



MultiMOD

Insight in global energy markets

Practical insights from a global multi-energy market & infrastructure model

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joint work with Daniel Huppmann (DIW) & others

CenSES



NTNU – Trondheim
Norwegian University of
Science and Technology

MODEL FEATURES

Approaches to energy modeling

Effects between energy system, wider economy & land use/nature aspects
incl. climate/environment

Effects between energy markets
& wider economy

“top-down”

IAM: Integrated
Assessment Models,
(e.g., GCAM)

CGE: Computable General
Equilibrium Models (with
energy/emissions focus),
e.g., MIT-EPPA, MSG

“bottom-up”

Energy System Models
(e.g., TIMES, PRIMES)

Sector models/partial-
equilibrium models, e.g.,
Ramona, Empire, Libemod

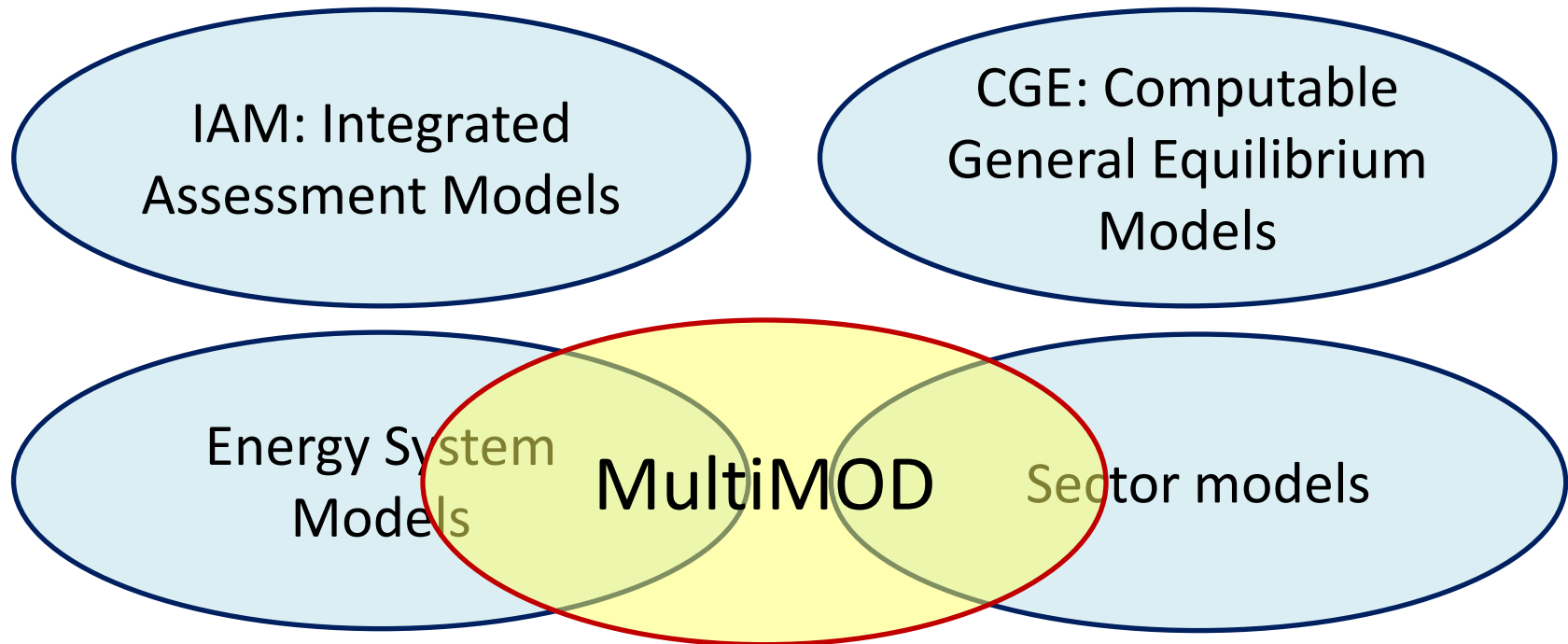
Analysis of fuel substitution and
different technology options

Analysis of market power
and operational/infrastructure
constraints

MultiMOD – Model features I

- Single model with all relevant energy market interactions in
 - energy supply
 - demand for *services*
 - infrastructure (development)
 - market power aspects
 - renewables integration
 - fuel substitution
 - climate policy
 - load & seasonal variations
 - *carbon leakage through goods trade*
 - *strategic and operational uncertainty*

MultiMOD – current version



MultiMOD – Model features II

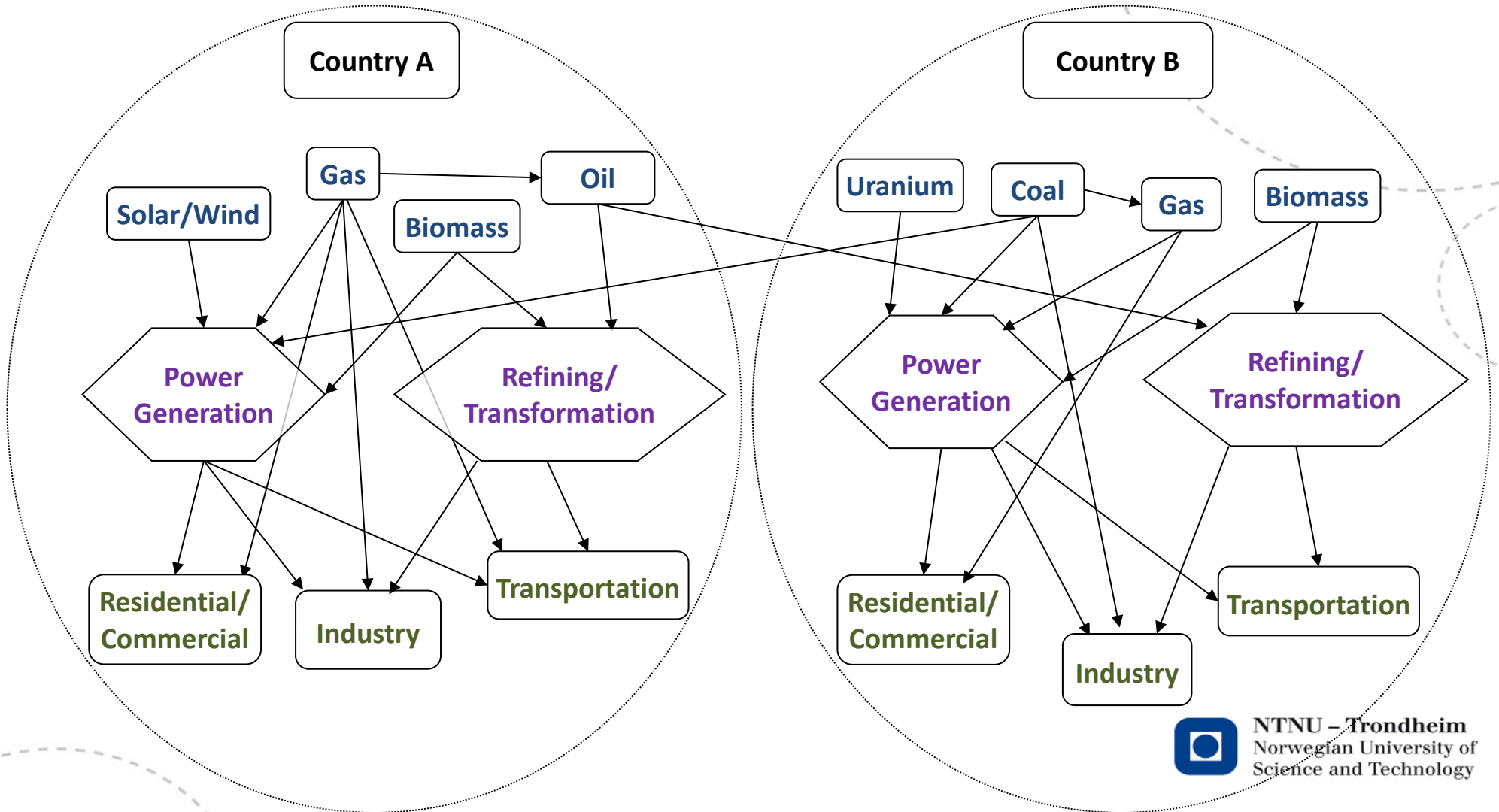
- Market power *across fuels*
 - Suppliers are aware of the impact of each fuel on the price
- Endogenous investment in infrastructure
 - Incl. implicit *learning*
- Fuel substitution/switching
 - in transformation and final demand sectors
- Technical constraints
 - fuel mix constraints in transformation and final demand, e.g., to reflect peak-load or installed equipment rigidity
- Policy/Regulatory constraints
 - governmental regulation (e.g., ETS, CO2 tax, biofuel mandate, portfolio emission standard)



Actors

- Suppliers of fuels
- Arc operators ("TSO"; pipeline, ship, rail, LNG, etc.)
- Transformation technology operators (electric power, refineries)
- Storage operators (gas storage, pump-hydro)
- Final demand (for services, by sector)
- Emission permit auctioneer

Trade & supply relations *illustration*



ILLUSTRATIONS

Data inputs

- Production, consumption, energy transport, transformation, storage
- Costs, reference prices, volumes, capacities, efficiencies, loss rates, prices
- No own forecasting, but *calibration* to reflect production & consumption in 2010 & forecasts IEA, EIA, EC, ...
- We add: country/infrastructure detail, market power assumptions, end-use & distribution cost
- Model use: what-if analysis

HIGH RENEWABLES AMBITIONS COMBINED WITH
PHASING OUT NUCLEAR

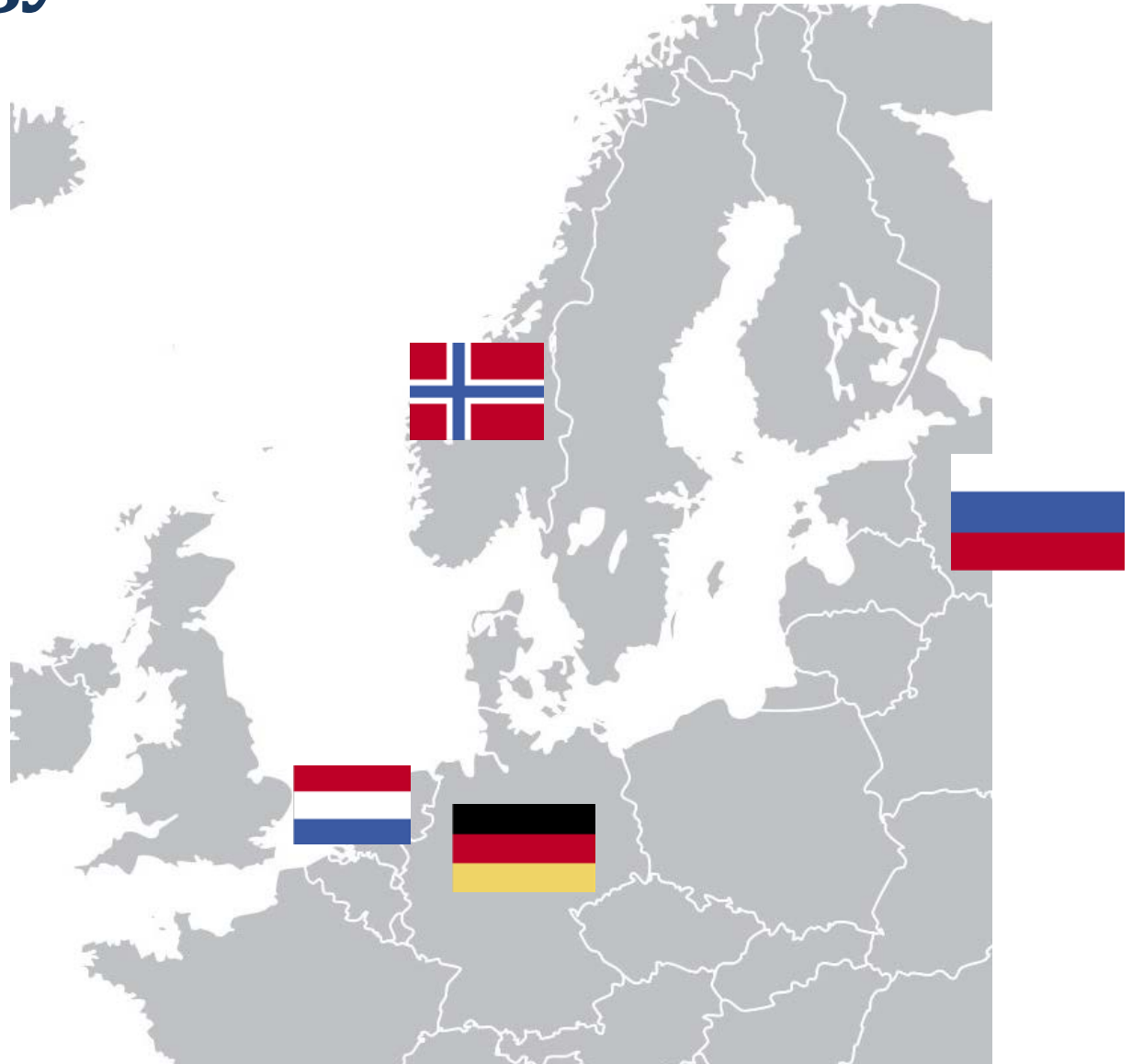
CASE 1. GERMAN ENERGIWENDE

German EnergieWende

- Current *business as usual* perspective for Germany
- Static 2010
- Phasing out nuclear power
- Full speed ahead with renewable energy
- Recently, NordStream, a major gas pipeline from Russia, has been constructed.
- What is impact on German energy market?
- Can Norway be a "Green Battery"?

German Energy context

- Main European energy suppliers



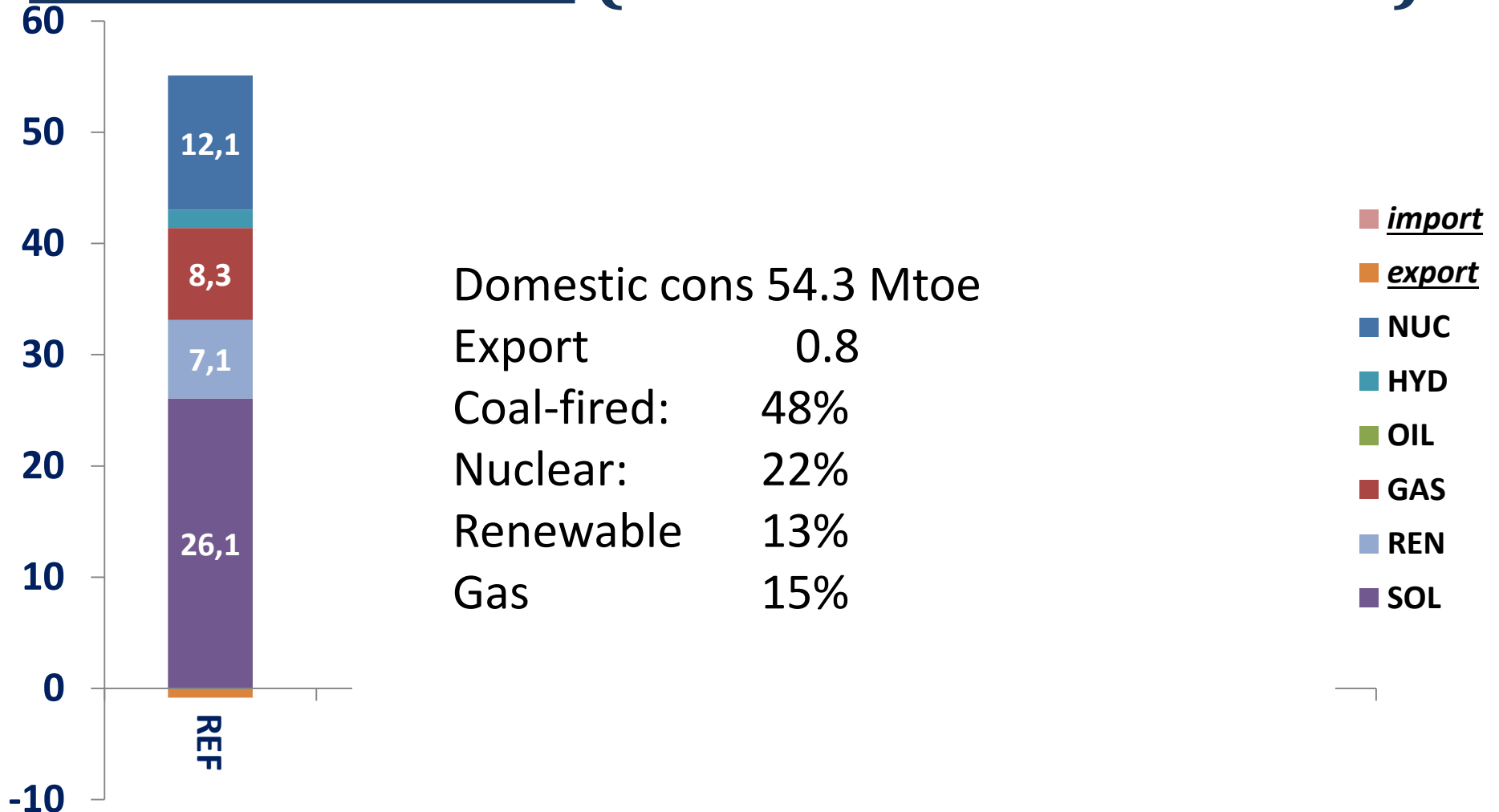
Germany - Shocks

- Nuclear phase out
- Renewables plus 50%
- Nord Stream I
- Green battery Norway?

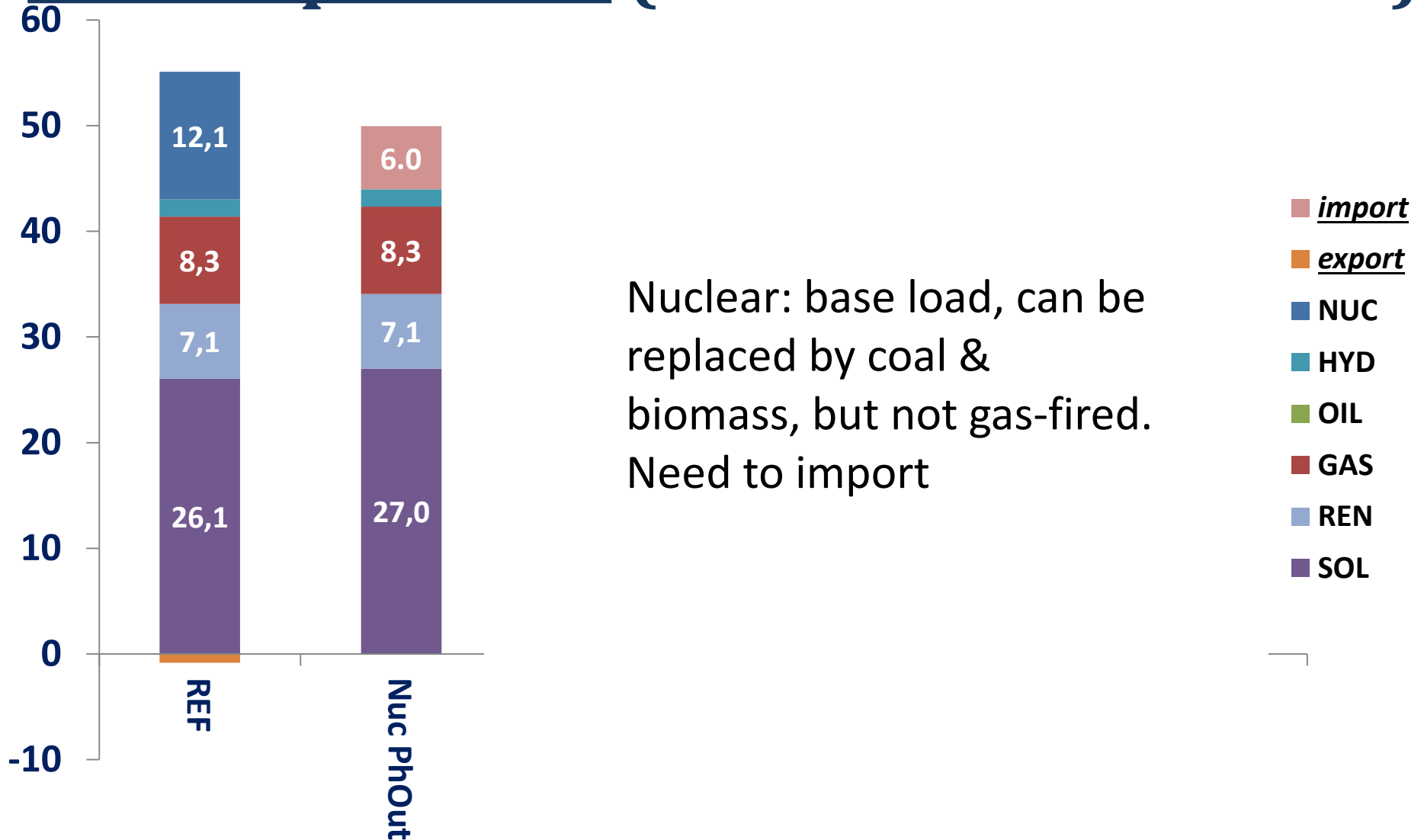


German supply mix in power generation

Base Case 2010 (Mtoe after conversion)

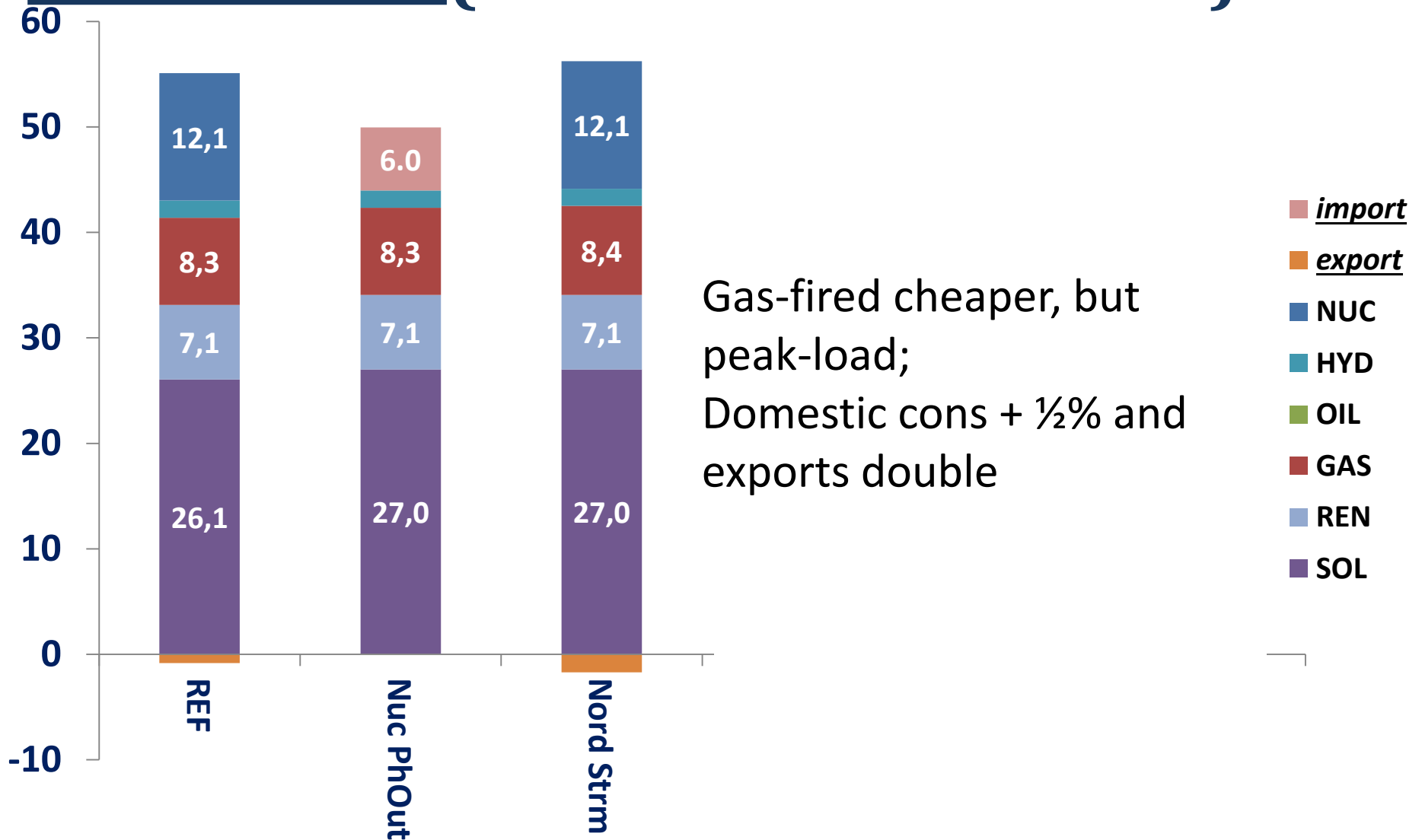


German supply mix power generation nuclear phaseout (mtoe after conversion)



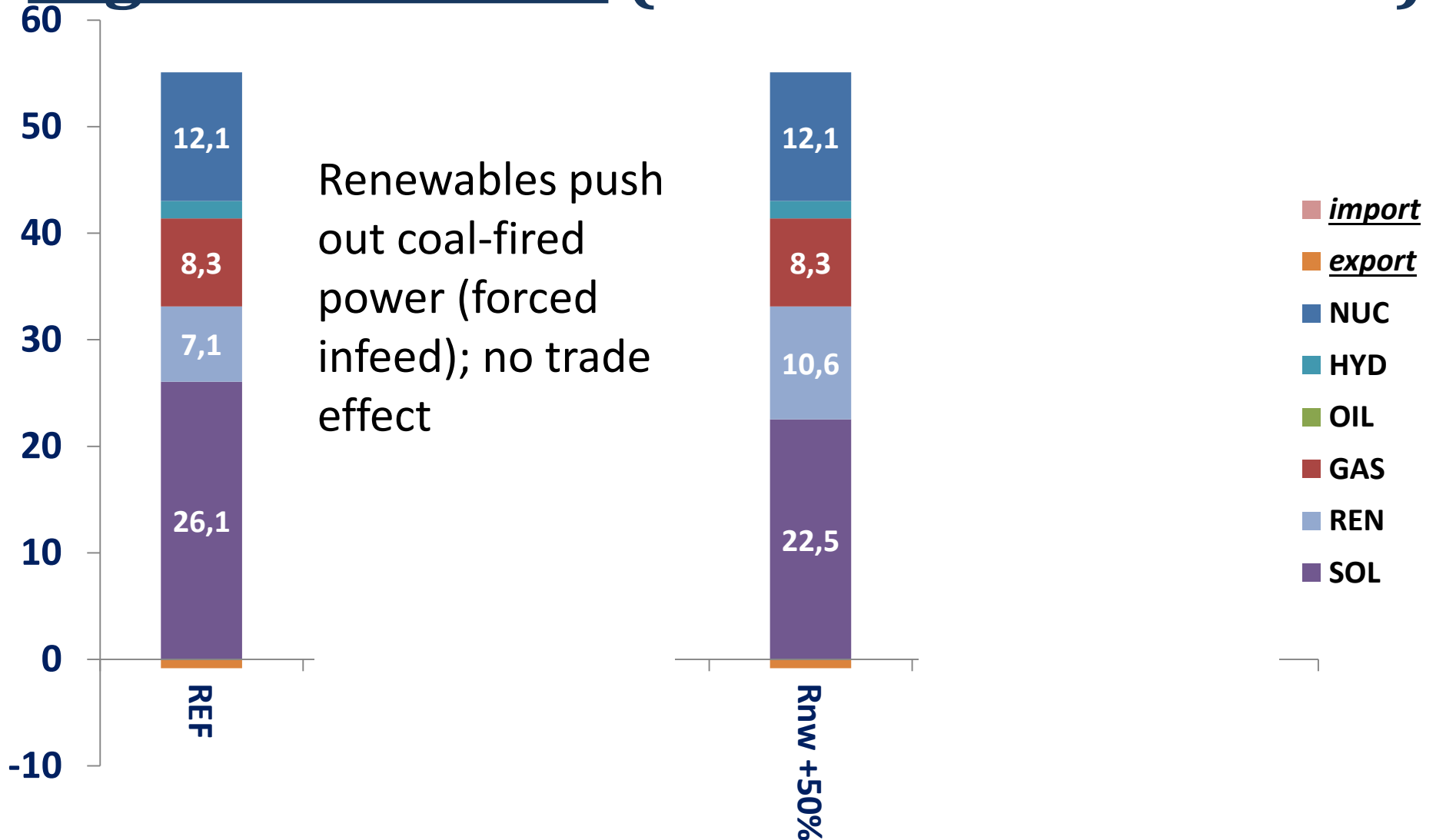
German supply mix in power generation

Nordstream (mtoe after conversion)



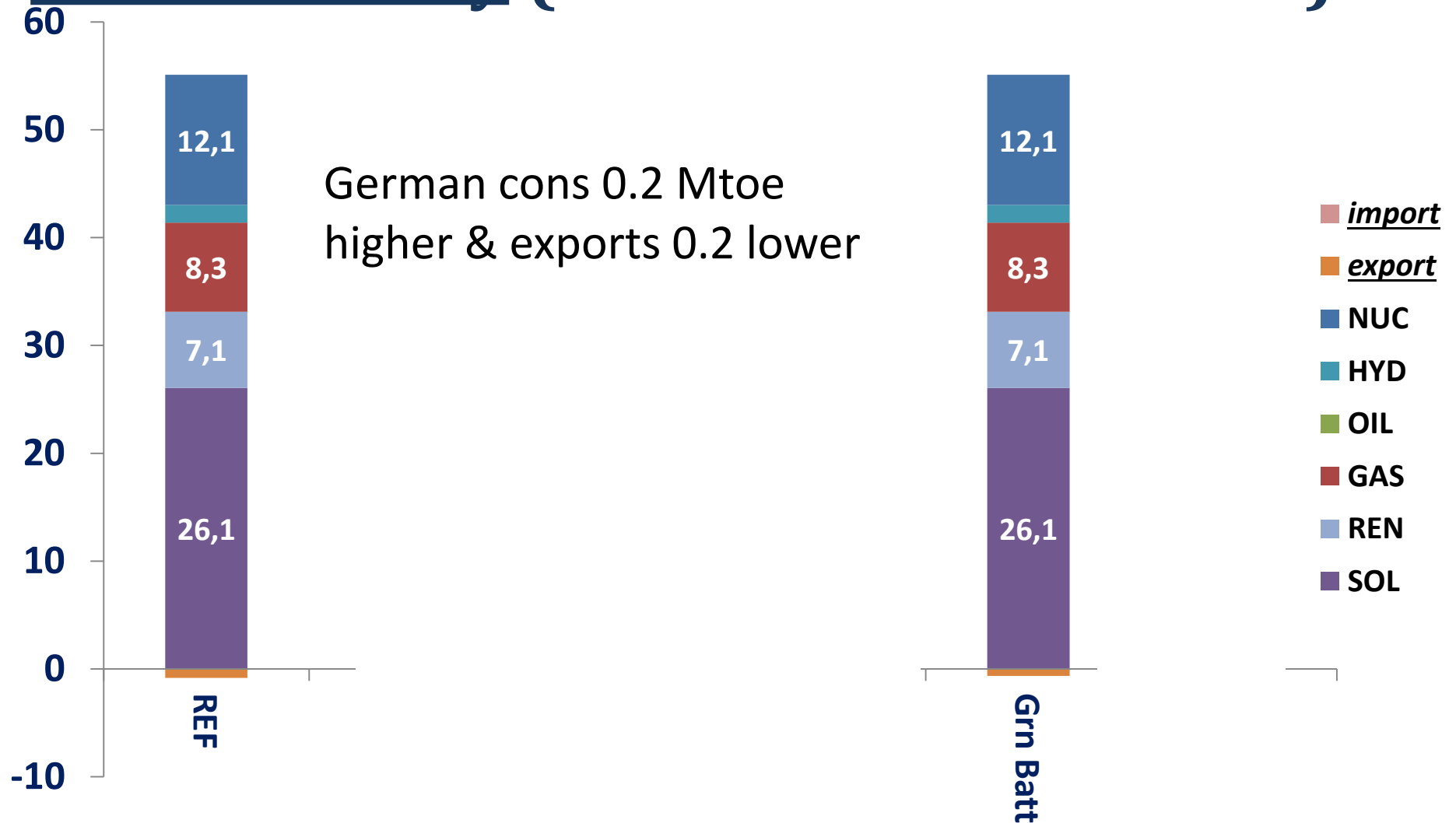
German supply mix in power generation

High Renewables (mtoe after conversion)



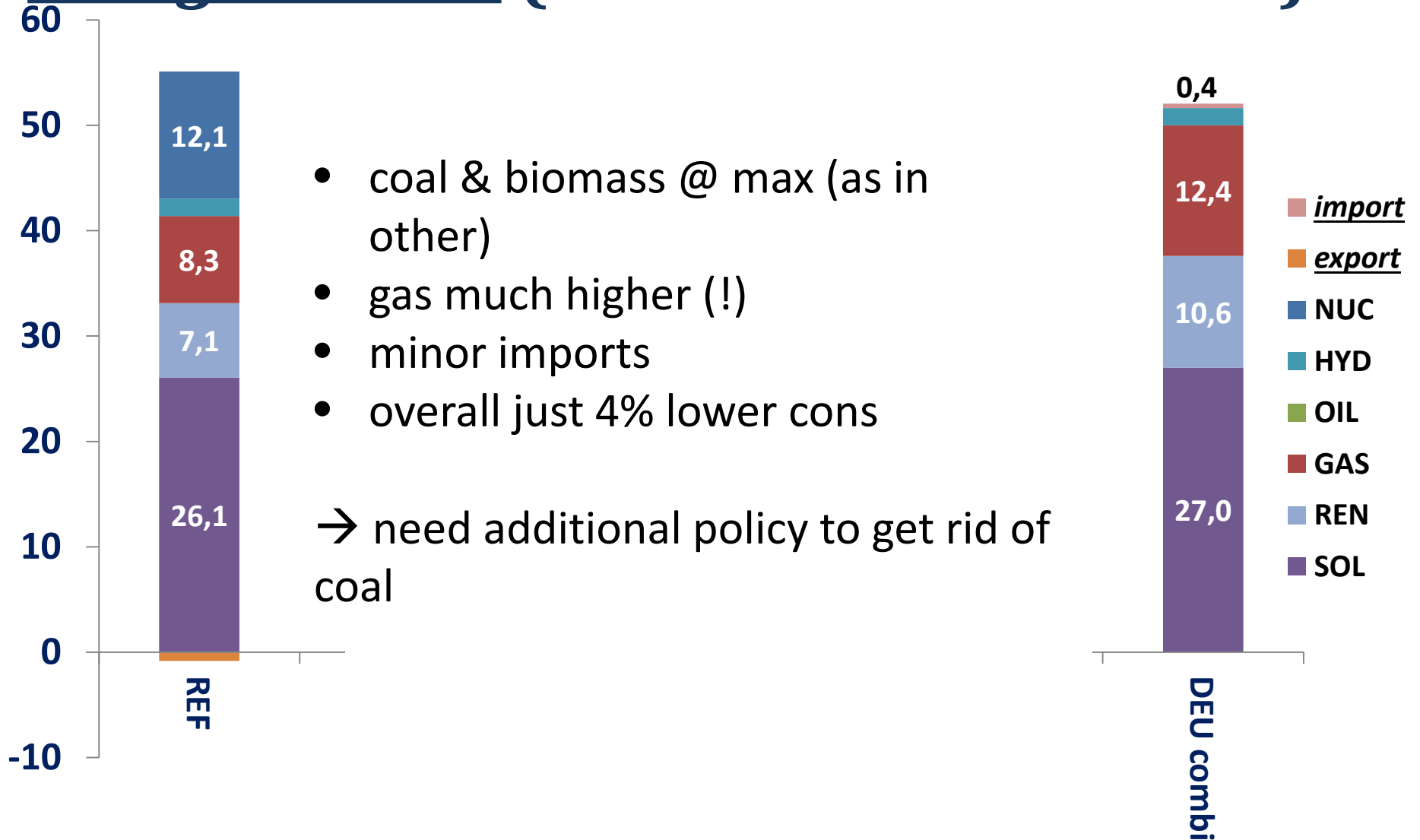
German supply mix in power generation

Green Battery (mtoe after conversion)



German supply mix in power generation

EnergieWende (mtoe after conversion)



Norway Green Battery..?

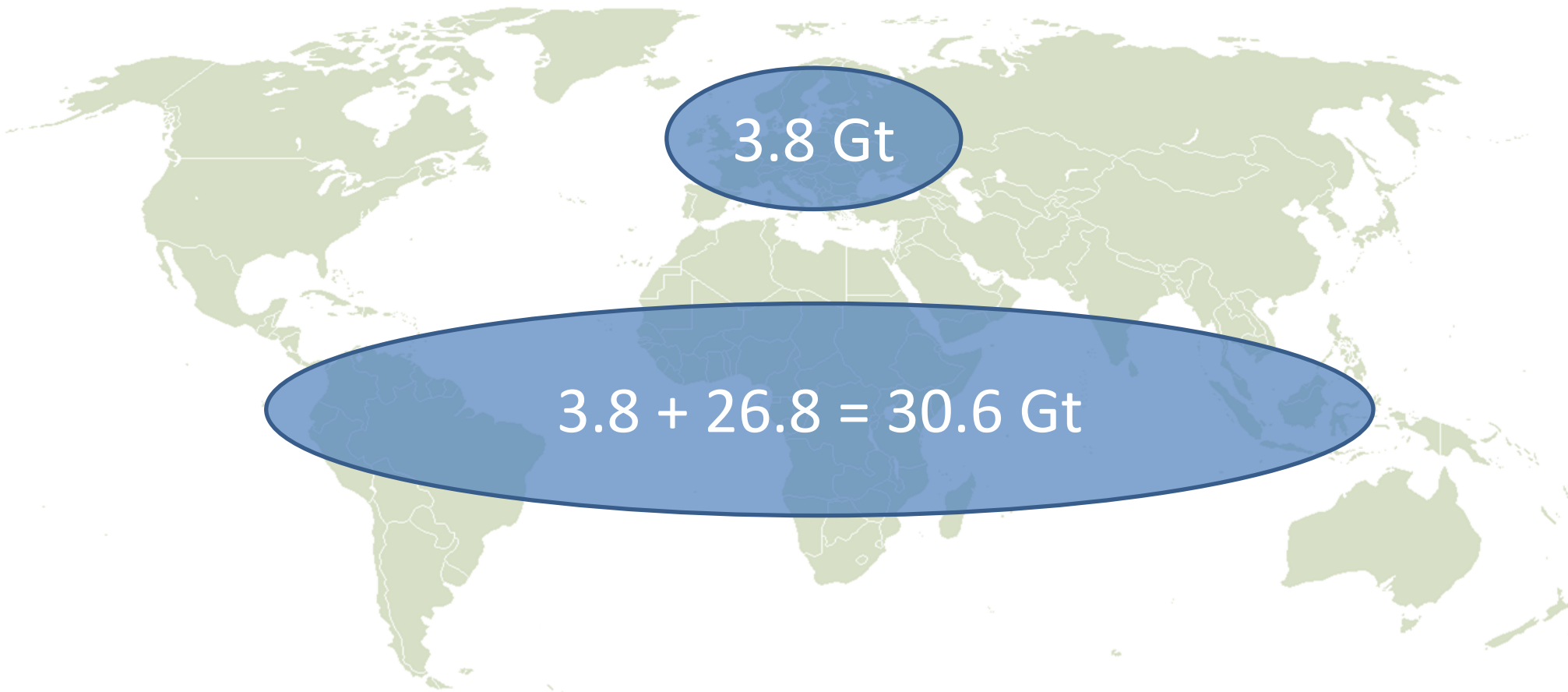
- Germany exported electricity in 2010
- In case studies Norway export only moderate amounts to Germany
- But, static model without seasonality / intermittency or transmission capacity expansion...

CO2 TAX EU-ETS

Regional CO2 tax: Carbon Leakage?

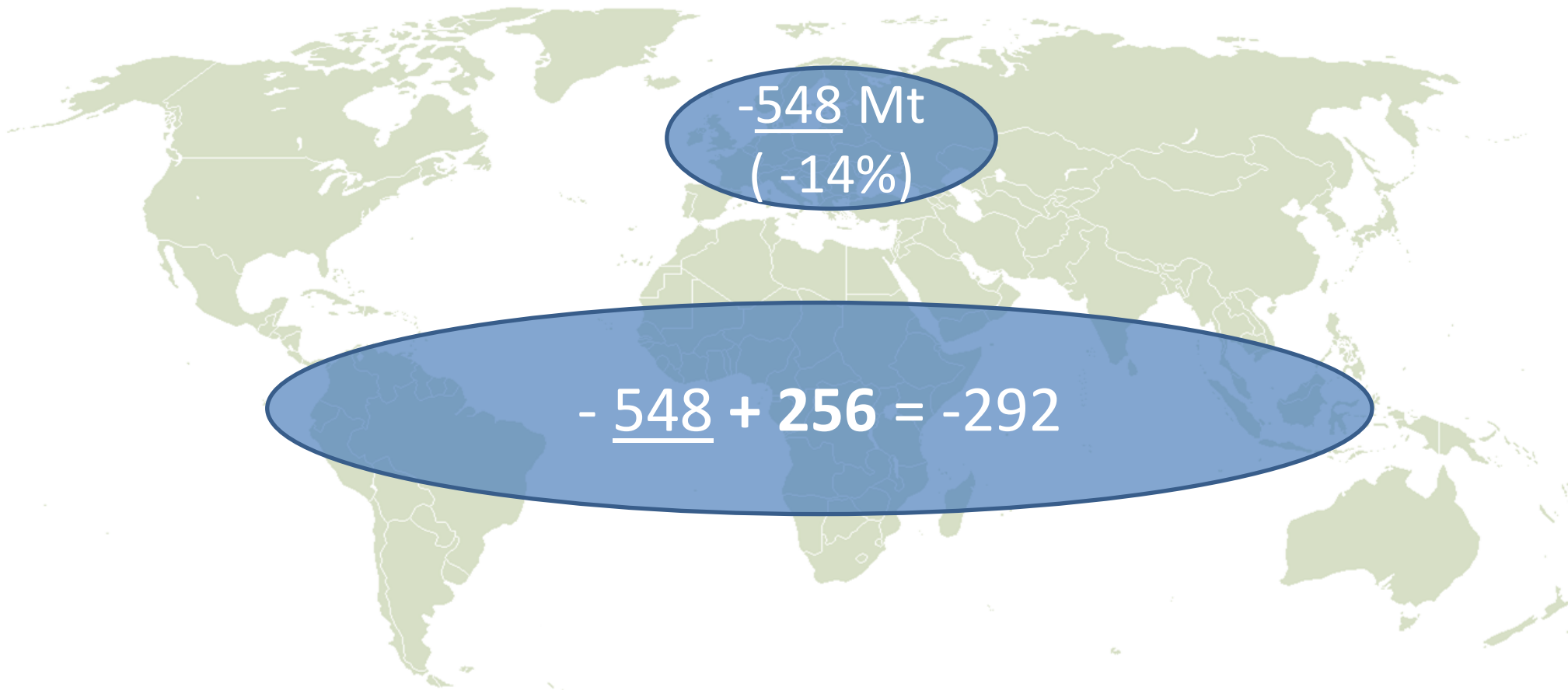
- What if Europe imposes a tax on CO2 emissions, and other regions don't?
- Reduction in Europe partly undone due imports: carbon leakage
- Should consider energy use for goods production..
- Effects in energy-only model?

CO₂ emissions ref 2010 (tax \$20/ton)



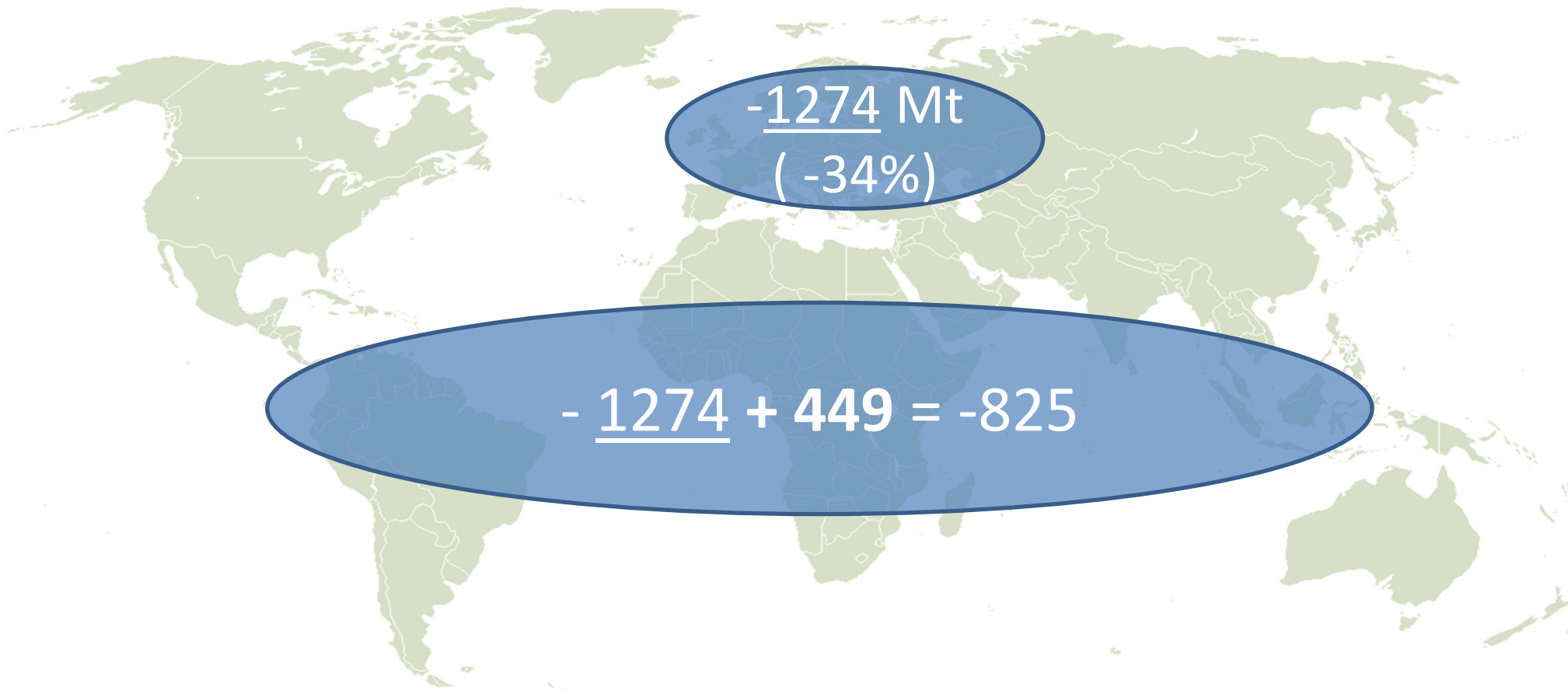
Giga ton = 10^3 bln kg

ETS CO₂ tax \$60/ton



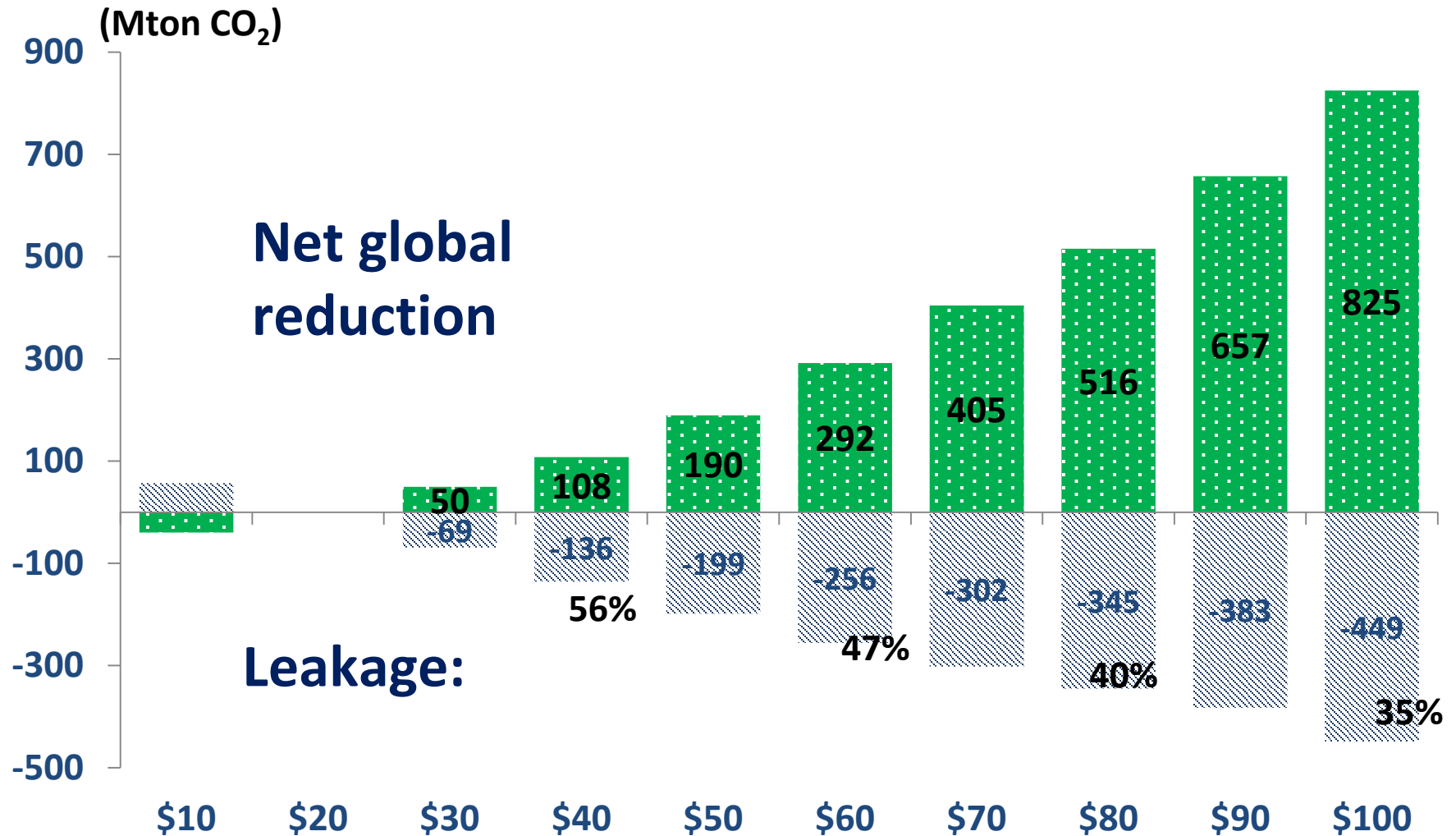
Carbon leakage: 47%

ETS CO₂ tax \$100/ton



Carbon Leakage: 35%

CO₂-emission reductions & leakage various ETS tax levels

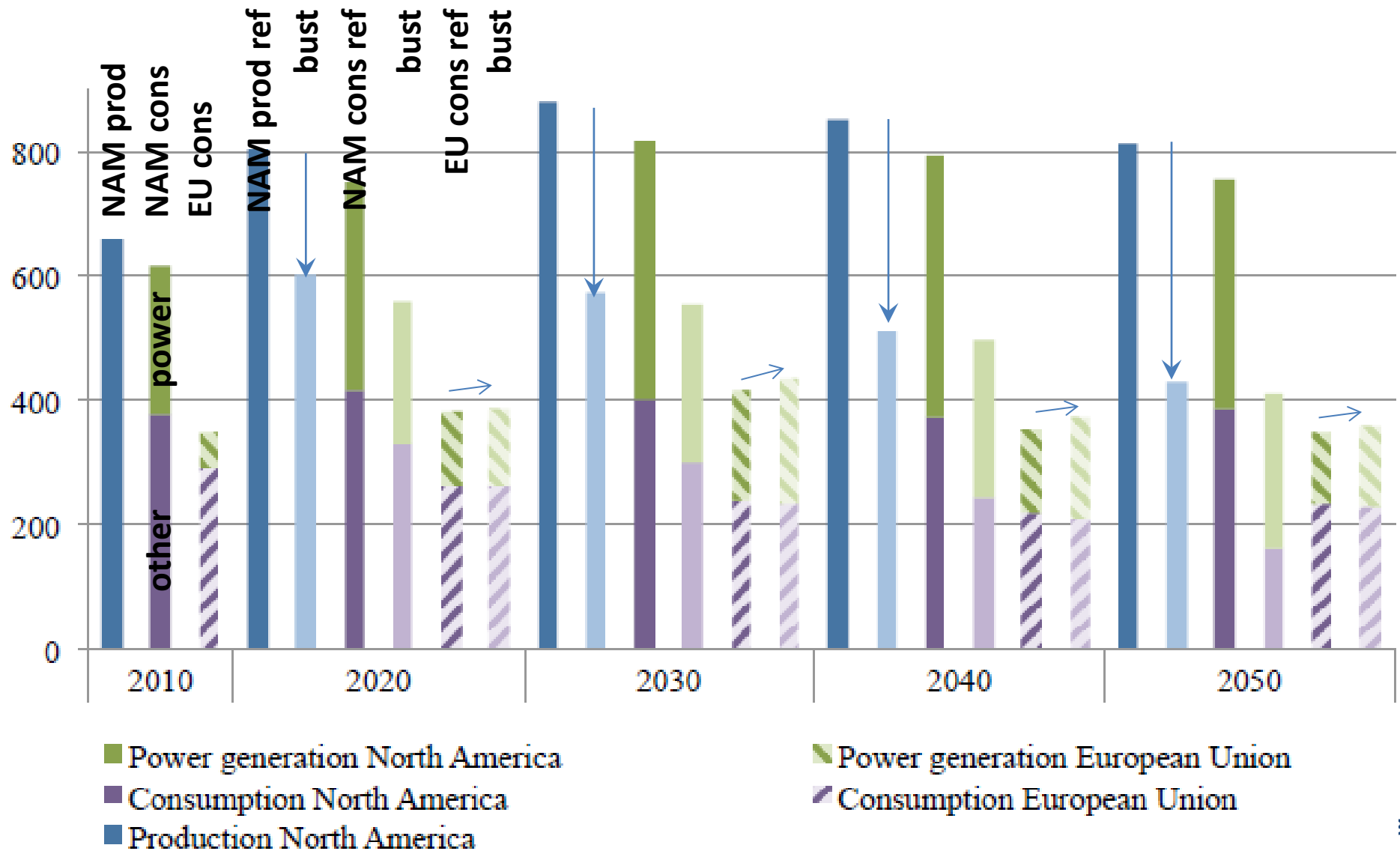


CASE 3. SHALE GAS BUST

Case details

- Current *business as usual* perspective: shale gas boom
- Environmental concerns (*bekymringer*), overly optimistic extrapolations of produced volumes and disappointing returns on investment...?
- rather than continued gas production growth, a reduction in projected US natural gas supply: steady decrease until 2050
- How will decreased shale gas affect US self-sufficiency and international (L)NG trade?

Shale disappointment - Gas production & consumption North America & EU (mtoe)

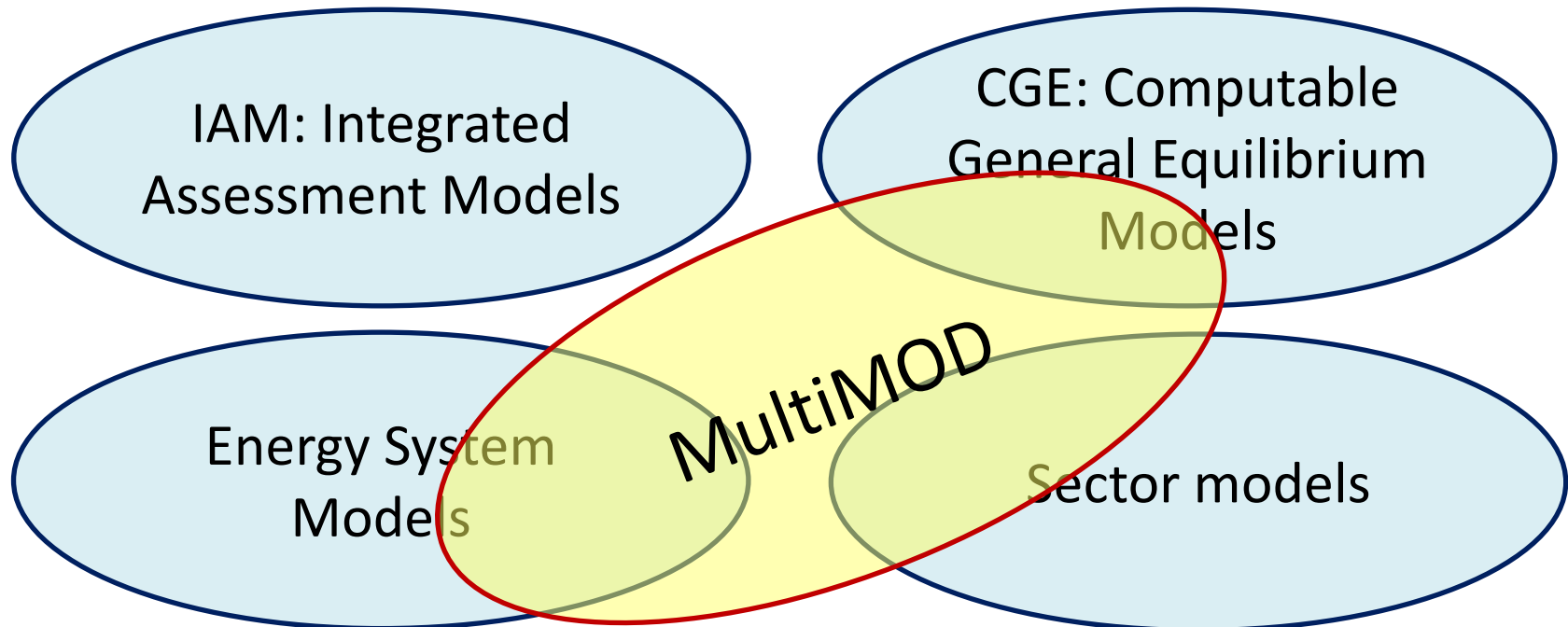


RELATED AND FUTURE WORK

(Related) work in progress

- Investment in demand side (efficiency)
- Chinese coal policies (Tsinghua, Beijing)
- Uncertainty & multi-horizon scenario trees (Z. Su, NTNU)
- CO₂ leakage - representing energy-intensive goods (DIW)
- Hybrid model - H2020 call May 2015 (international partners)
- Investment risk related to shale gas in Europe (Master's)
- Decomposition for large-scale models (funding requested)

MultiMOD - work in progress



Highlights

- Global perspective on energy markets and infrastructure allows for integrated analysis
- large-scale model for policy analysis with endogenous fuel substitution, infrastructure detail, strategic behavior
- supplier market power across fuels
- strategic: endogenous investment in upstream & mid-stream infrastructure
- operational: load variation, seasonality & storage
- Huppmann & Egging, 2014, Market Power, Fuel Substitution and Infrastructure: A Large-Scale Equilibrium Model of Global Energy Markets. Energy 75 pp. 483-500



MultiMod

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Credits

- Green-blue globe:
 - <http://www.wpclipart.com/terms.html>
- World map:
 - http://commons.wikimedia.org/wiki/Category:Maps_of_the_world