

Global Mapping of Greenhouse Gas Abatement Opportunities up to 2030

Agriculture and Waste sector deep-dive

January, 2007

Agriculture and waste sector – Key messages

Current emissions

- The agriculture/waste sector emissions amounted to 7.2 Gt CO₂e/year in 2002
 - N₂O from soil fertilization (30%) and other sources (8%)
 - CH₄ 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 CO₂e/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 CO₂e/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 GtCO₂e per year at less than EUR 40 per ton of CO₂e
 - Rice: upland rice, reduced flooding, and fertilizer shift can each reduce emissions 20-30%
 - Soils: fertilizer shifts reduce N₂O emissions and reduced tilling encourages CO₂ 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 GtCO₂e, 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
-

Overview

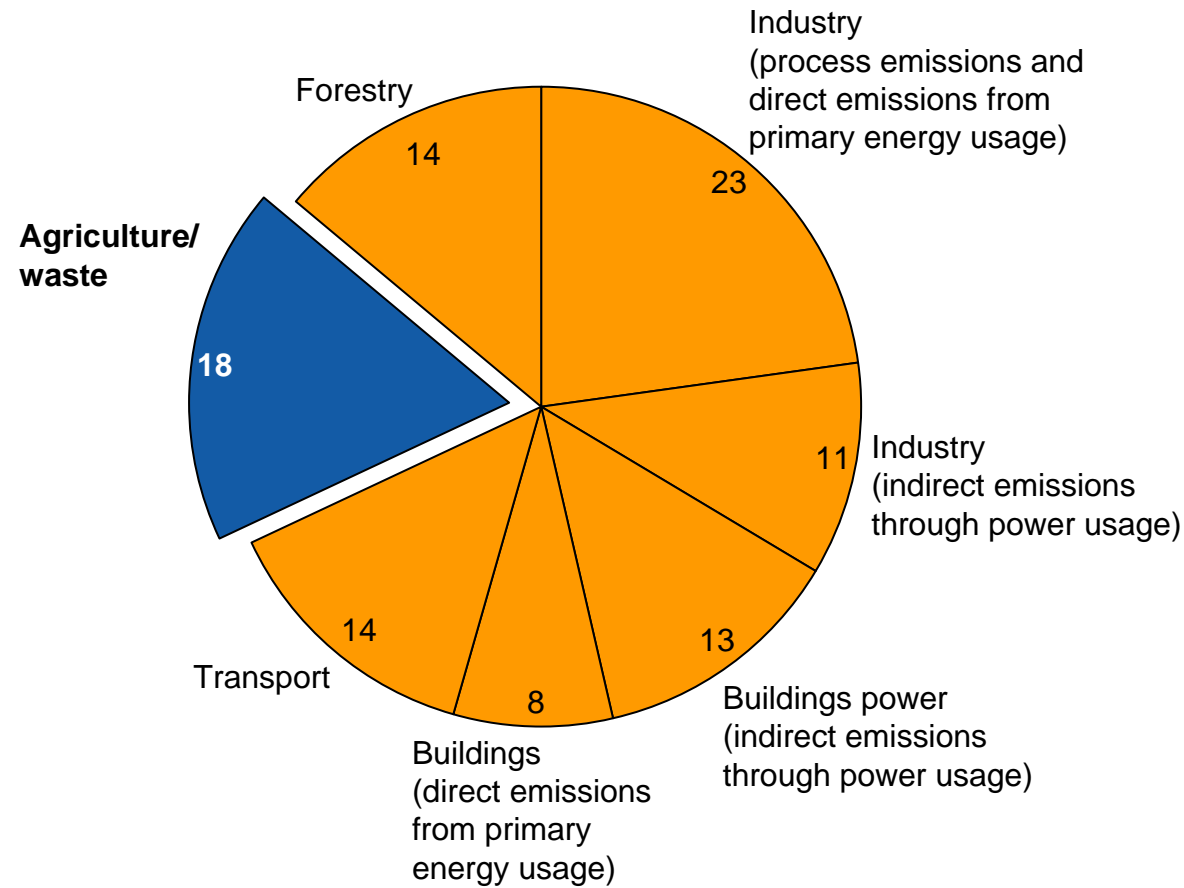
Details of abatement opportunities

Appendix

Global greenhouse gas emissions, 2002

Percent

100% = 40 Gt CO₂e



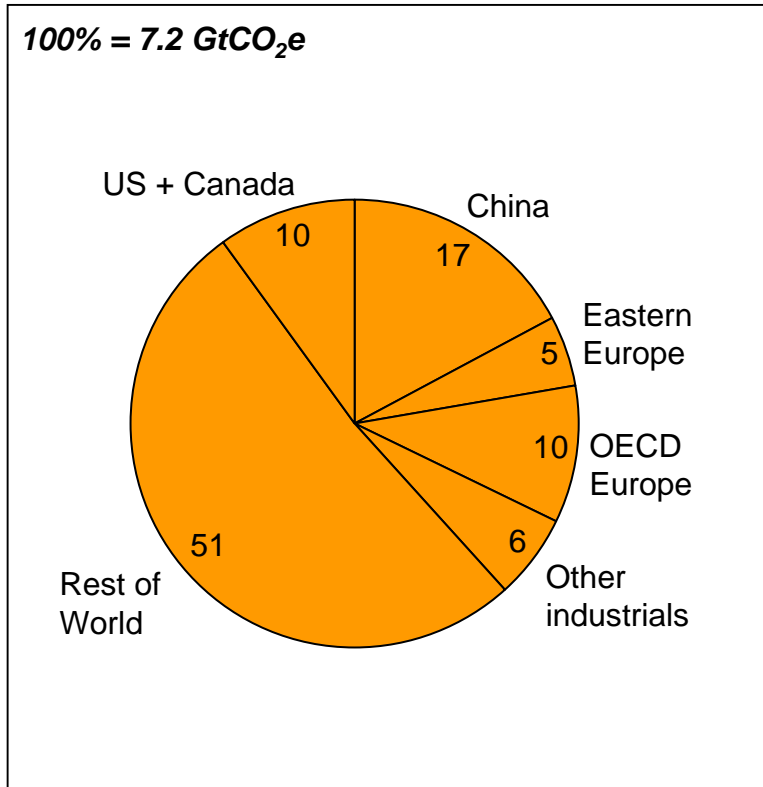
- Agriculture and waste account for 18 percent of current CO₂e emissions
- All of these emissions are N₂O and CH₄ since any CO₂ releases from new conversion of forests to agriculture are allocated to the forestry sector
- However, atmospheric CO₂ can be sequestered in agricultural soils through conservation tillage

Source: IEA

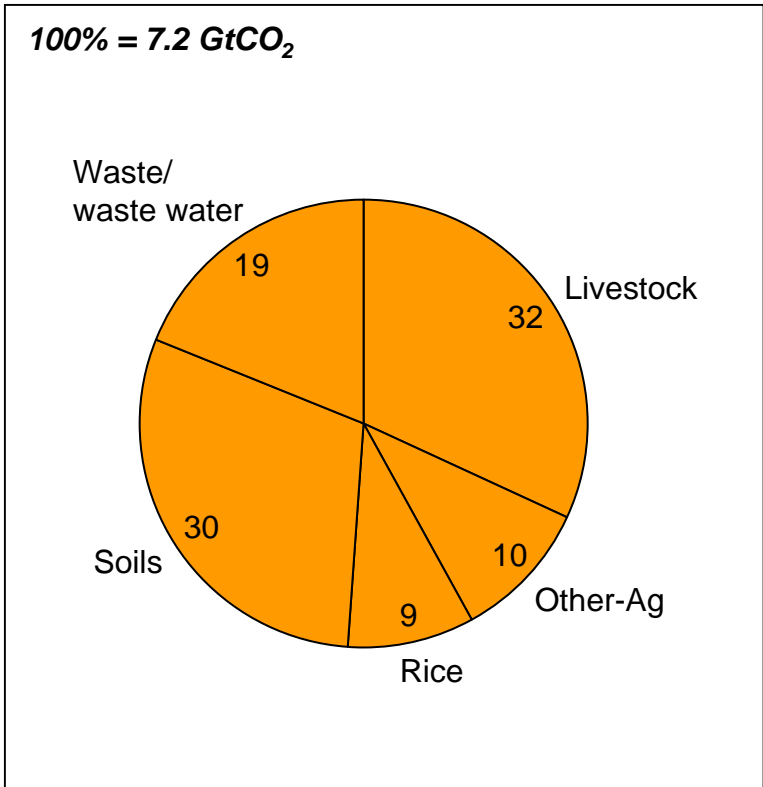
Emissions by region and end-use 2002

Percent

Geographic distribution



End-use distribution



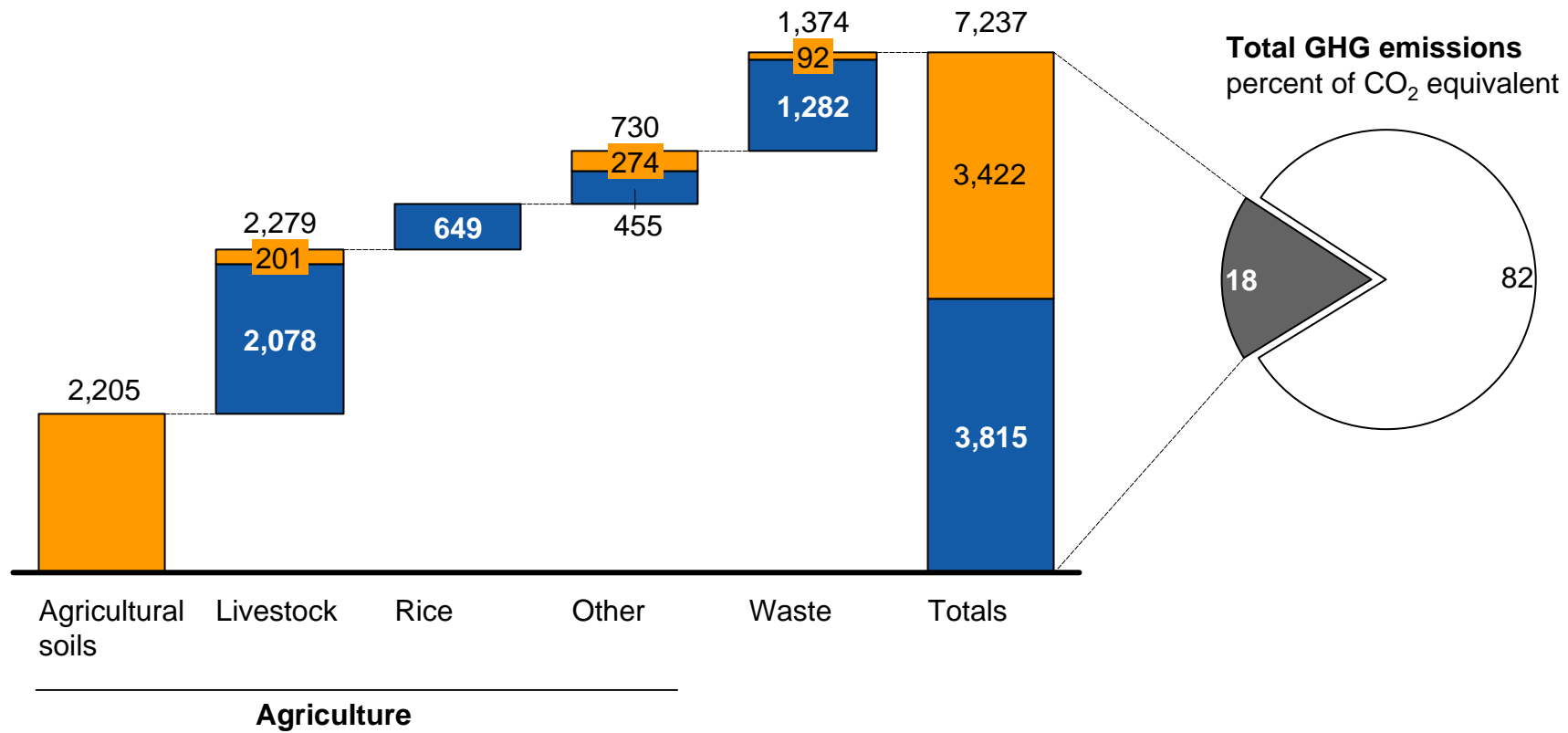
- Agriculture/waste sector emissions are concentrated in emerging economies
- Agriculture and livestock account for over 80% of current emissions from this sector

Source: EPA

Agriculture and waste emissions by greenhouse gas

Mt CO₂e/year, 2002*

BACKUP
■ N₂O
■ CH₄

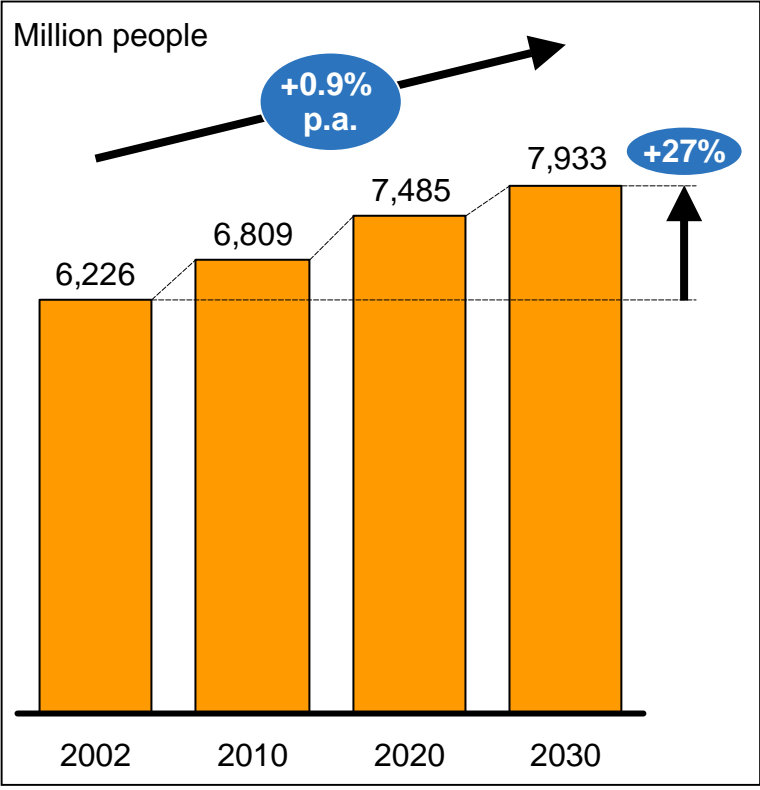


* Excludes land use change which is captured in the forestry sector deep-dive as part of deforestation emissions

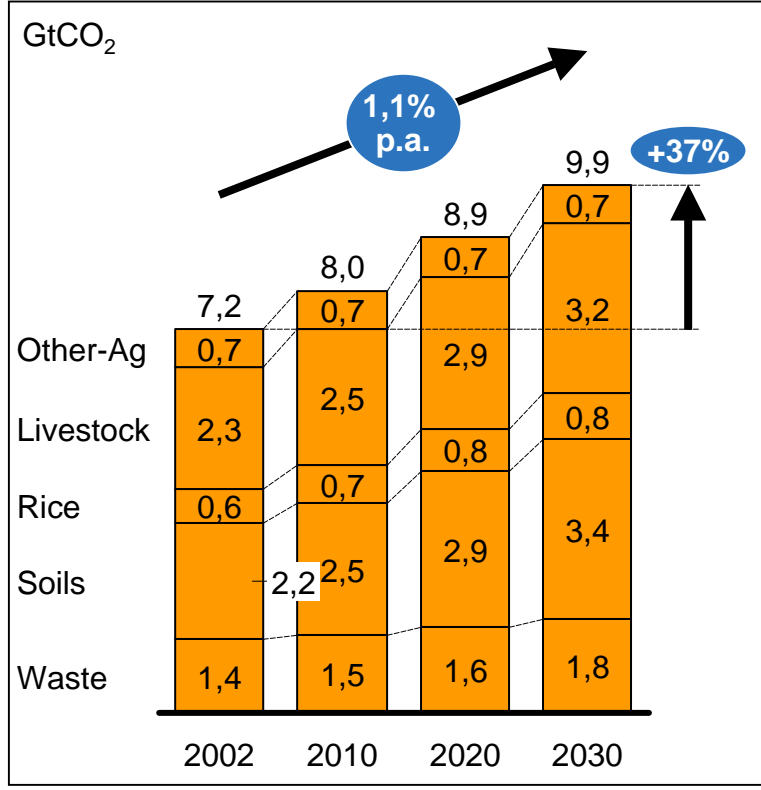
Source: EPA

BAU development in the agriculture and waste sector

World population



Emissions

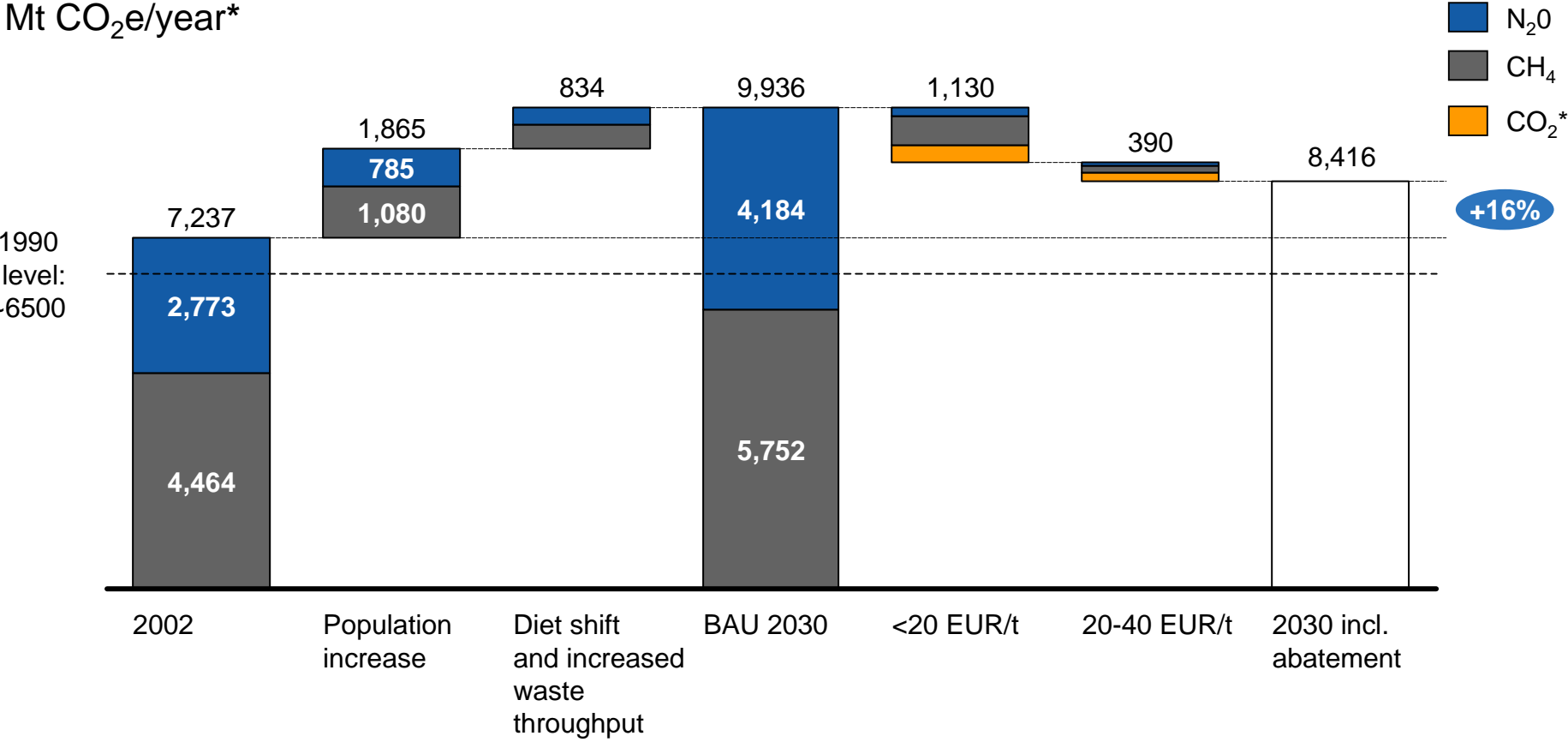


The agriculture and waste sector is expected to grow 37% by 2030, relatively more than total population due to a shift in nutritional habits (more meat) and an increase in waste production per capita

Source: IEA

Emissions from agriculture and waste, and abatement opportunities

Mt CO₂e/year*



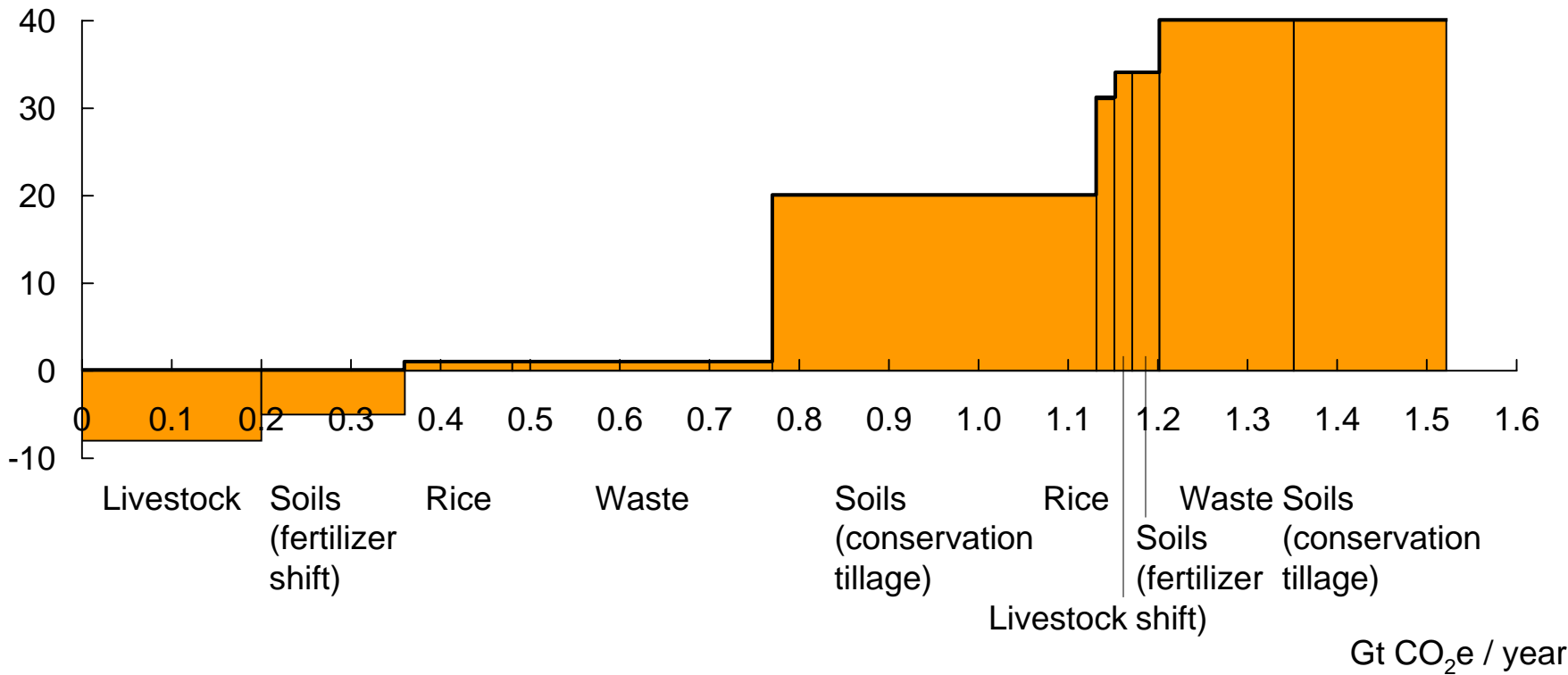
- Emissions from the agriculture/waste sector are projected to grow 37% by 2030 under BAU
- If the maximum practical abatement potential at less than EUR 40 per ton is realized, emissions growth could be held to 16%

* CO₂ emissions from conversion of forests to agriculture are allocated to the forestry sector, but CO₂ abatement from sequestering atmospheric CO₂ through conservation tillage is included in this sector

Source: EPA; Pacala

Marginal abatement cost curve for the agriculture and waste sector 2030

EUR/t CO₂e



- **Sequestration of atmospheric CO₂ 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

Agriculture and waste sector feasible abatement opportunities

Gt CO₂e/year, 2030

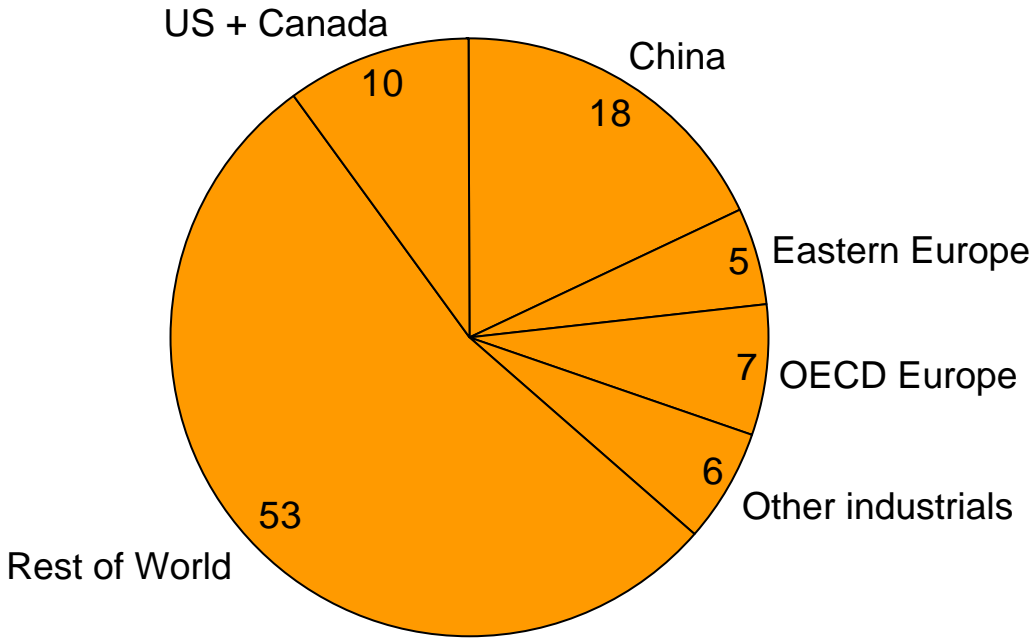
Agriculture	Description	Technical maximum potential	Assumed realistic abatement potentials				
			At	< 20	< 40	EUR/t	
Rice	<ul style="list-style-type: none"> Reduced flooding of rice fields Fertilizer shift <ul style="list-style-type: none"> Ammonium sulfate Slow release fertilizer 	0.8		0.12	0.14		
	Livestock	<ul style="list-style-type: none"> Improved feeding Drugs: antibiotics, bST Manure management 	1.1		0.20	0.22	
		Soils	<ul style="list-style-type: none"> Fertilizer shift Conservation tillage: cultivation of soils with reduced or no plowing 	2.5		0.52	0.72
Waste							
Landfills	<ul style="list-style-type: none"> Capture and use CH₄ with system of pipes and wells Reduce landfills by recycling 	0.7		0.19	0.24		
	Wastewater	<ul style="list-style-type: none"> Improved filtering/treatment to reduce amount of decomposable substances Anaerobic digesters to extract CH₄ 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/tCO₂e

100% = 1.5 Gt CO₂e

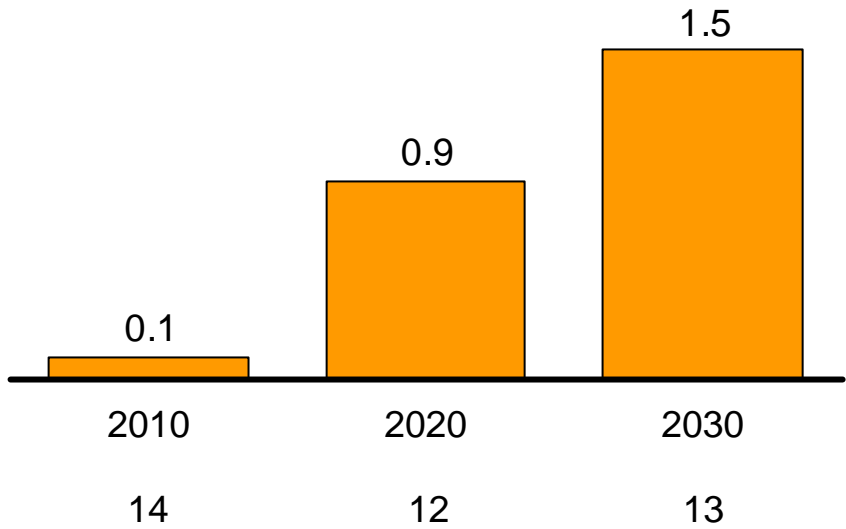


Most of the abatement opportunities are in developing Countries, in line with current emissions distribution

Development of abatement opportunities over time

Gt CO₂e

Opportunities <40 EUR/t CO₂e



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

Average abatement cost
EUR/t CO₂e

Overview

Details of abatement opportunities

Appendix

Agriculture abatement opportunities – Rice

Gt CO₂e/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	<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 ₂ O 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 CO₂e/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	<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 CO₂e/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	<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 CO₂e/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	<40 EUR/t
Capture and/or use CH₄	<ul style="list-style-type: none"> Build system of wells and pipes in the landfill to collect and flare CH₄, with some additional equipment, the CH₄ may be compressed and used*** 	<ul style="list-style-type: none"> 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	<ul style="list-style-type: none"> Split waste and recycle or treat components 	<ul style="list-style-type: none"> 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 CH₄ 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 CO₂e/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	<40 EUR/t	
Improved treatment	<ul style="list-style-type: none"> Better filtering of wastewater reduces amount of decomposable substances in the water and thus the emissions 	<ul style="list-style-type: none"> Already in use in some countries 	0.3	}	0.6	0.1 (17%)	0.2 (33%)
Digesters	<ul style="list-style-type: none"> Let wastewater emit CH₄ in anaerobic digesters before releasing it out of the sewage system 	<ul style="list-style-type: none"> 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

Overview

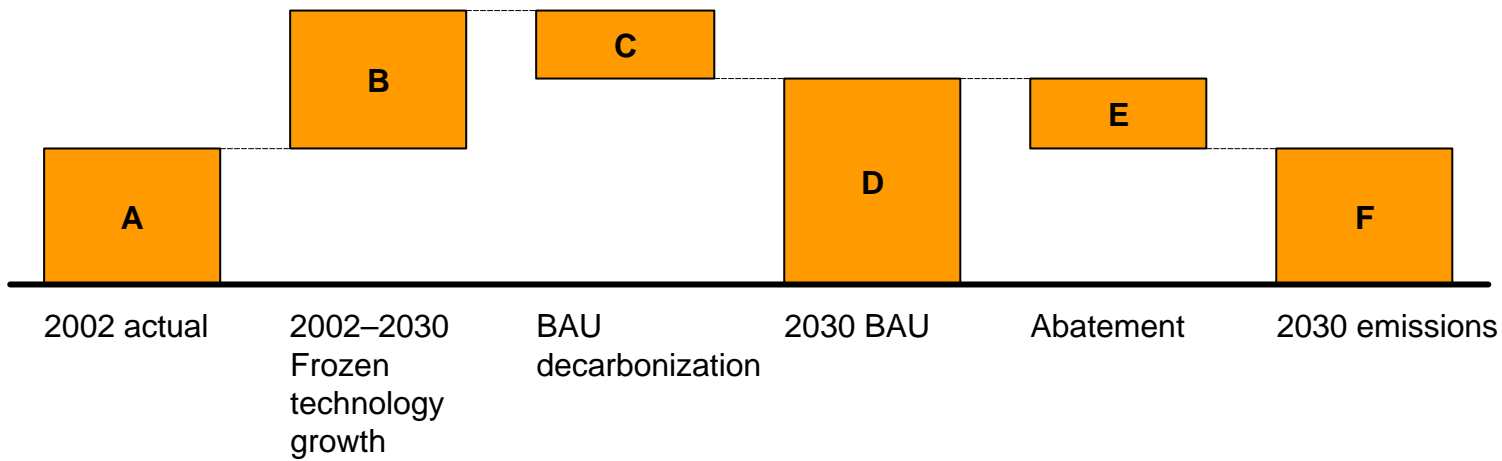
Details of abatement opportunities

Appendix

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 CO₂e 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	<ul style="list-style-type: none"> N/A 	<ul style="list-style-type: none"> EPA*
B. Fixed carbon intensity	<ul style="list-style-type: none"> Scaled by global population growth 	<ul style="list-style-type: none"> UN
C. BAU Decarbonization	<ul style="list-style-type: none"> Residual 	<ul style="list-style-type: none"> N/A
D. 2030 BAU emissions	<ul style="list-style-type: none"> N/A 	<ul style="list-style-type: none"> EPA*
E. Abatement	<ul style="list-style-type: none"> Regional abatement assumed proportional to BAU emissions 	<ul style="list-style-type: none"> EPA*, realization rate estimated for “aggressive policy” scenario
F. Potential emissions in 2030	<ul style="list-style-type: none"> Residual 	<ul style="list-style-type: none"> N/A

* Primary source is the June 2006 “Global Mitigation of Non-CO₂ Greenhouse Gases” report

- 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