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# $CO_2$ mitigation options from energy production and use in GAINS

# Objective and methodology

Identify and quantify factors that lead to objective differences in mitigation potentials and costs

Bottom-up approach:

- detailed technical level,
- all major stationary energy consumers included,
- starts from baseline macroeconomic and energy projections (IEA or national),
- determines technical, economic and market potentials,
- optimization in GAINS allows ranking of options according to cost efficiency.

# The GAINS optimization in brief

Objective function: Minimization of total GHG emission control costs *C* for structural changes in the energy sector *(y) and* add-on measures *(x)*

$$C = \sum_{i,k} \left( \sum_{m} c^{x}_{i,k,m} \cdot x_{i,k,m} + \sum_{k'} c^{y}_{i,k,k'} y_{i,k,k'} \right)$$

Application levels *(x)* and structural changes *(y)* are constrained:

$$x_{i,k,m} \leq appl^{\max}_{i,k,m} x_{i,k} \qquad y^{\min}_{i,k,k'} \leq y_{i,k,k'} \leq y^{\max}_{i,k,k'}$$

Emissions are calculated from activity levels and emission factors:

$$E_{i,p} = \sum_{k} \sum_{m} ef_{i,k,m,p} \cdot x_{i,k,m}$$

Activity levels plus structural measures must satisfy demand:

$$x_{i,k} + \sum_{k'} y_{i,k,k'} - \sum_{k'} \eta_{i,k,'k} \cdot y_{i,k,'k} = x^{CLE}_{i,k}$$

# Power generation and other energy industry

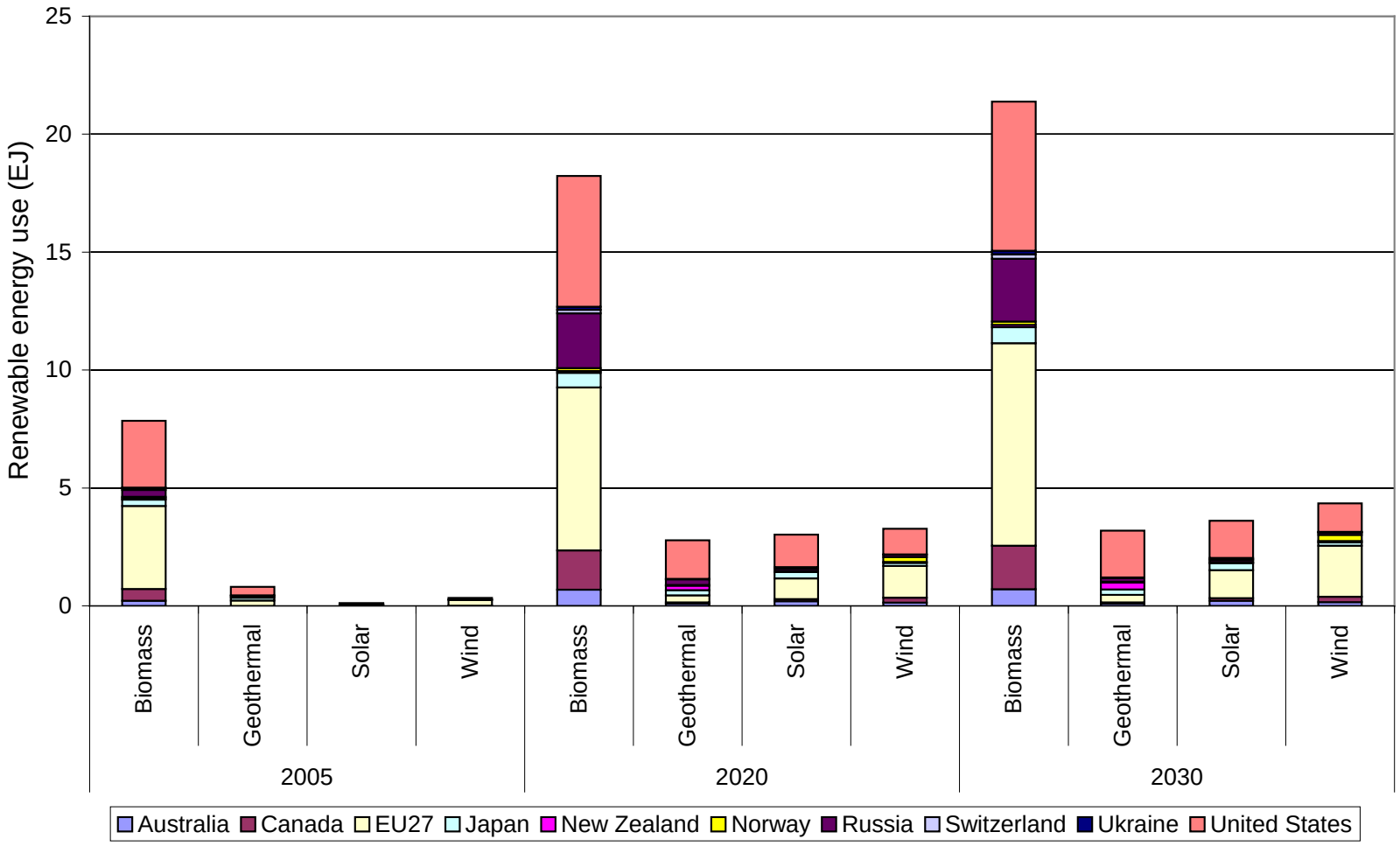
# Mitigation options

- Replacement of coal in power generation with gas and biomass fuels
- Combined heat and power (CHP) plants
- Technologies with higher efficiency (e.g., IGCC)
- Power from renewable sources (wind, solar, hydro, geothermal)
- Refineries: efficiency improvement, CHP and fuel switching
- Reduction of transmission and distribution losses of electricity and heat
- Biofuels production
- Carbon capture and storage (CCS)

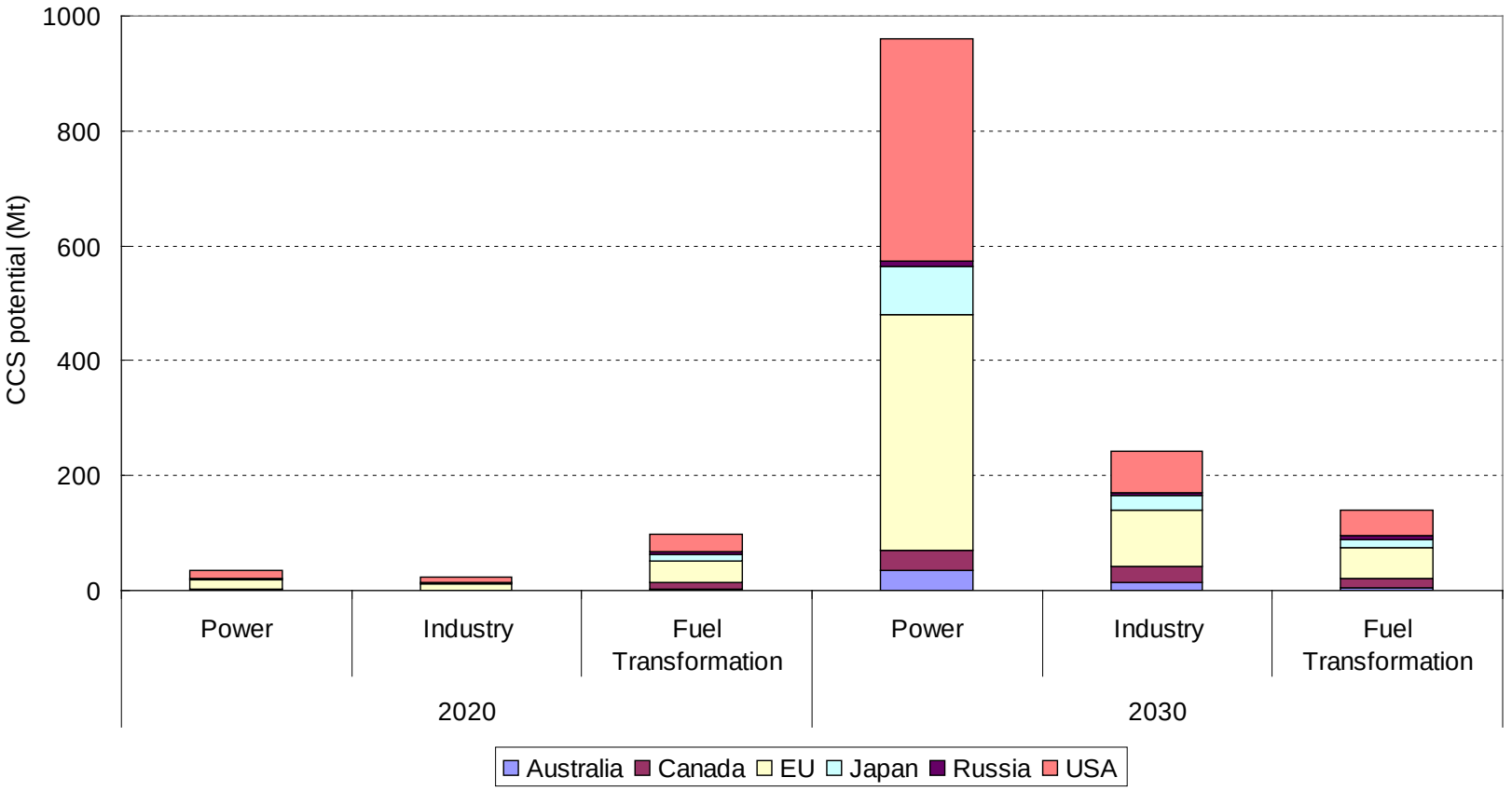
For each option country- specific potentials and costs assessed

Data sources: OECD/IEA, 2008, IEA/OECD, 2008, IEA, 2008 a-c, Panos, 2009, EIA, 2008, NEA/IEA, 2005 and other

# Potentials for renewable sources



# Potentials for carbon capture and storage (CCS)



# Other potentials and supply constraints - 2020

Natural gas:

- national supply constraint
- final use in buildings and in industry: up to 20 % higher than in the Baseline
- power generation: only constraints on technology penetration and national gas supply

Heat (in CHP schemes):

- buildings: 20 % more than in the Baseline
- industry – up to 90 % of heat produced in boilers

Nuclear:

- as in the Baseline

# Domestic sector

# Sources and options

Separate treatment of residential and commercial energy use

Needs:

- Space heating + ventilation + air conditioning (HVAC)
- Water heating
- Cooking
- Lighting
- Appliances (large and small)

Flats/Single family houses

Built before/after 2010

Differences in climate included (e.g., USA – 11 regions)

For each source category:

- Up to 3 efficiency stages
- Switch to less carbon-intensive fuels (coal to gas or biomass, solar…)
- District heat with CHP instead of local boilers

# Energy needs in the domestic sector

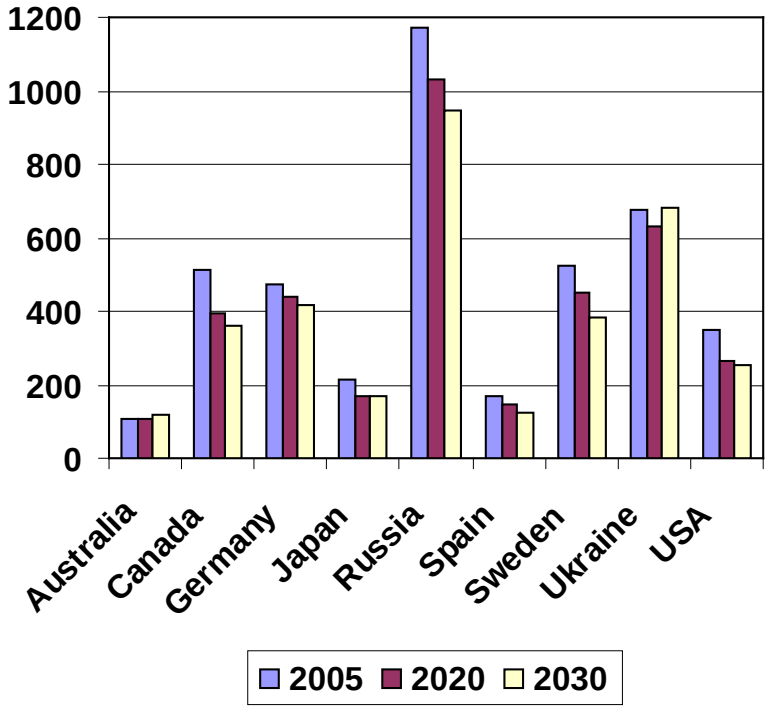
Each need characterized by:

- Energy intensity in the base year (2005)
- Change in consumption of thermal energy and electricity by efficiency option
- Capital investments and operating and maintenance costs
- Uptake of options in the baseline scenario (2005, 2020, 2030) which reproduces baseline energy consumption
- Maximum uptake (potential) for 2020 and 2030. No premature scrapping of existing equipment

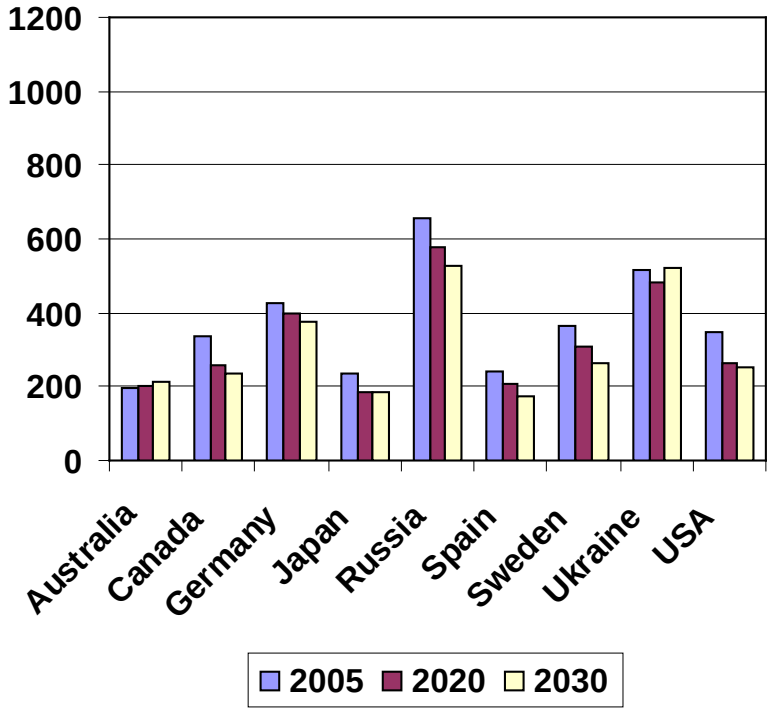
Data sources: USCB, 2006, AGO, 1999, , EIA, 2008, EPA, 2008, APEC, 2006, CCS, 2007, METI, 2008, ECC,2007, Astroem et al., 2009, USCB, 2006 and other

For Australia, New Zealand, Russia and Ukraine data verified by national experts

# Baseline intensities in residential sector – heating, ventilation and air conditioning, MJ/m$^2$ floor space

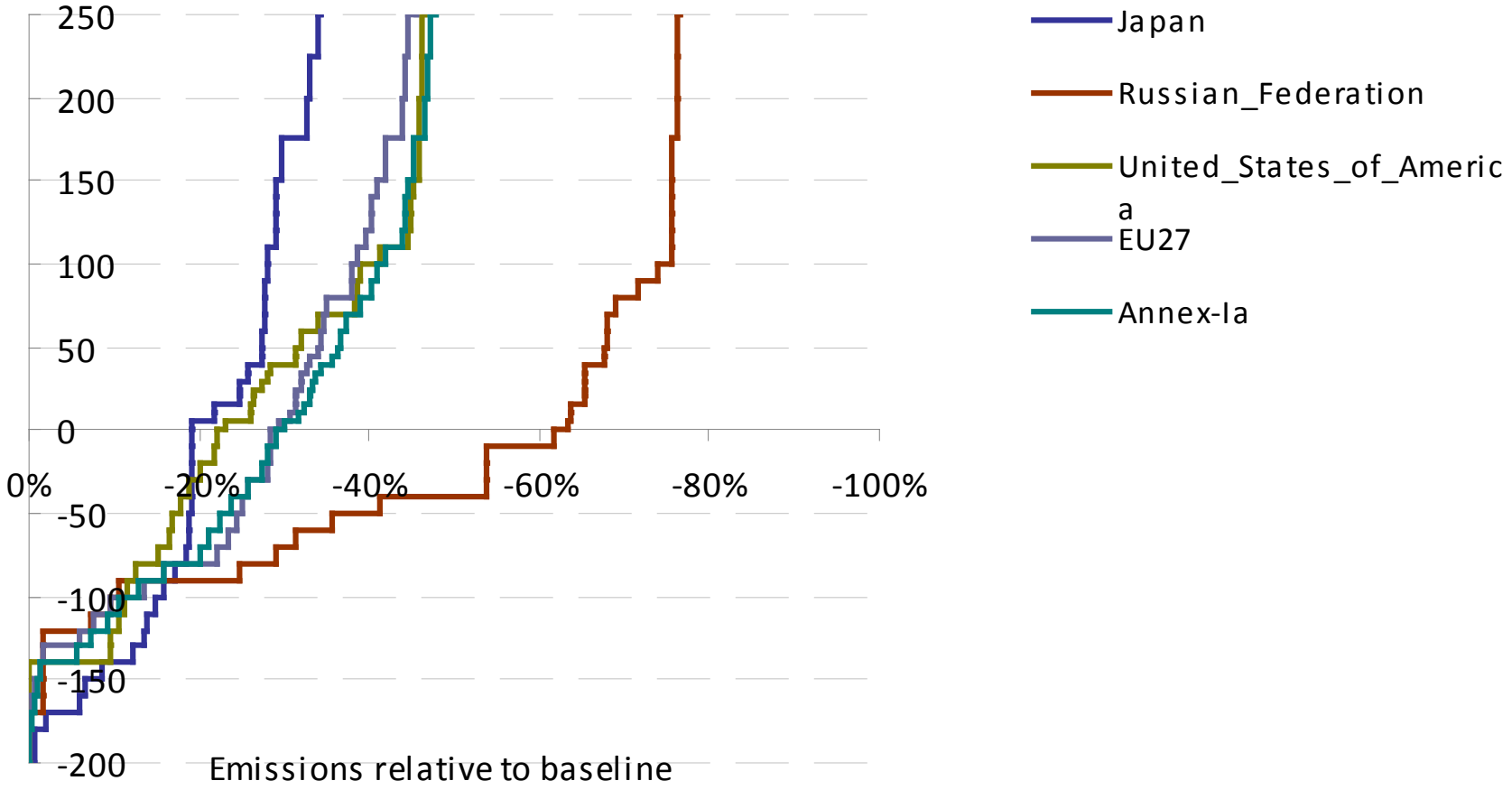



Unadjusted




Adjusted to US average degree-days

# GHG mitigation cost curves – Domestic sector (downstream emissions)



# Manufacturing industry

# Aggregation and data sources

Manufacturing of energy-intensive products:

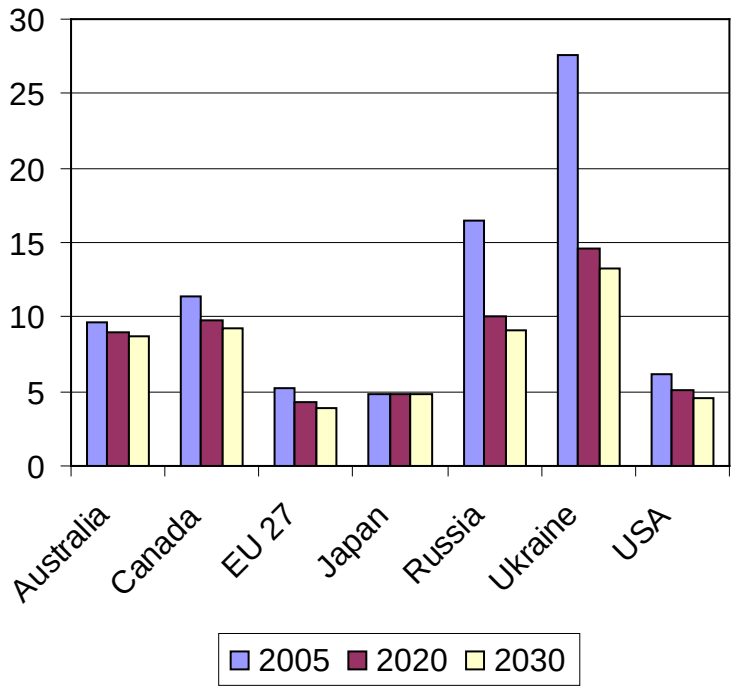
| Iron and steel | Non-ferrous metals | Non-metallic minerals |
|---|---|---|
| Sinter | Primary aluminium | Cement production |
| Pellets | Secondary aluminium | - of which clinker |
| Pig iron | Other metals - primary | Lime production |
| Direct reduced iron | Other metals - secondary | |
| Open hearth furnace steel | | Pulp and paper |
| Basic oxygen steel | Chemicals | Pulp from wood |
| Electric arc furnace steel | Ammonia | Pulp from recovered paper |
| Casting, rolling finishing | Ethylene | Paper and paperboard |
| Thin slab casting | Chlorine | |

Remaining energy consumption related to sectoral value added

Data sources: IEA, 2008, APEC, 2006, NRCan, 2008, Worrell, 2000, 2007,, Nilsson et al., 2005, Martin et al., 1999, 2000, Chen et al., Capros and Mantzos, 2006 and other

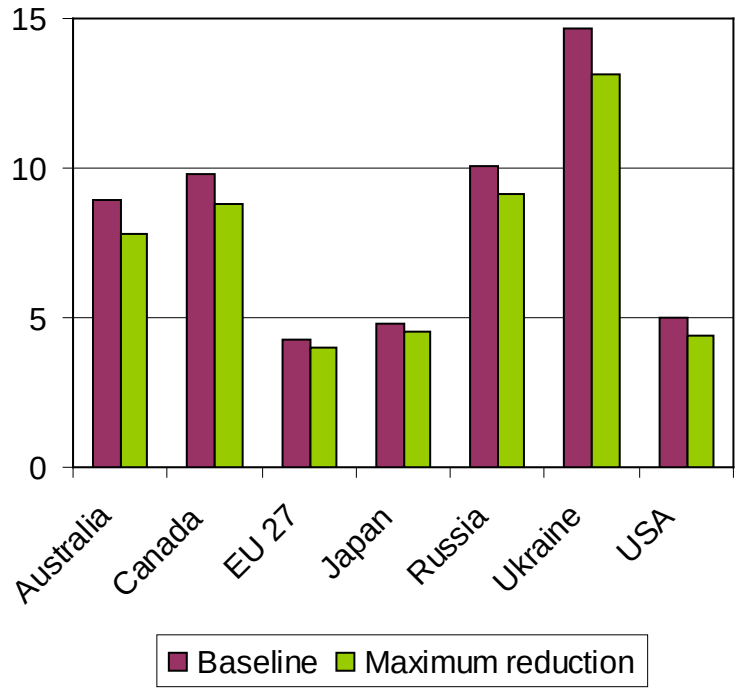
# Energy intensities in manufacturing industry

## MJ/€ VA

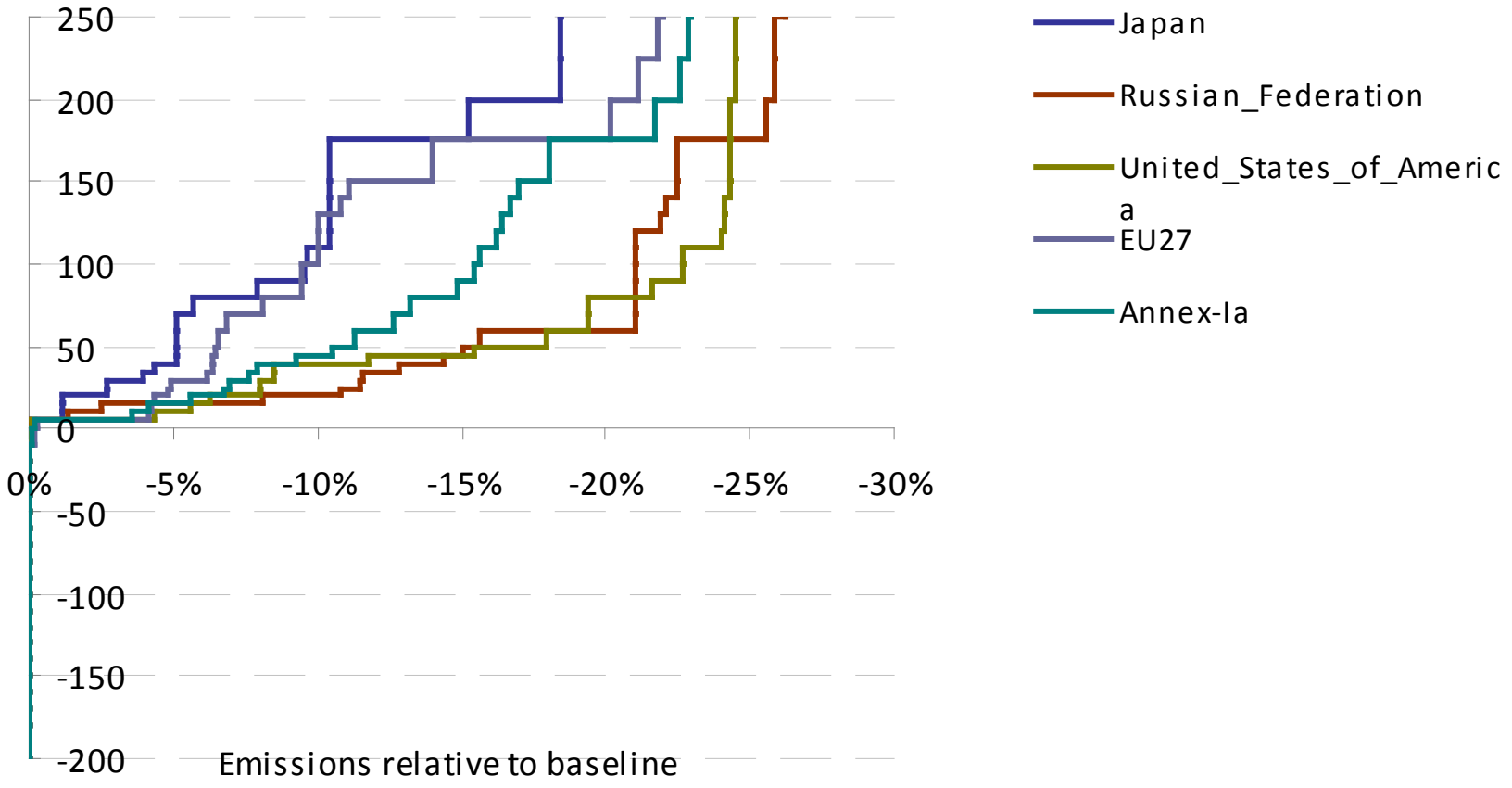



Baseline

2020



# GHG mitigation cost curves – manufacturing industry (downstream emissions)



# Potential biases

Assumptions:

- Measures kick-off in 2010
- No premature scrapping of existing capital stock
- Only currently available technologies
- No changes in demand and lifestyles compared to baseline
- No macro-economic feedbacks
- Availability of CCS as in IEA blue map scenario
- No expansion of nuclear power beyond baseline projection
- Technical potential, without consideration of implementation barriers

Do these assumptions lead to conservative estimates?

# Conclusions

- The methodology provides an internally consistent assessment of mitigation potentials across sectors and countries
- Use of exogenous baseline activity projection with assumptions on autonomous efficiency improvements
- Further mitigation potential derived from international comparison of sectoral energy efficiency performances
- We estimate for this sector a mitigation potential of 3.9 Gt $CO_2$ in 2020 for a carbon price below 100 €/t $CO_2$eq
- Estimates are sensitive towards exogenous energy and economic projections and the timing of mitigation measures