The Economics of Uranium, Fossil Fuels and Climate Change Stabilization

Trade-offs, synergies and solutions

13th IAEE Conference
„Energy Economics of Phasing out Carbon and Uranium“

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I. Introduction – Uranium and Nuclear Power

- On the one hand
  - Nuclear power does not emit CO_2, sulphur and PM
  - Low operational costs
  - Base load supply

- On the other hand
  - Operational safety and security of supply
  - Availability of uranium and fissil material
  - Investment costs and building time
  - Age of reactors and refurbishment costs
  - Age of technical work force
  - Waste management
  - Proliferation

How to use models and scenarios?

- How would maps look like without *cartographers*? *Scientists* can play the role of cartographers for the exploration of the solution map.
- And would maps be of any use without *navigators*? *Policy makers* navigate through the maze of possible solutions in the solution map.

All models are wrong, but some are useful...

And so these men of Hindostan
Disputed loud and long,
Each of his own opinion
Exceeding stiff and strong,
Though each was partly in the right,
And all were in the wrong.

The Blind Men and the Elephant
John Godfrey Saxe

Phasing out carbon

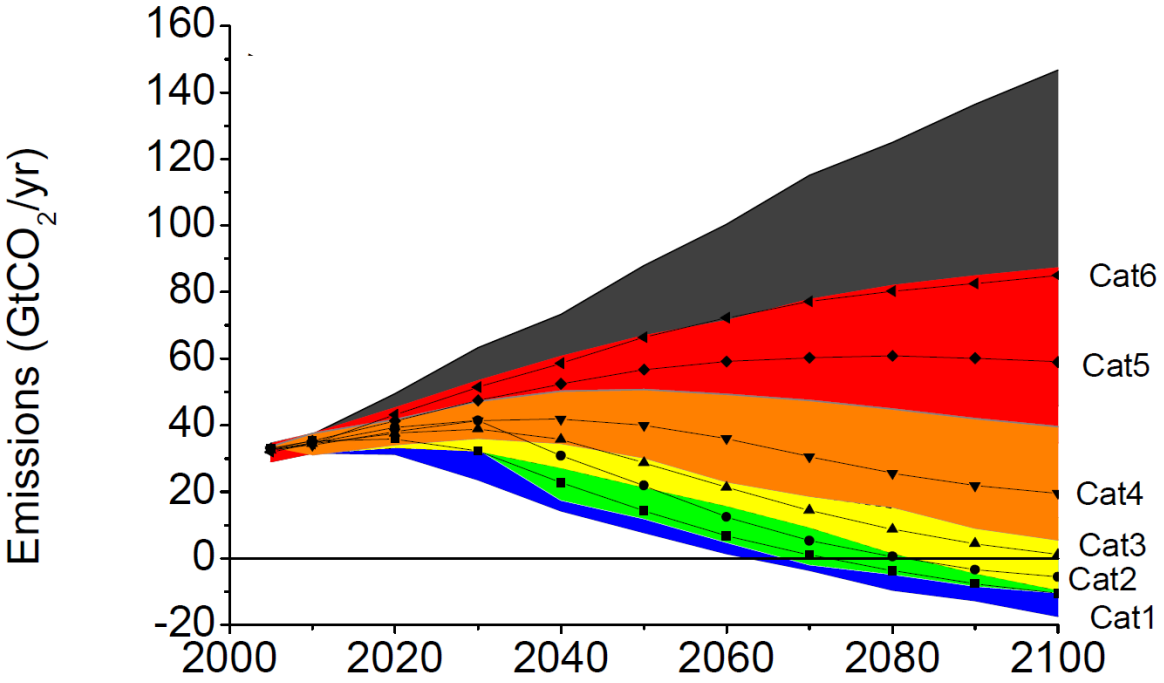
What is the scale of the carbon problem?

Restructuring supply or reducing demand?

What role does the electricity sector play?

Phasing out carbon

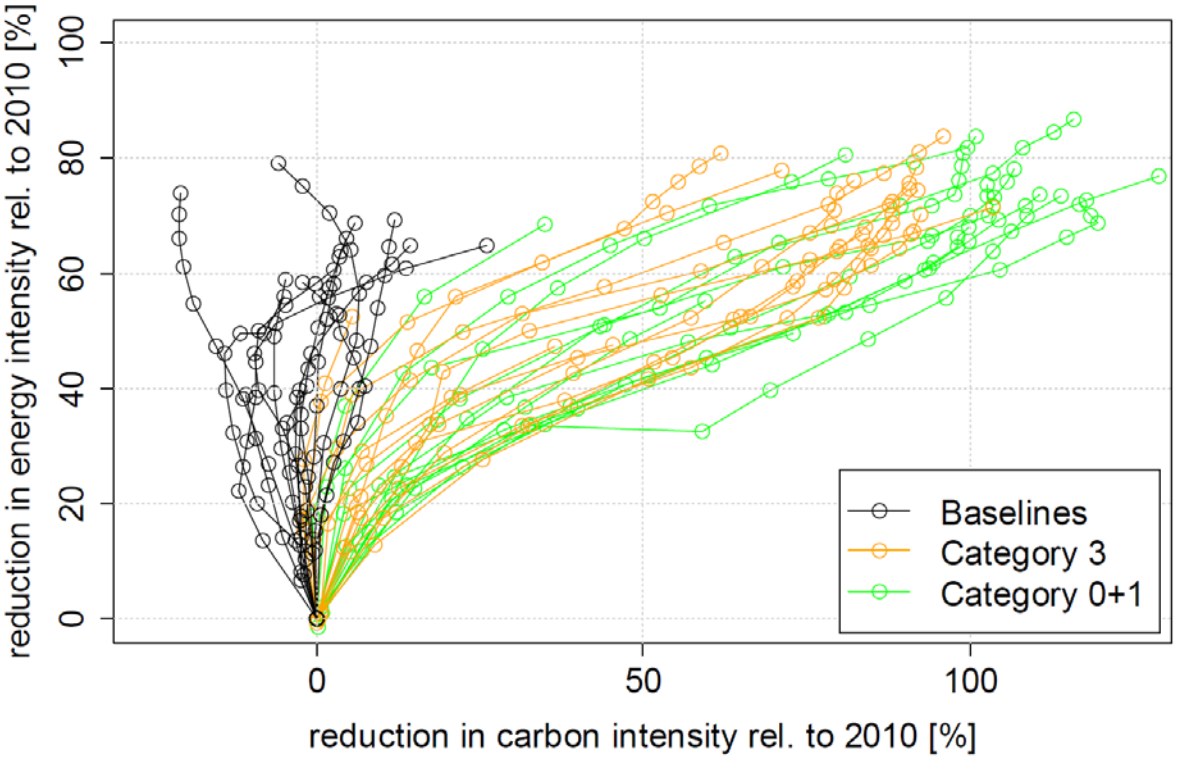
Global CO_2 emissions from fossil fuel & industry



- W/o climate policy dramatic increase
- 2°C target requires limitations of emissions
- Near-term emissions peak
- Long-term even negative emissions

Phasing out carbon
Restructuring supply or reducing demand?

Multi-model comparison for baseline and stabilization scenario



EI improves in baseline

With mitigation more EI improvements

CI even increases in baseline

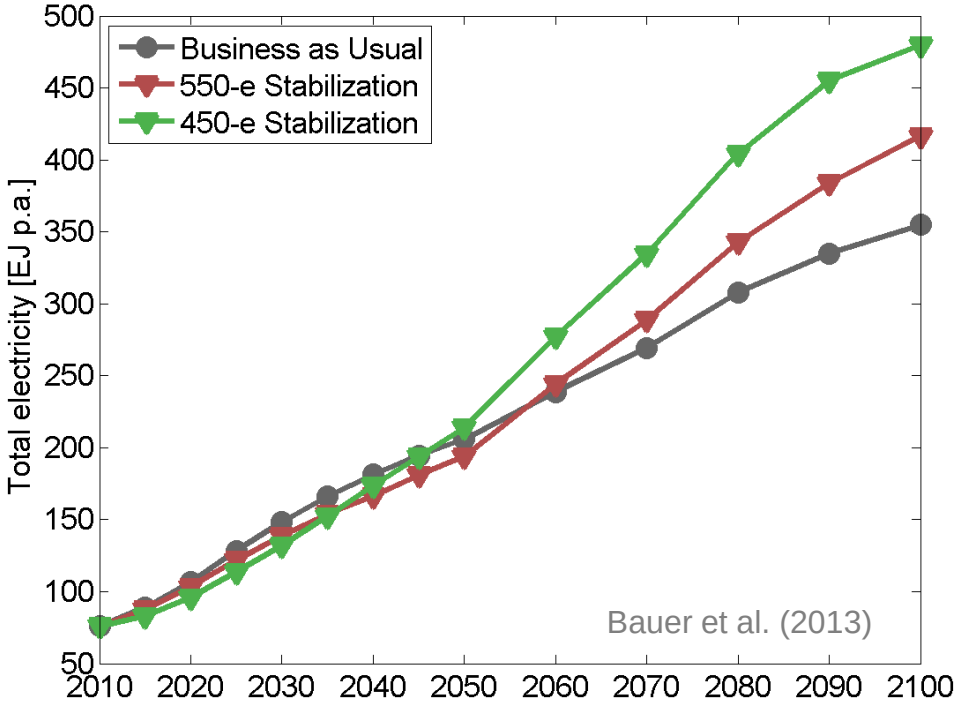
CI decreases strongly in mitigation scenarios

➔ Demand side improvements are important anyway

➔ Mitigation strategy must focus on supply side in the long-term!

Phasing out carbon
What role does the electricity sector play?

Global electricity for baseline and stabilization scenarios



Electricity grows strongest of all final energy carriers

Long-term growth even stronger in stabilization scenarios

If electricity generation is strongly decarbonized, then electricity can substitute other final energy carriers

➔ Electricity sector is key for future final energy supply

Phasing out uranium

What is the potential nuclear power production?

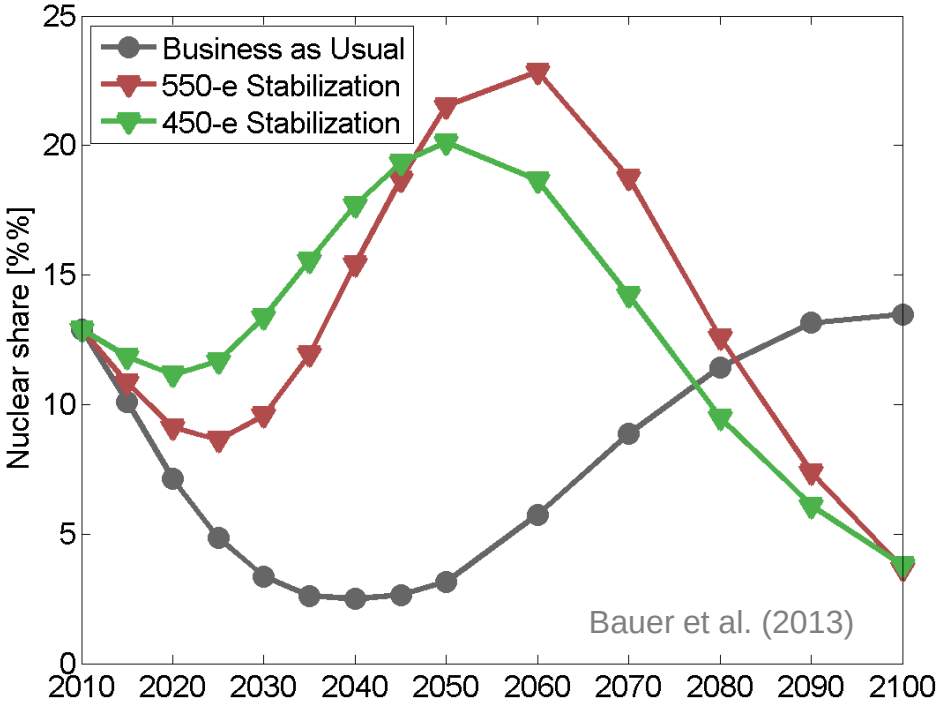
What is the emission mitigation potential?

What replaces nuclear when phased out?

What climate change stabilization costs without nuclear?

Phasing out uranium
What is the potential of nuclear power production?

Nuclear share for baseline and stabilization scenarios



Nuclear share in generation mix
- limited in all scenarios
- never >25%

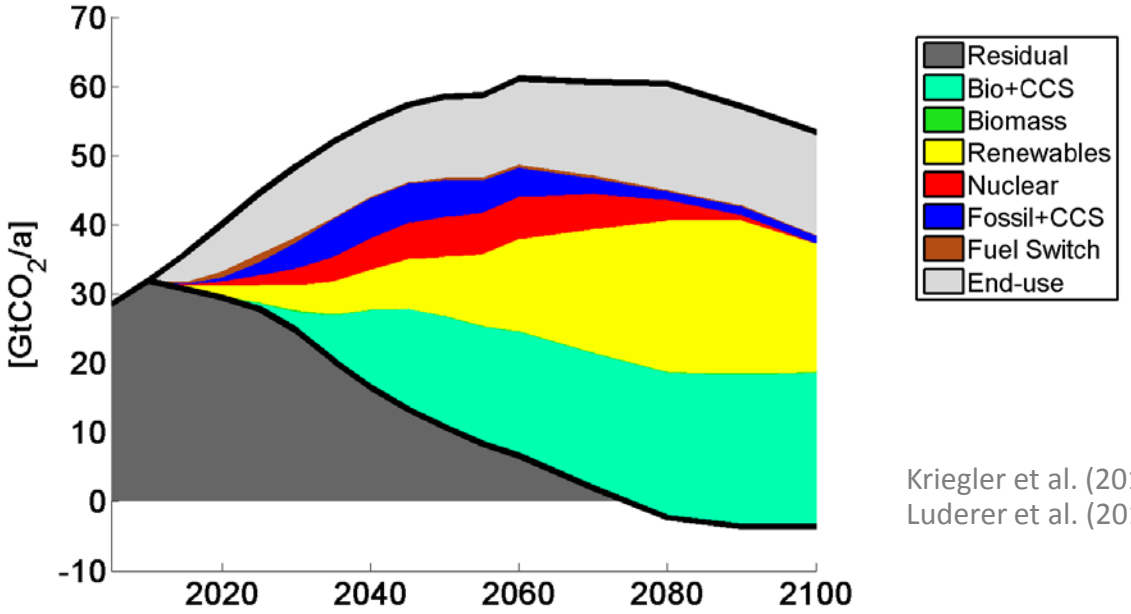
Climate policy makes nuclear deployment competitive earlier

Uranium availability constrains nuclear power generation

Max. 23Mt uranium

Additional nuclear is mainly determined by baseline level, not by policy constraint

Phasing out uranium
What is the emission mitigation potential?

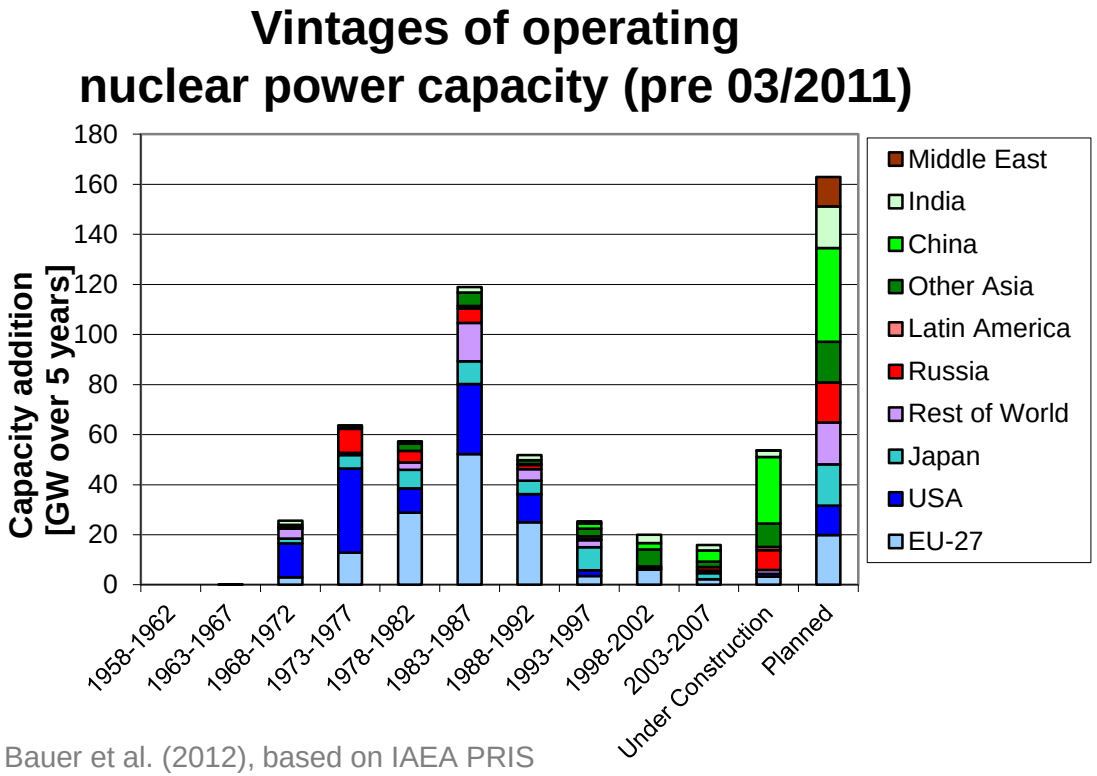


Kriegler et al. (2013a)
Luderer et al. (2012)

Mitigation potential of **nuclear** is relatively small

Higher economic growth requires
more **efficiency improvements** and **renewables**

Phasing out uranium
What replaces nuclear when phased out?



Bauer et al. (2012), based on IAEA PRIS

Most existing nuclear capacity is
- in OECD countries
- older than 20 years
- hardly any older than 45years

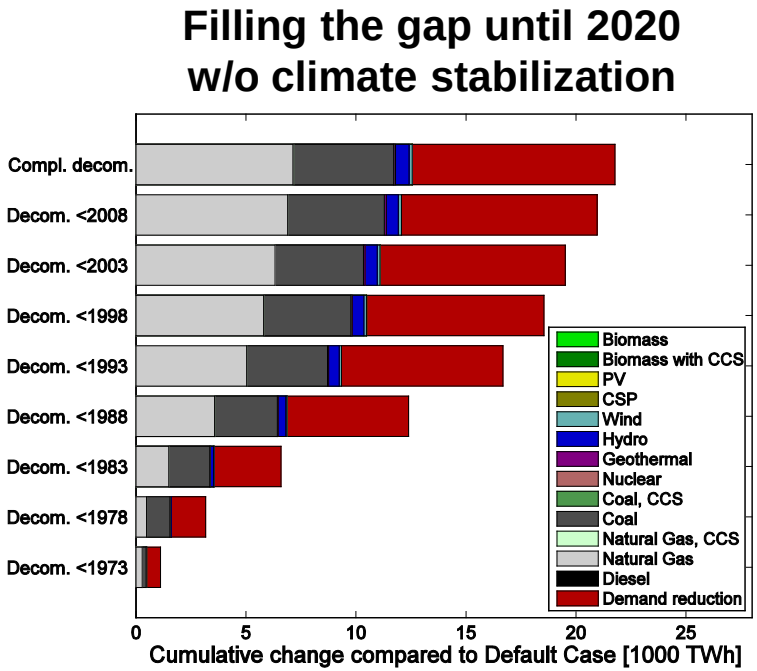
Life-time extensions needed

New capacities are under revision

Subject to approvals

What if these capacities are decommissioned because of policy choice or regulator‘s discretion?

Phasing out uranium
What replaces nuclear when phased out?



Bauer et al. (2012)

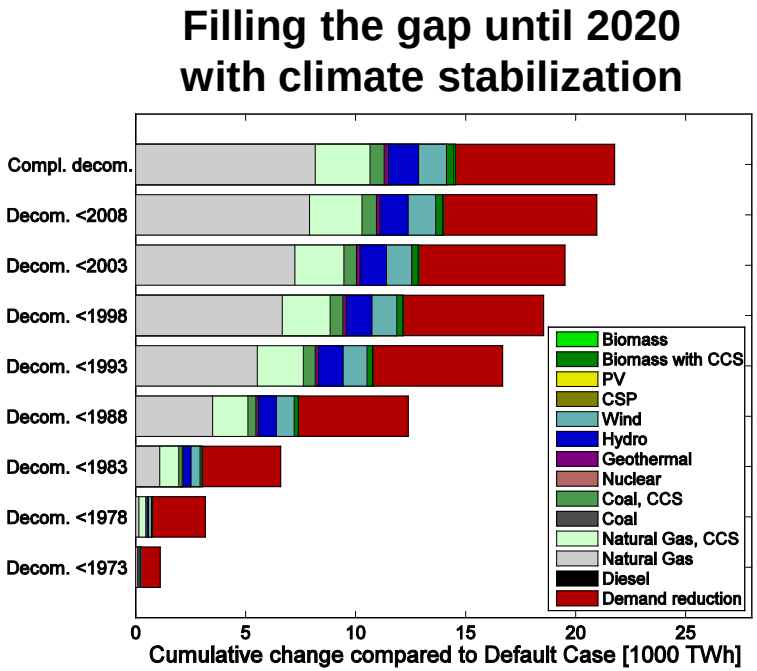
More **gas generation** and **demand reduction** are most important

Also **coal** is expanded

Renewables do not play big role

Max. additional emission : 1GtCO$_2$/yr in 2025

Phasing out uranium
What replaces nuclear when phased out?



Bauer et al. (2012)

Climate stabilization via inter-temporal carbon budget

Gas generation gets more important and **demand reduction** is slightly reduced

Some additional **coal with CCS**

Renewables play a minor role

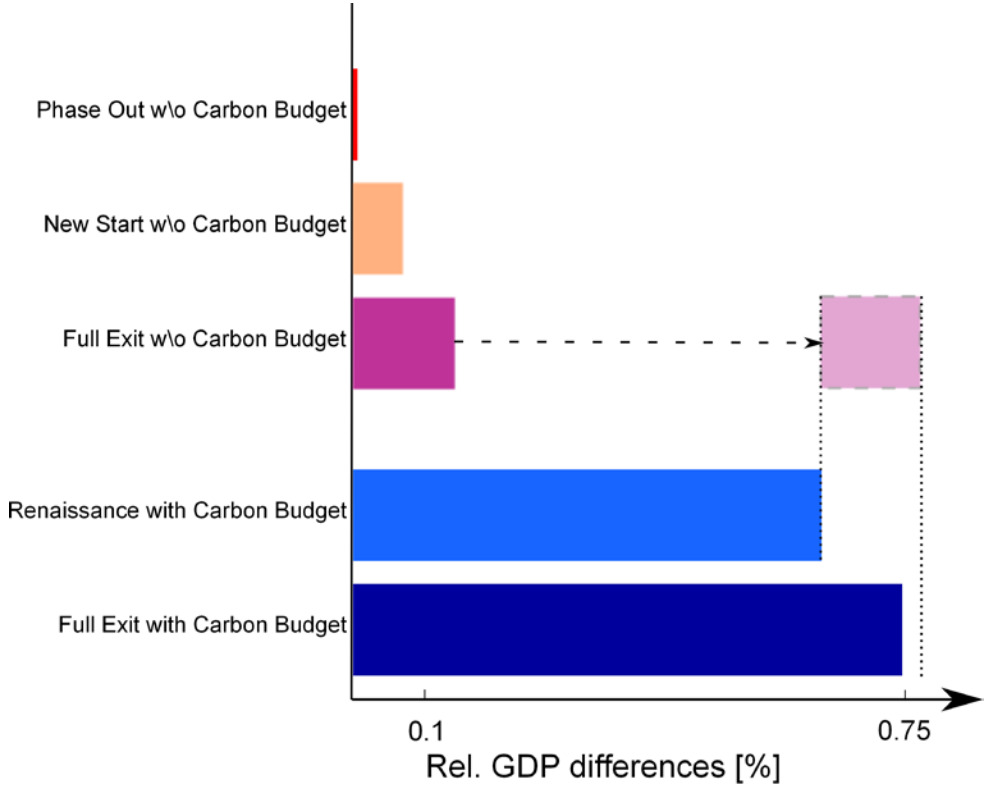
Max. additional emission : 0.3GtCO_2/yr in 2015

Carbon reallocation less than 1% of C-budget

Emission flexibility allows higher use of gas

Phasing out uranium
What climate change stabilization costs without nuclear?

Loss of NPV of GDP 2010-2020



Bauer et al. (2012)

Full nuclear exit comes with costs

With carbon budget additional costs are less, because

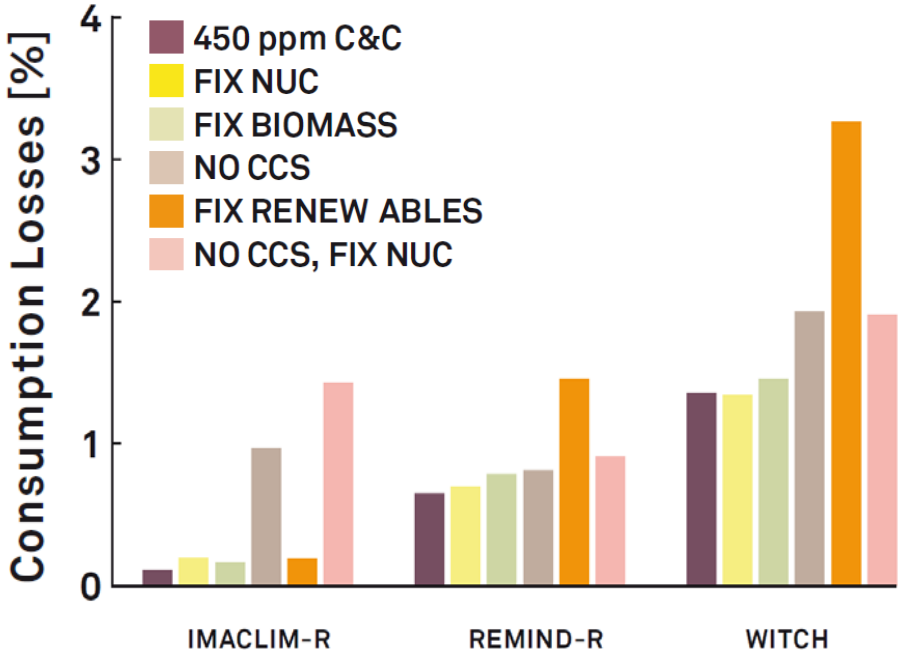
- lower gas prices
- no refurbishment costs

However, climate stabilization is a bigger challenge than the nuclear exit, be it partial or full

Climate stabilization affects all sectors

How robust is this result?

Phasing out uranium
What climate change stabilization costs without nuclear?



- 450ppm CO_2 stabilization costs are about 1% loss of consumption losses
- Not using the nuclear option increases the costs only little
- Other options like renewables and CCS are more important to contain mitigation costs

Edenhofer et al. (2009)

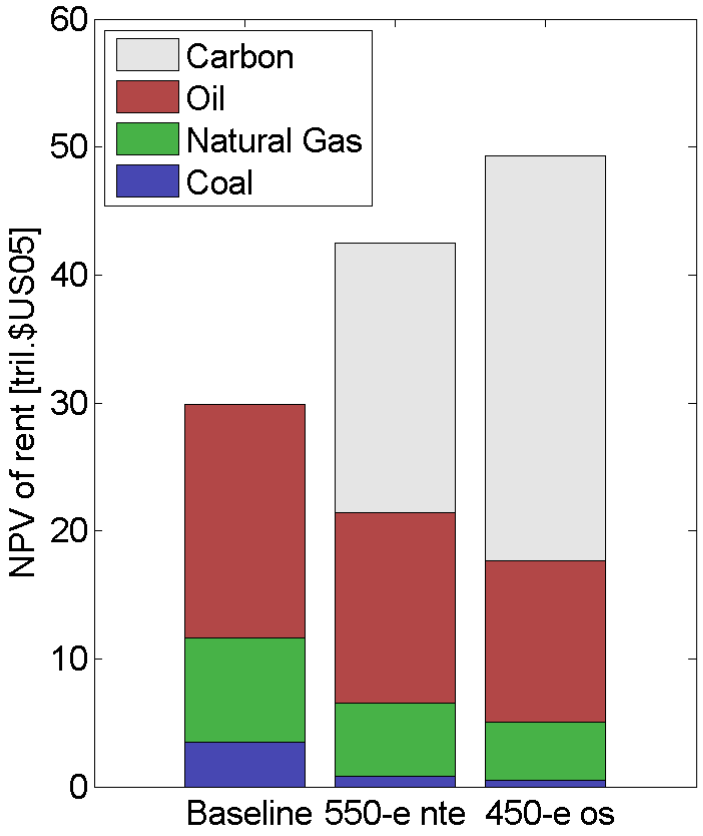
Climate and fossil fuel rent

Impact of climate policy on fossil fuel markets?

What impact on rents?

What are the CO_2 prices and the Social Cost of Carbon?

Climate rent and fossil fuel rent
Impact of climate policy on fossil fuel markets?



Bauer et al. (2013)

Coal rent is lowest, oil rent is highest

Fossil rents decrease with climate target

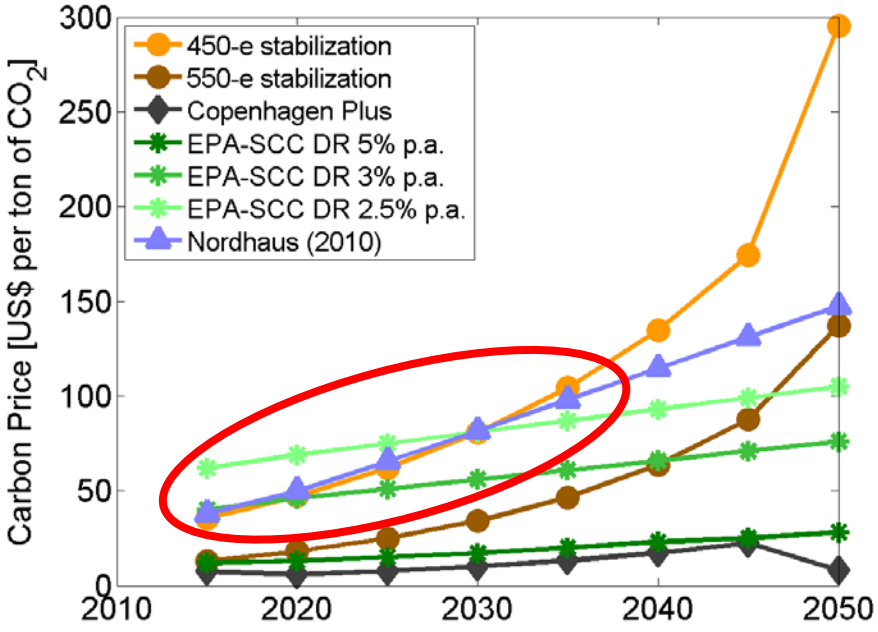
Coal
- rent vanishes nearly completely
- reserve remains partly underground

Oil
- rent reduced, but still significant
- consumption exceeds reserve
- only resources partly untouched

Over-compensation by carbon rent

However, carbon rent cannot compensate loss of GDP

Climate rent and fossil fuel rent
What are the CO_2 prices and Social Cost of Carbon?



Bauer et al. (2013)

Copenhagen Plus is the extension of the non-binding pledges (ReMIND result)

EPA computes social cost of carbon to justify regulation under Clean Air Act

Nordhaus computes carbon price from cost-benefit analysis

Main Results
Nordhaus and EPA start at relatively high levels, but increase only linearly

Stabilization prices start relatively low, but increase exponentially

If we agree on some consensus the **range narrows down** a lot

Conclusions

- Phasing out carbon is the much larger challenge than phasing out uranium
- **Economically** nuclear has only small **emission reduction** potential because...
- The electricity sector can be decarbonized in different ways, therefore it is relatively easy to phase out uranium
- Climate change stabilization requires decarbonization of the entire **energy** sector

III. How to make climate policy more compelling for decision makers?

The „old“ double dividend argument

The „new“ triple dividend argument

The traditional „Double Dividend“ Argument

- Impose a CO_2 tax, reduce labour and capital taxes
- Amend this policy with border adjustments
- Some studies (e.g. Fischer/Fox 2012) derive a net benefit of this policy
- The problem with this story:
  - Infrastructure investment as productivity enhancing investments are neglected
  - The challenge of tax competing governments is omitted
  - Increase in public debt is not feasible

The New Triple Dividend Story (I)

I. The current situation:

- Capital taxation is inefficent, labor taxation is socially infeasible and carbon leakage is a threat
- Infrastructure investment:
  social return is much larger than private return

Social under-investment in infrastructure?

Highway construction in the USA (Gramlich 1994):

- maintenance projects: **35%**
- new urban construction projects: **15%**
- rural construction projects: (low)

Return on ”ordinary“ investments in USA (1926-2000): **8.8 %**

Positive correlation between growth and infrastructure stocks (Calderon and Serven 2004):

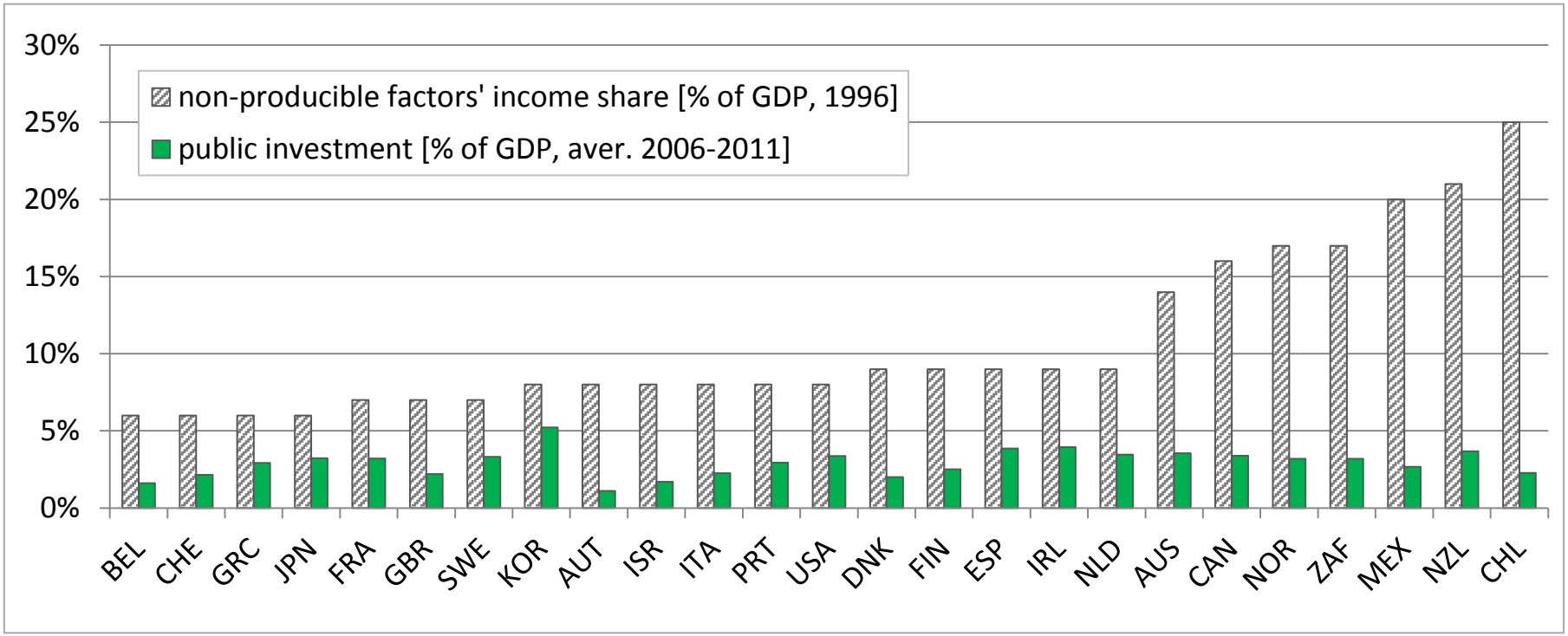
- 0.15 for phones,
- 0.13 for power generating capacity,
- 0.21 for road length

The New Triple Dividend Story (II)

II. The solution:

- Taxation of CO_2 is the most preferable option to finance infrastructure investment (even if there is no interest in climate policy)
- Because the high social returns on investment attracts private capital investments and
- Carbon leakage is tamed by capital mobility

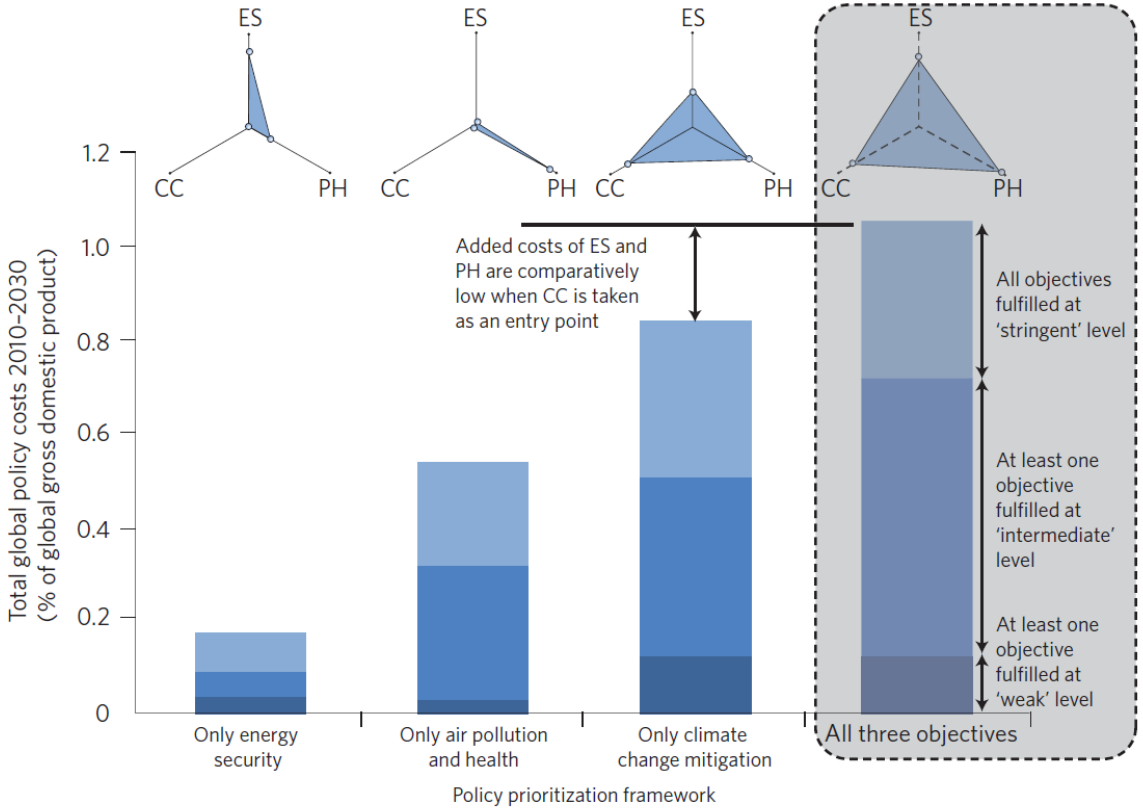
Magnitude of resource & land rents vs. public investment



Data sources: (1) Non-producible factors' income share: Caselli and Feyrer (2007); (2) Public investment: OECD (2013); ISO3 country codes.

➔ **Rent taxation has potential to finance public goods!**

The third element of the triple dividend



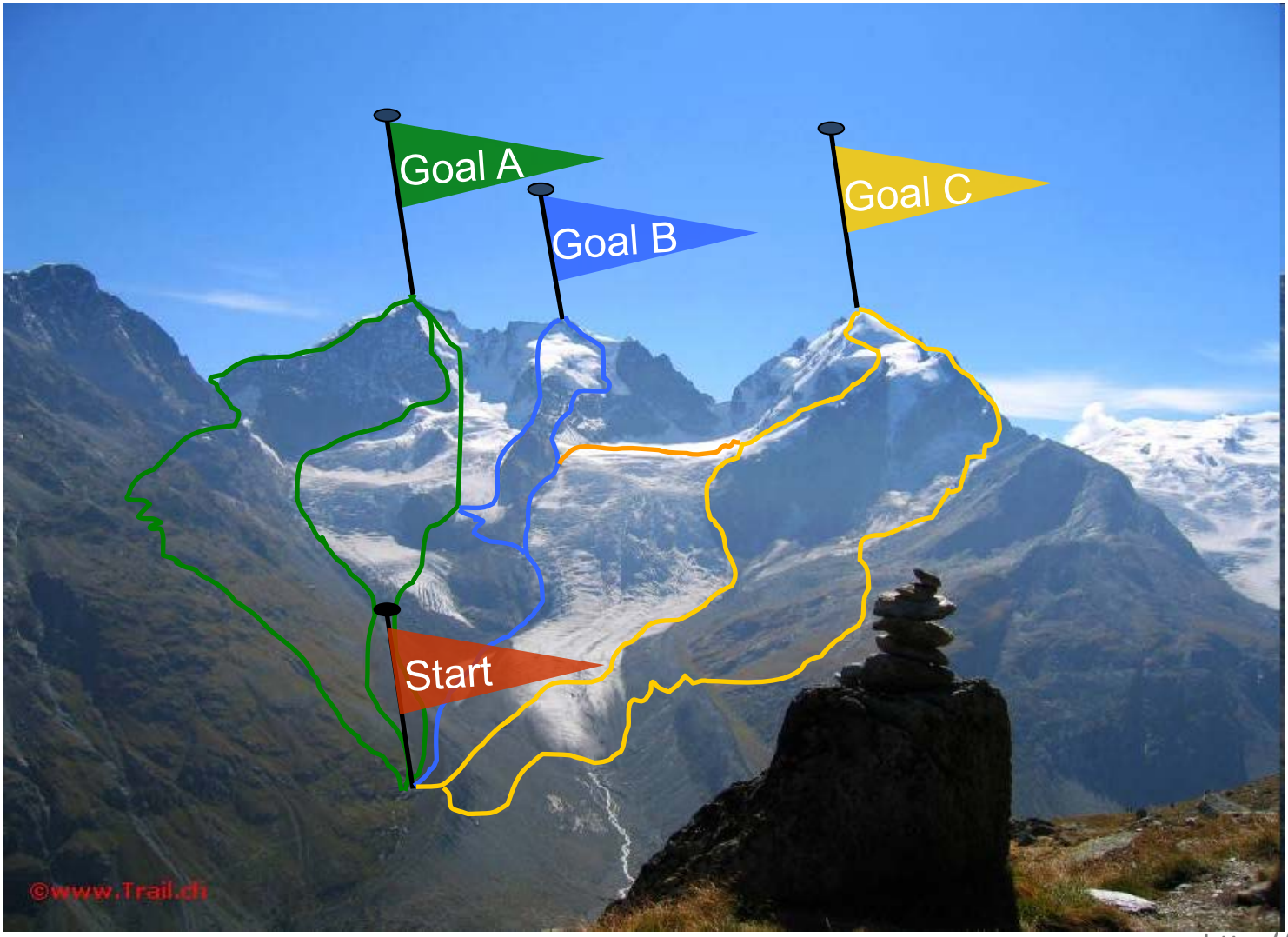
Degree of fulfilment of policy objectives	Climate change mitigation (CC) (probability of staying within 2 °C warming limit)	Air pollution and health (PH) (million disability-adjusted life years, 2030)	Energy security (ES) (total global imports as % of total primary energy supply, 2030)
Stringent	>50%	<15	<18%
Intermediate	20–50%	15–33	18–20%
Weak	<20%	>33	>20%

McCollum, et al. (2013)

Conclusions

- Tackling the climate challenge generates a large carbon rent
- It overcompensates the loss of fossil fuel rent
- Carbon rent is available for redistribution and/or investment
- Developing countries can finance infrastructure and other growth enhancing investments (e.g. education, health, …)
- Rent taxation is particular favourable in situation of tax competition
- Reducing CO_2 emissions has positive synergies with other issues as air pollution and energy security

There is always more than one way…



http://www.trail.ch

Back-Up Slides

Phasing out uranium
What is the potential of nuclear power production?

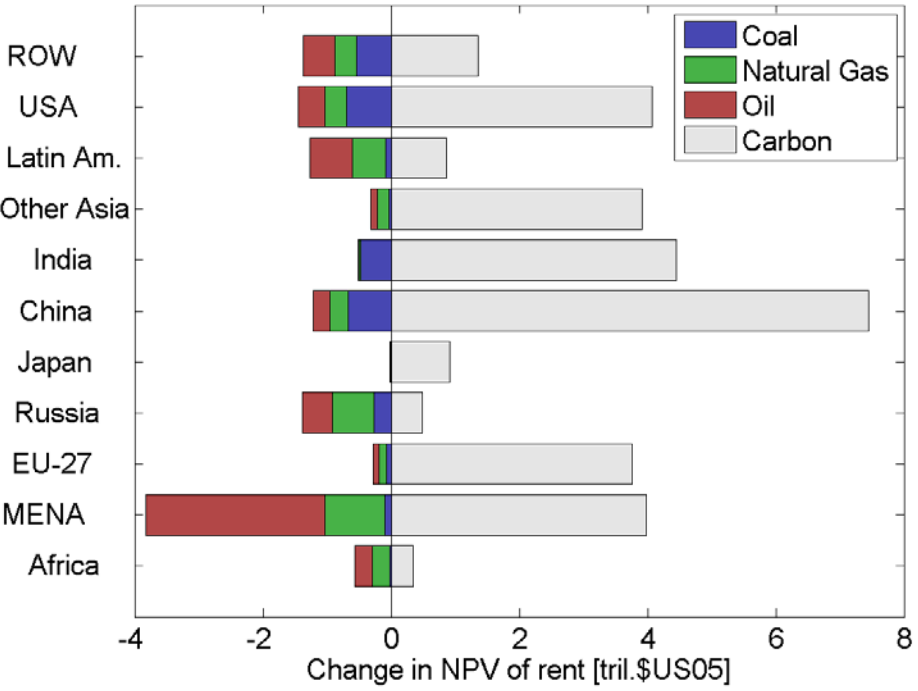
- Uranium is a scarce resource; higher extraction cost doesn‘t boost availability
- Breeding and reprocessing are subject to safety and proliferation
- Deposits with decreasing share (sea water) require more energy

Uranium availability in Mt

			BGR	NEA	WEC
Conventional resource	Identified resource	<80 $US per kg	2.5	3.7	
		<130 $US per kg		1.7	5.4
		<260 $US per kg	3.8	0.9	0.9
	Undiscovered resource	Prognostic	2.9	2.9	6.8
		Speculative	3.9	7.5	3.6
Unconventional resource				<22	10-22

BGR – Bundesanstalt für Geowissenschaften und Rohstoffe
NEA – Nuclear Energy Agency
WEC – World Energy Council

Climate rent and fossil fuel rent
Impact of climate policy on fossil fuel markets?



Bauer et al. (2013)

Assumption: unique global tax with domestic revenue recycling to achieve 450-e stabilization

In most regions carbon rent exceeds loss of fossil fuel rent

It includes MENA, but not Russian and Latin America

For large emitters (China, US, India, EU) the carbon rent is clearly dominant