemes and options for tackling carbon leakage
- Tackling Leakage project led by Susanne Droege at the German Institute for International and Security Affairs (SWP), Berlin, with research by: IDDRI, Öko-Institut, Vrije Universiteit, Georgetown University, Ecologic Institute, Ryukoko University, National Institute for Environmental Studies (NIES), CIRED, Mineral and Energy Economy Research Institute, University of Greifswald
- Academic papers and final reports available from www.climatestrategies.org

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Climate Strategies and Climate Trust publications on ETS design, competitiveness and carbon leakage

	Climate Strategies Academic Synthesis Reports* www.climatestrategies.org	Carbon Trust Insights publications www.carbontrust.co.uk
EU ETS design and Incentives	Σ National allocation plans in the EU ETS (2006)** Σ Grubb, Neuhoff et al.: Submission to EU ETS review Σ Neuhoff et al. paper on Auctioning	Σ EU ETS Phase II allocation: implications and lessons (2007). Σ Cutting Carbon in Europe: The 2020 plans and the future of the EU ETS (2008)
Competitiveness and carbon leakage	Σ Emissions trading and competitiveness (2006)** Σ Hourcade et al, Differentiation *and dynamics of EU ETS industrial competitiveness* (2007) Σ Droege et al., 'Tackling carbon leakage' (2009)	Σ The European emissions trading scheme: implications for industrial competitiveness (2004) Σ Allocation and competitiveness in the EU emissions trading system: options for Phase II and beyond (2007). Σ EU ETS impacts on profitability and trade: a sector by sector analysis (2008). Σ Tackling carbon leakage (Jan 2010)

** Key papers published as Special Issue of the Climate Policy journal

Own academic papers: http://www.econ.cam.ac.uk/faculty/grubb/index.html