Global Mapping of Greenhouse Gas Abatement Opportunities up to 2030

Agriculture and Waste sector deep-dive

June, 2007

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Agriculture and waste sector – Key messages

Current emissions

- The agriculture/waste sector emissions amounted to 7.2 Gt CO_2e/year in 2002
  - N_2O from soil fertilization (30%) and other sources (8%)
  - CH_4 from livestock (29%), landfills/wastewater (18%), rice (9%) and other sources (6%)

BAU growth

- Under BAU (projected based on EPA 2020 estimates), emissions grow 37% from 7.2 in 2002 to 9.9 Gt CO_2e/year in 2030; primarily driven by population growth in the developing world plus a shift towards eating more meat and greater waste production per capita

Abatement opportunities

- The maximum theoretical abatement potential below 40 EUR/t is about 5.7 Gt CO_2e/year by 2030; however, implementation is very challenging
  - 68% of emissions in developing countries
  - Diffuse sources
  - Measurement and monitoring difficult
  - Strong relation to poverty issues
- Assuming ~25% as a realistic average realization rate for agriculture and 34% for landfills/waste, the practical potential by 2030 is about 1.5 GtCO_2e per year at less than EUR 40 per ton of CO_2e
  - Rice: upland rice, reduced flooding, and fertilizer shift can each reduce emissions 20-30%
  - Soils: fertilizer shifts reduce N_2O emissions and reduced tilling encourages CO_2 accumulation
  - Livestock: improved feeding, and manure management reduces methane emissions
  - Landfills: 90% of methane can be captured at properly outfitted landfills

Implications

- Achieving these practical potentials would mean 2030 emissions of 8.4 GtCO_2e, or about 16% higher than today
- To achieve this abatement, local standards and policies would likely be needed, in addition to a financial incentive for developing countries to act

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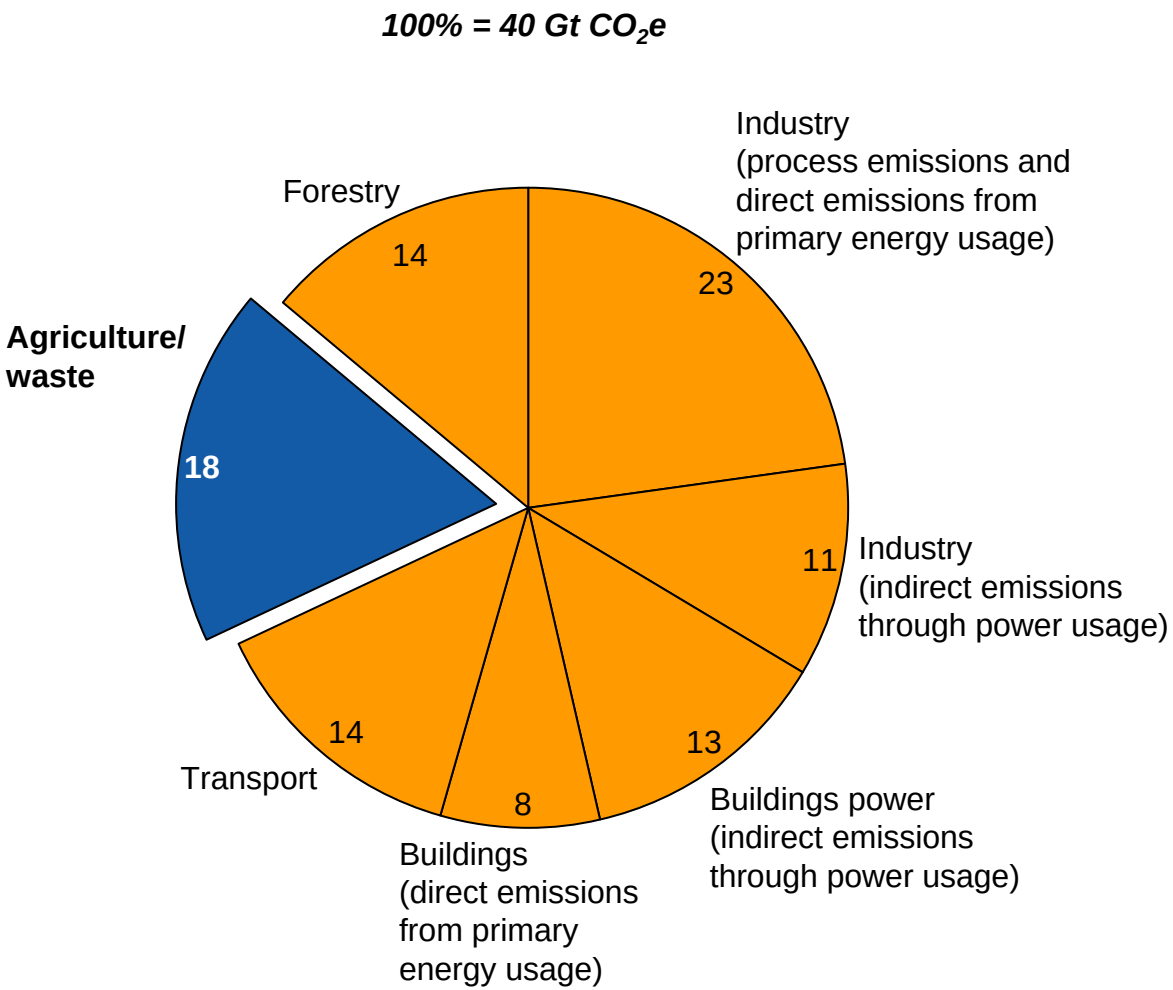
Global greenhouse gas emissions, 2002

Percent



- Agriculture and waste account for 18 percent of current CO_2e emissions
- All of these emissions are N_20 and CH_4 since any CO_2 releases from new conversion of forests to agriculture are allocated to the forestry sector
- However, atmospheric CO_2 can be sequestered in agricultural soils through conservation tillage

Source: IEA

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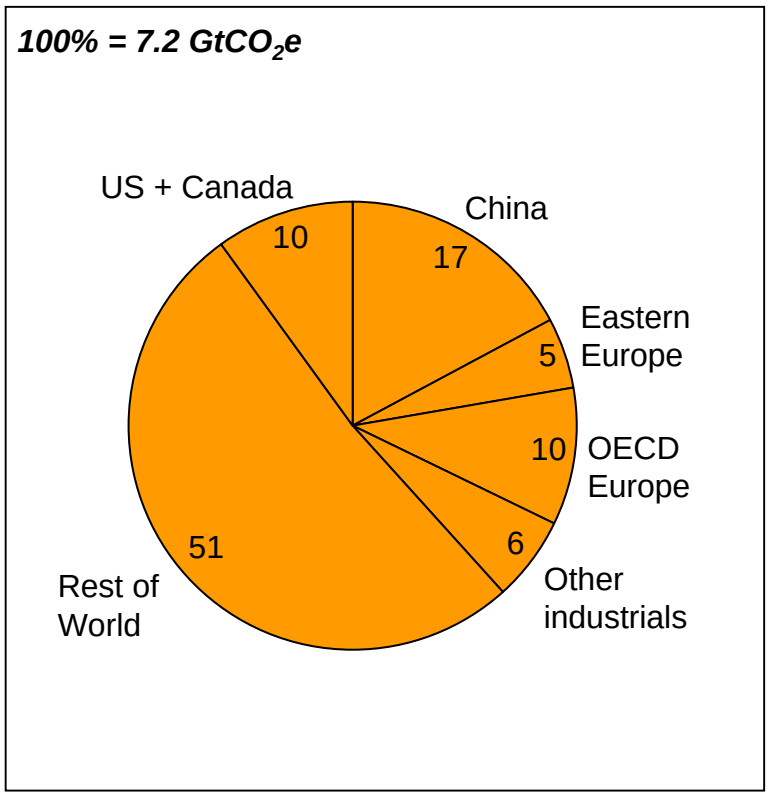
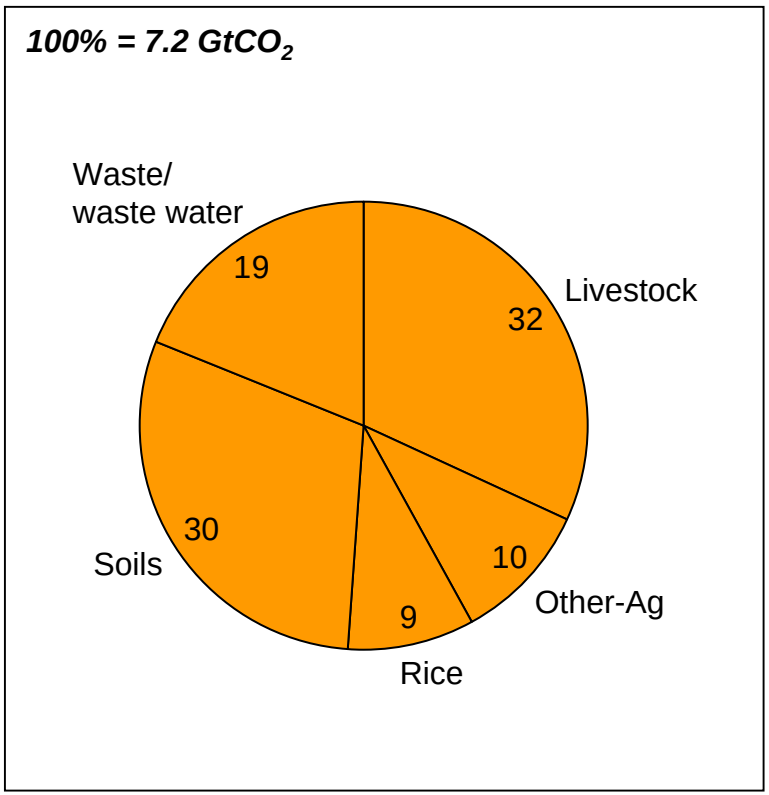
Emissions by region and end-use 2002

Percent

Geographic distribution



End-use distribution



- **Agriculture/waste sector emissions are concentrated in emerging economies**
- **Agriculture and livestock account for over 80% of current emissions from this sector**

Source: EPA

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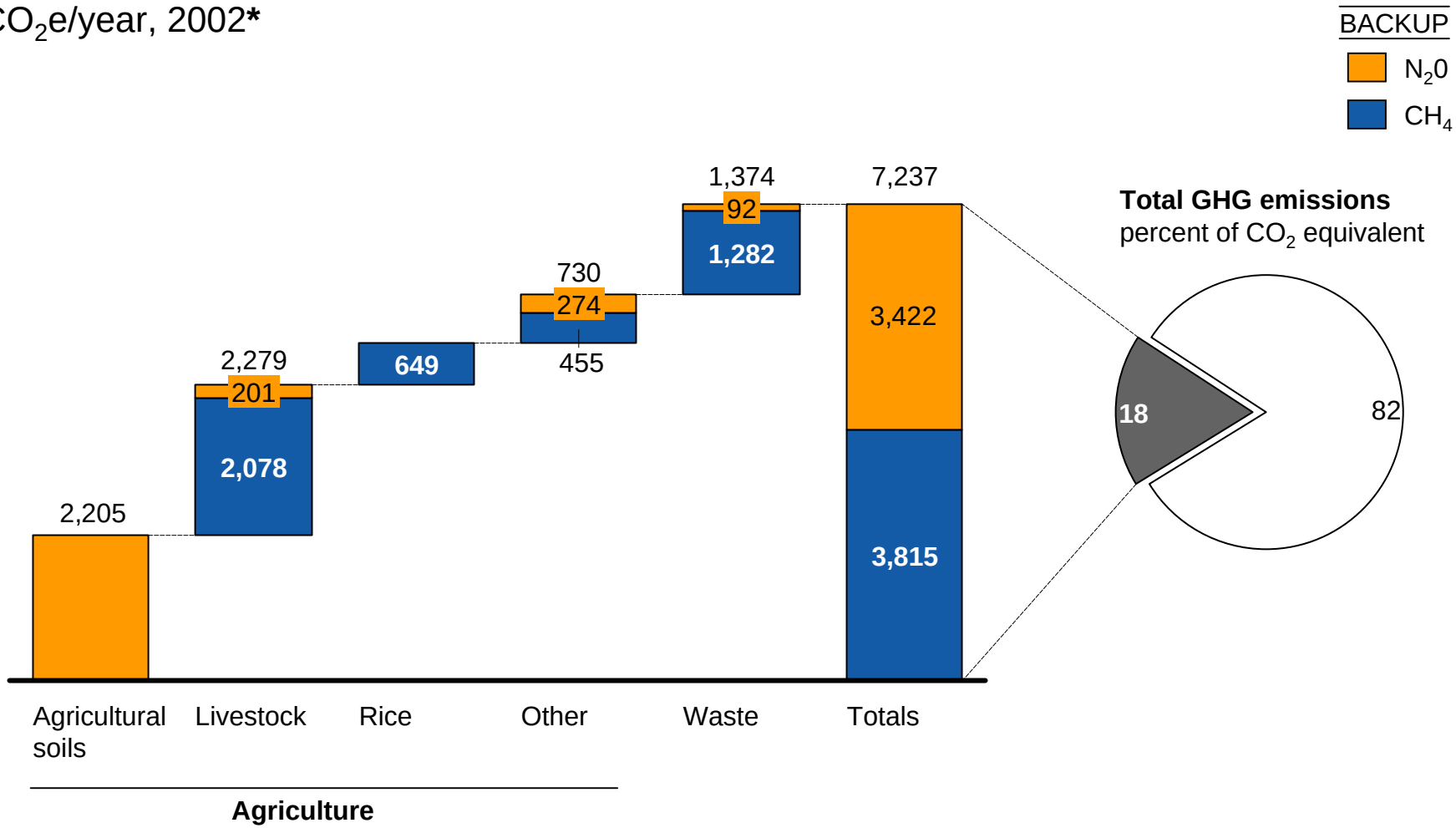
Agriculture and waste emissions by greenhouse gas

Mt CO_2e/year, 2002*



* Excludes land use change which is captured in the forestry sector deep-dive as part of deforestation emissions

Source: EPA

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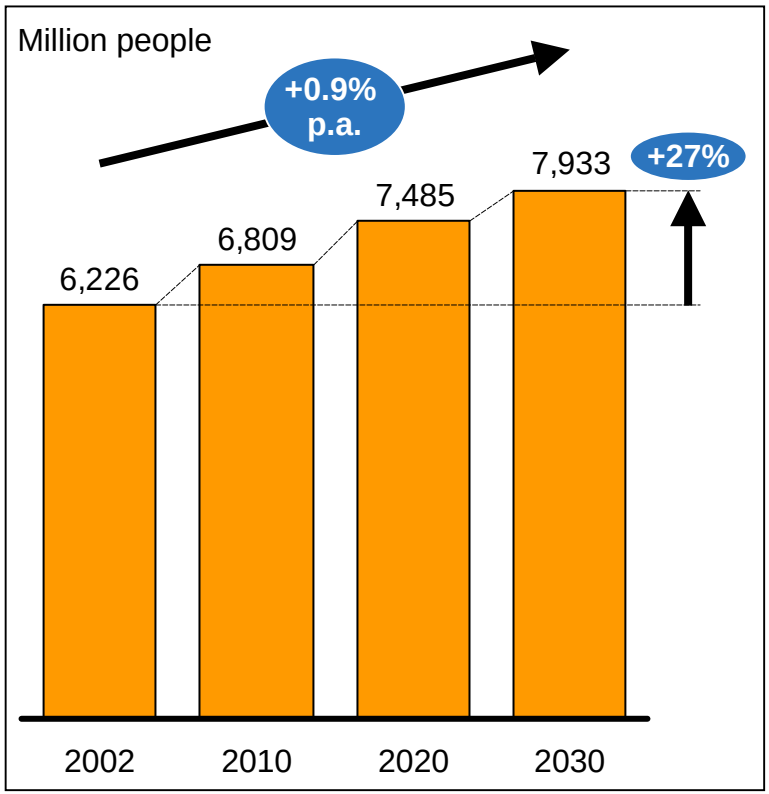
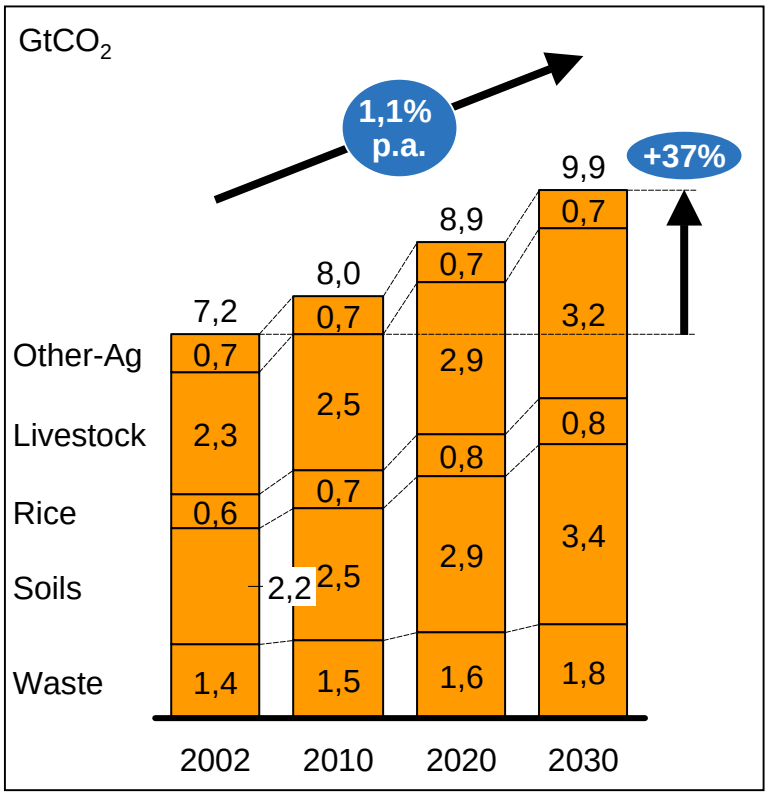
BAU development in the agriculture and waste sector

World population



Emissions



The agriculture and waste sector is expected to grow 37% by 2030, relatively more than total population due to a shift in nutritional habits (more meat) and an increase in waste production per capita

Source: IEA

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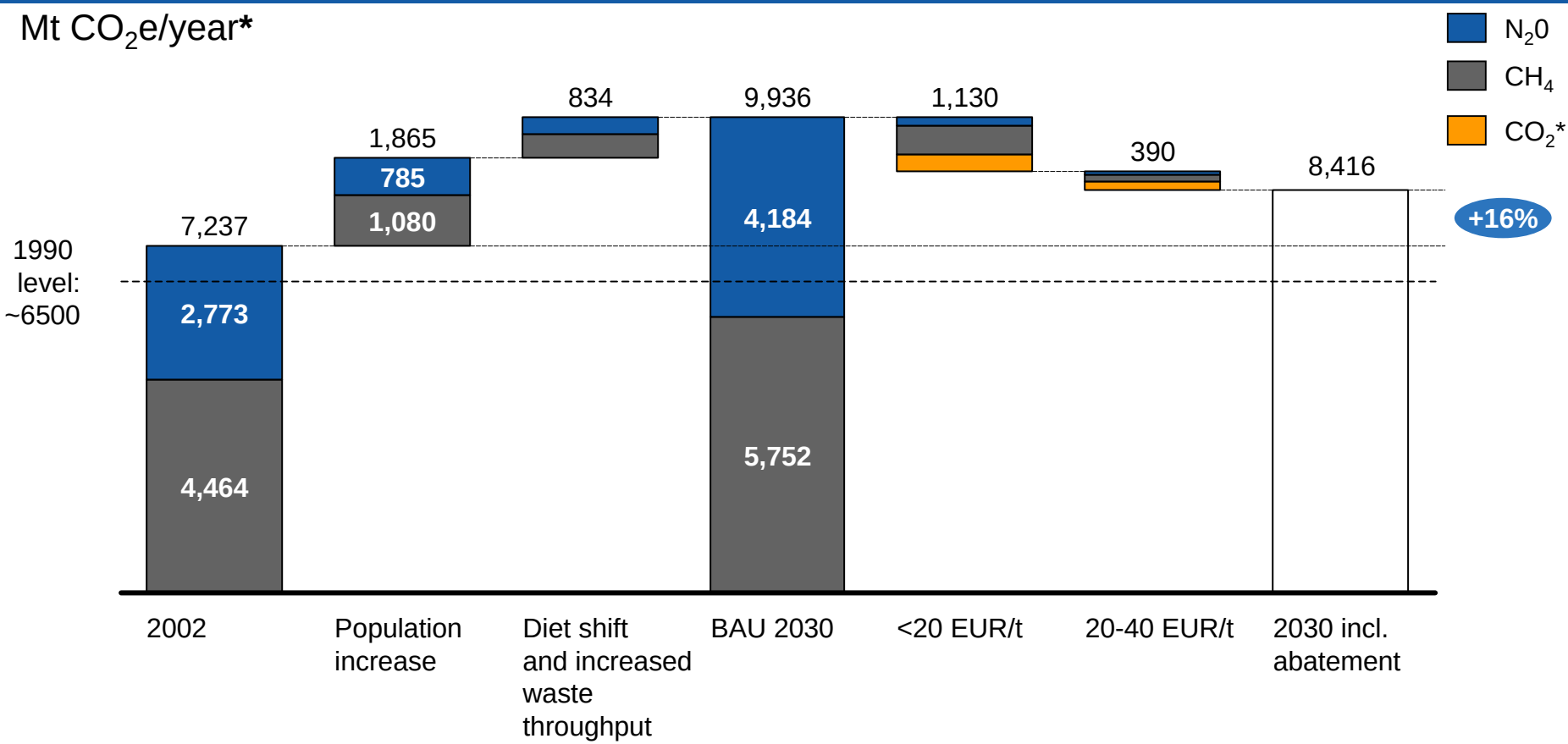
Emissions from agriculture and waste, and abatement opportunities



- **Emissions from the agriculture/waste sector are projected to grow 37% by 2030 under BAU**
- **If the maximum practical abatement potential at less than EUR 40 per ton is realized, emissions growth could be held to 16%**

* CO_2 emissions from conversion of forests to agriculture are allocated to the forestry sector, but CO_2 abatement from sequestering atmospheric CO_2 through conservation tillage is included in this sector

Source: EPA; Pacala

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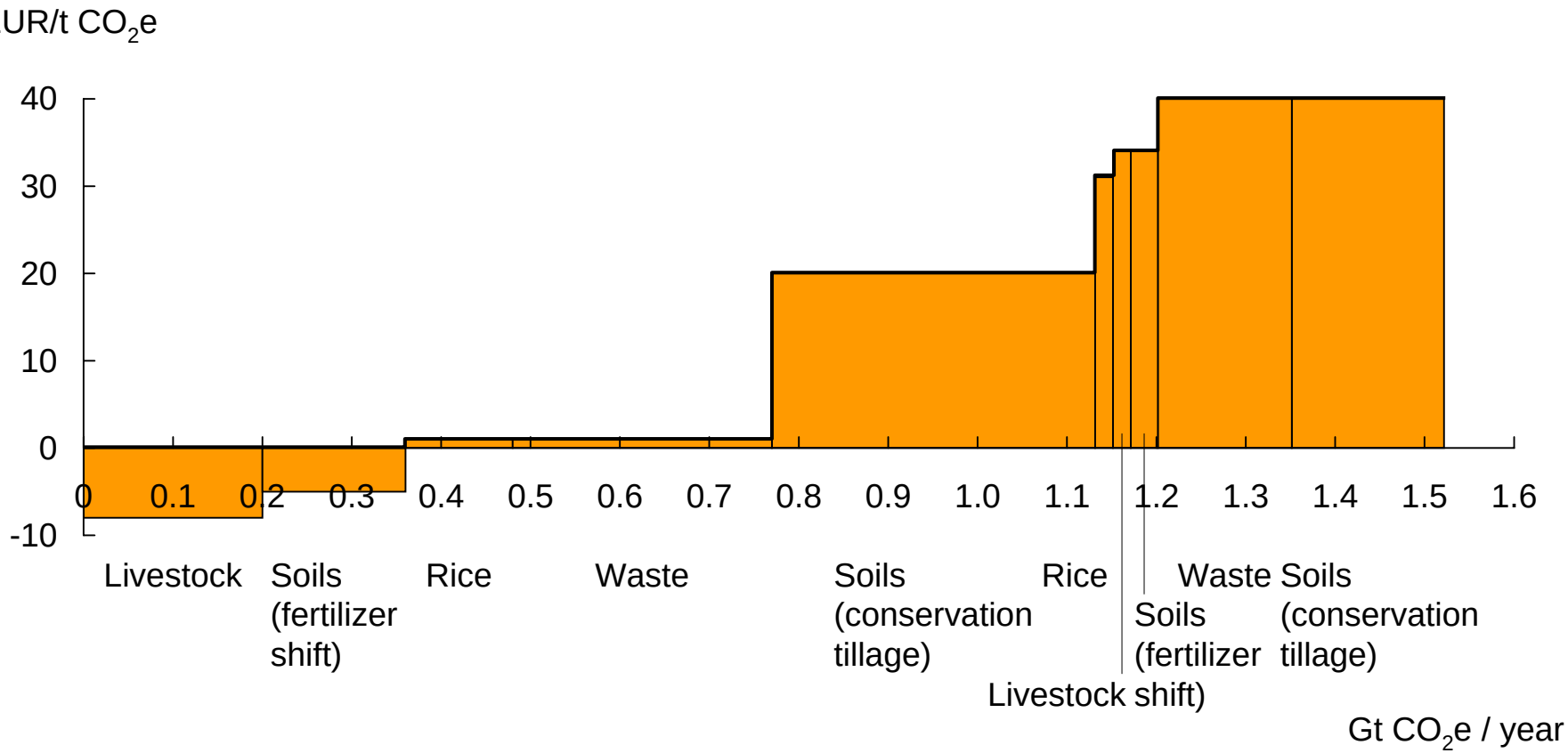
Marginal abatement cost curve for the agriculture and waste sector 2030



- **Sequestration of atmospheric CO_2 into soils through conservation tillage represents the single largest abatement opportunity from this sector (35% of the total potential)**
- **Methane abatement from waste and wastewater represents the second most important opportunity (29% of the total potential)**

Source: EPA

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Agriculture and waste sector feasible abatement opportunities

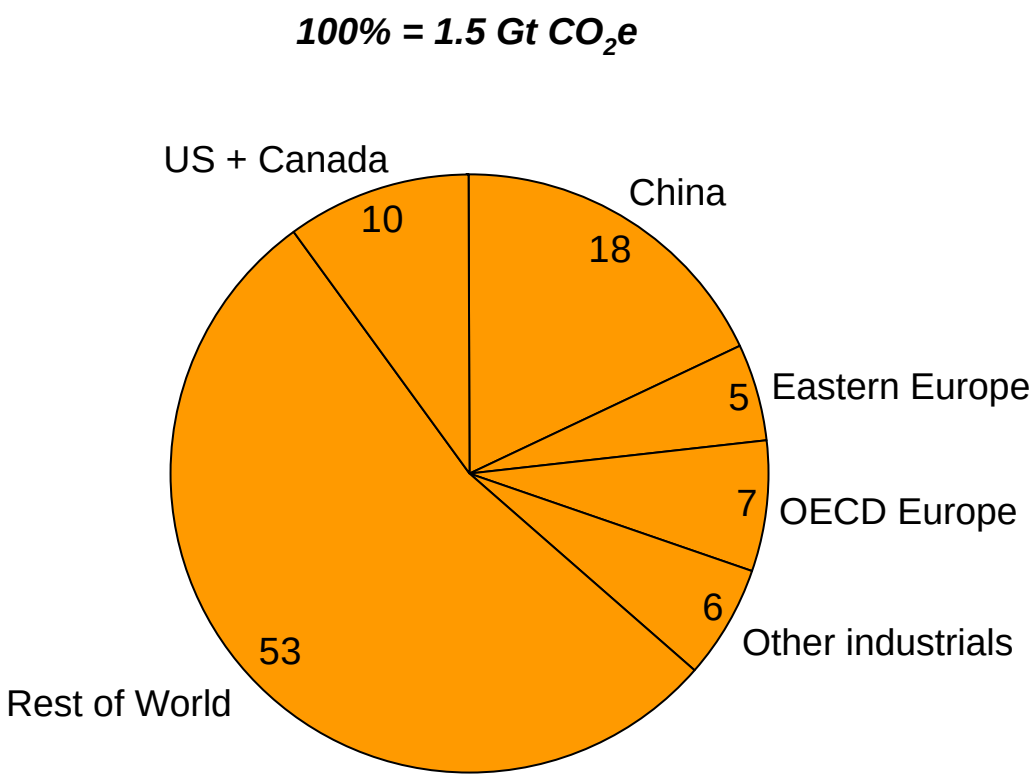
Gt CO_2e/year, 2030

Agriculture	Description	Technical max-imum potential	Assumed realistic abatement potentials At < 20	< 40 EUR/t
Rice	• Reduced flooding of rice fields • Fertilizer shift – Ammonium sulfate – Slow release fertilizer	0.8	0.12	0.14
Livestock	• Improved feeding • Drugs: antibiotics, bST • Manure management	1.1	0.20	0.22
Soils	• Fertilizer shift • Conservation tillage: cultivation of soils with reduced or no plowing	2.5	0.52	0.72
Waste				
Landfills	• Capture and use CH_4 with system of pipes and wells • Reduce landfills by recycling	0.7	0.19	0.24
Wastewater	• Improved filtering/treatment to reduce amount of decomposable substances • Anaerobic digesters to extract CH_4 before releasing water	0.6	0.1	0.2
	Totals	**5.7**	**1.13**	**1.52**

Source: EPA; industry experts

Regional split of abatement opportunities

Percent, 2030, opportunities below 40 EUR/tCO_2e

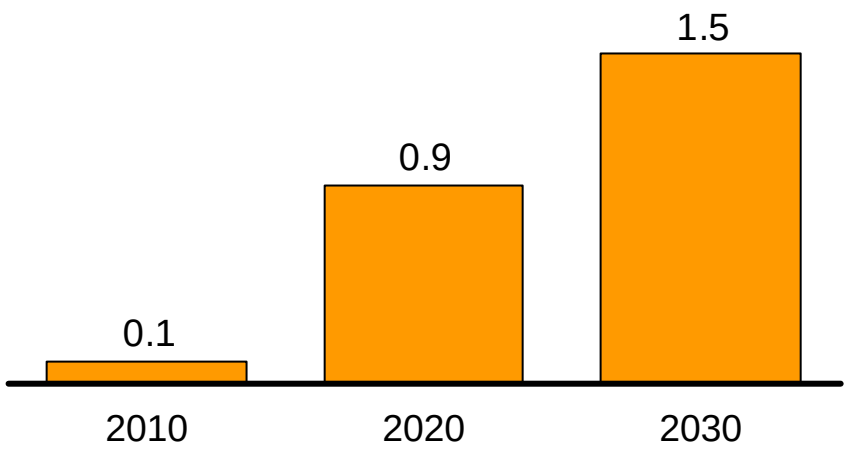


Most of the abatement opportunities are in developing Countries, in line with current emissions distribution

Development of abatement opportunities over time

Gt CO_2e

Opportunities <40 EUR/t CO_2e



	2010	2020	2030
Average abatement cost EUR/t CO_2e	14	12	13

- More than half of the abatement potential could be achieved by 2020
- Abatement cost remains roughly constant over time

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Agriculture abatement opportunities – Rice

Gt CO_2e/year

BACKUP

	Sub-measures	Comments on feasibility	Sub-measure theoretical potential	Combined* theoretical potential at <80 EUR/t	Assumed realistic abatement potentials (% realization rate)** At <20 EUR/t	At <40 EUR/t
Reduced flooding	• Mid-season drainage of rice fields to reduce anaerobic conditions	• Depends on watering system. Already in use in China. Increase N_2O emissions	0.26	0.5	0.07 (14%)	0.08 (16%)
	• Shallow flooding	• Reduces yield ~10%, not possible in rain-fed areas	0.52			
	• Shift to upland rice that does not require flooding	• Reduces yield 30–40%, only possible in certain regions	0.54			
Fertilizer shift	• Reduced use by 10–30%	• Reduced yield, very hard to force	Low	0.3	0.05 (17%)	0.06 (20%)
	• Slow-release fertilizer	• Hard to force	Low			
	• Ammonium sulfate replaces urea and ammonium bicarbonate	• Can be implemented by selling alternatives at subsidized prices	0.13			
	• Off-season straw amendment reduced amount of available biomass for decomposition	• Requires some changes in practices	0.19			
			Total:	**0.8**	**0.12**	**0.14**

* Combined potential eliminates double counting for non-additive measures

** Realization rates reflect expert opinion and are broadly consistent with EPA sector-specific MACs, but with realization rates shown explicitly

Source: EPA; industry experts

Agriculture abatement opportunities – Livestock

Gt CO_2e/year

BACKUP

	Sub-measures	Comments on feasibility	Sub-measure theoretical potential	Combined* theoretical potential at <80 EUR/t	Assumed realistic abatement potentials (% realization rate)** At <20 EUR/t	At <40 EUR/t
Feeding	• Improved feed conversion make livestock grow faster	• In use in developed countries, may be extended to developing	0.04	0.05	0.01 (20%)	0.01 (20%)
	• Intensive grazing by more frequent rotation between pastures	• Hard to force due to reduce yields	0.01			
Drugs and vitamins	• Antibiotics make livestock grow faster	• In use, prohibited in some countries	0.09	0.5	0.11 (22%)	0.12 (24%)
	• Bovine somatotropin increases milk yield	• In use, may be extended to developing countries	0.25			
	• Propionate precursors reduces methane	• In use in some developed countries, too advanced for developing	0.32			
	• Methane reducing vaccine under development		0.11			
Manure management	• Collect manure and store it in various kinds of digesters, exacted CH_4 can be used for power generation or cooking	• In use in India and some developed countries, may be extended to other. Easy to introduce in dairy farms	0.33	0.33	0.08 (24%)	0.09 (27%)
			Total:	**0.88**	**0.20**	**0.22**

* Combined potential eliminates double counting for non-additive measures

** Realization rates reflect expert opinion and are broadly consistent with EPA sector-specific MACs, but with realization rates shown explicitly

Source: EPA; industry experts

Agriculture abatement opportunities – Soils

Gt CO_2e/year

BACKUP

	Sub-measures	Comments on feasibility	Sub-measure theoretical potential	Combined* theoretical potential at <80 EUR/t	Assumed realistic abatement potentials (% realization rate)** At <20 EUR/t	<40 EUR/t
Fertilizer shift	• Reduced use of fertilizer	• Hard to force, small impact	Low	0.4	0.16 (40%)	0.19 (48%)
	• Split fertilization into smaller pieces over time	• Increases yield, small cost	0.19			
	• Nitrification inhibitors are chemical agents that inhibit or retard nitrification in soil	• Increases yield, small cost	0.29			
Conservation tillage	• Cultivation of soils with reduced or no plowing	• Implies large shift in cultivation methods	2.1	2.1	0.36 (17%)	0.53 (25%)
			Total:	**2.5**	**0.52**	**0.72**

* Combined potential eliminates double counting for non-additive measures
** Realization rates reflect expert opinion and are broadly consistent with EPA sector-specific MACs, but with realization rates shown explicitly
Source: EPA; industry experts

Agriculture abatement opportunities – Landfills

Gt CO_2e/year

BACKUP

	Sub-measures	Comments on feasibility	Sub-measure theoretical potential	Combined* theoretical potential at <80 EUR/t	Assumed realistic abatement potentials (% realization rate)** At <20 EUR/t	At <40 EUR/t
Capture and/or use CH_4	• Build system of wells and pipes in the landfill to collect and flare CH_4, with some additional equipment, the CH_4 may be compressed and used***	• Required by law in the US primarily due to public health issues around the landfill. May be extended to other countries	0.6	0.7	0.19 (27%)	0.24 (34%)
Reduce landfills by recycling	• Split waste and recycle or treat components	• Germany and Sweden have already made great efforts. Harder to force in most countries	0.3			
			Total:	**0.7**	**0.19**	**0.24**

* Combined potential eliminates double counting for non-additive measures
** Realization rates reflect expert opinion and are broadly consistent with EPA sector-specific MACs, but with realization rates shown explicitly
*** Use of waste as fuel, both solid waste and CH_4 extracted from waste, is excluded from the model since the power production potential and thus the emissions reduction from displaced power sector production are modest

Source: EPA; industry experts

Agriculture abatement opportunities – Wastewater

Gt CO_2e/year

BACKUP

	Sub-measures	Comments on feasibility	Sub-measure theoretical potential	Combined* theoretical potential at <80 EUR/t	Assumed realistic abatement potentials (% realization rate)** At <20 EUR/t	<40 EUR/t
Improved treatment	• Better filtering of wastewater reduces amount of decomposable substances in the water and thus the emissions	• Already in use in some countries	0.3			
				0.6	0.1 (17%)	0.2 (33%)
Digesters	• Let wastewater emit CH_4 in anaerobic digesters before releasing it out of the sewage system	• Pilot installations already in use	0.5			
			Total:	**0.6**	**0.1**	**0.2**

* Combined potential eliminates double counting for non-additive measures

** Realization rates reflect expert opinion and are broadly consistent with EPA sector-specific MACs, but with realization rates shown explicitly

Source: EPA; industry experts

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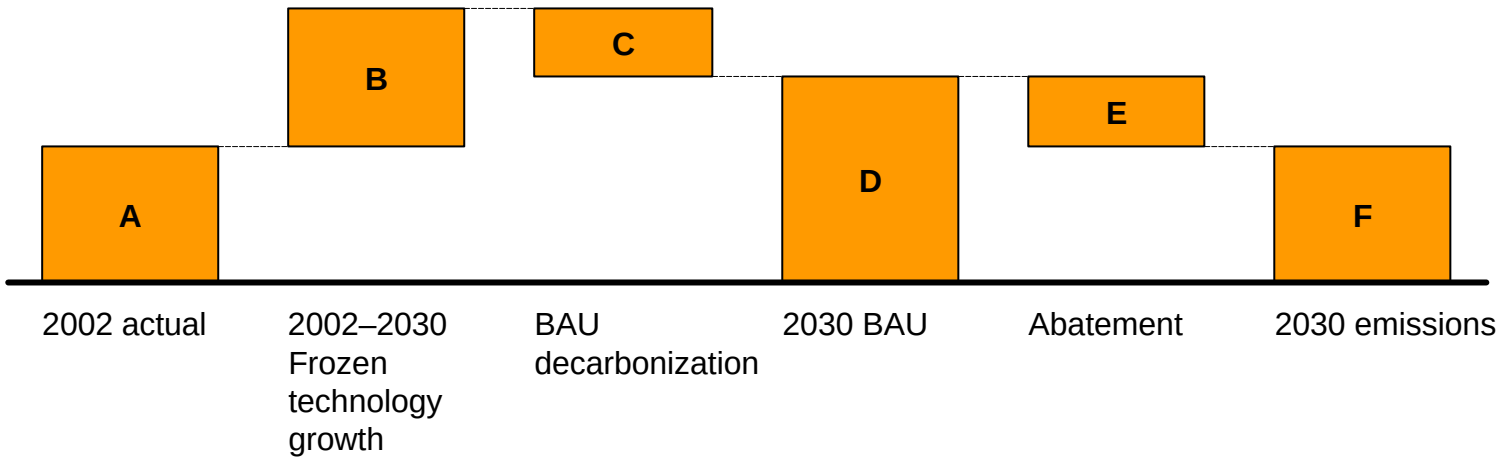
Methodology overview

- EPA's June 2006 "Global Mitigation of Non-CO2 Greenhouse Gases" report has been used to define the baseline scenario through 2030
- Only abatement opportunities at a cost lower or equal to 40 EUR/t CO_2e have been considered
- Given significant challenges posed by implementation (very high percentage of emissions in developing countries, diffuse sources, difficult measurement/monitoring and strong link to poverty issues), "realistic" realization rates have been assumed, averaging 25% for agriculture and 34% for landfills/waste
- Cost development of abatement measures is flat (no technological development is assumed); average abatement cost changes because of shifts in relative mix of measures throughout the period 2010-2030
- No specific knowledge on the sectors has been identified within Vattenfall, consequently all assumptions are based on institutional and academic data sources

Sources and assumptions



Item	Calculation	Source / Assumptions
A. 2002 emission	• N/A	• EPA*
B. Fixed carbon intensity	• Scaled by global population growth	• UN
C. BAU Decarbonization	• Residual	• N/A
D. 2030 BAU emissions	• N/A	• EPA*
E. Abatement	• Regional abatement assumed proportional to BAU emissions	• EPA*, realization rate estimated for “aggressive policy” scenario
F. Potential emissions in 2030	• Residual	• N/A

* Primary source is the June 2006 “Global Mitigation of Non-CO_2 Greenhouse Gases” report

Key uncertainties

- Actual measurability and monitorability of any launched measure potentially difficult, consequently posing a challenge to the set up of financial incentives from rich Countries

- Institutional capability of developing countries, especially very poor ones, to deliver on commitments is unclear