The TIMES Integrated Analysis Model: Update and sample results

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Map of presentation

1. The TIMES Integrated Assessment Model (TIAM), and the EMF-22 objectives.
2. Brief summary of TIAM database.
3. New options introduced since May 2005.
4. Base Case.
5. Results: Base case vs. alternate scenarios.
6. Future work: 2005, 2006.
7. Conclusions

Appendix: additional details on assumptions and results

I. TIMES Integrated Assessment Model

- Global TIMES model with 15 regions linked by energy and emission trading
- Climate Module:

  Emissions→ Concentrations → Forcing → Global temperature
  - Constraints on CO2-equivalent concentration possible
  - Constraints on radiative forcing possible
  - Constraint on **equilibrium** temperature possible, using approximation
- Stochastic Programming (forthcoming)
- Interface: VEDA-FE, newest version

TIAM for EMF-22

Objectives of EMF-22

1. Climate Stabilisation trajectories in the presence of uncertainty on climate sensitivity (uncertainty range: 1 ºC to 9 ºC for a doubling of CO2 concentration)
2. Transition Policies (horizon: 2015-2035)
3. Other GHG's (black carbon, atmospheric organic carbon)
4. Land use changes

Work Plan for TIAM

1. Add emissions and mitigation options for CH_4 and N_2O
2. Experiment with uncertain climate sensitivity parameter
3. Review/revise resources, upstream, and electricity supply
4. Produce results for EMF-22, publications
5. Transition Policies (if time permits)?

II. TIAM database in brief

CRUDE OIL (21)	
Conventional (9)	
Bitumen (very heavy) (6)	
Oil sands (3)	
Oil shales (3)	
NATURAL GAS (11)	
Conventional (9)	
Not connected (1)	
Not conventional (1)	
COAL (4)	
Brown (2)	
Hardcoal (2)	

- Primary fossil extraction
  - Cumulative resource constraint, calibrated to international literature
  - Different types: located, reserve growth, new discovery, not connected (gas), unconventional
  - Up to three stepped supply curve for each one
- Renewable sources
  - Wind (4), hydro (2), geothermal (3), solar (2), biomass (8 incl. industry, municipal, crop, solid, liquid)
- Upstream
  - Flexible oil refinery produces 17 RPP's
  - Natural gas: pure or mixed with H_2 (<15%)
  - Liquefied natural gas
  - H_2 production via reforming and via electrolysis, w/wo CO_2 capture

TIAM database in brief

- Electricity generation
  - Six time slices (3 seasons x day/night)
  - Cogeneration (centralized, industry, and upstream sectors)
  - CO_2 capture
- End-uses
  - 42 energy service demands
  - 5 sectors (RES,COM, AGR, IND, TRA)
- Traded commodities
  - Coal: exogenous
  - Oil: exogenous control of OPEC oil production, endogenous pricing
  - Gas, LNG, Emission permits: endogenous prices and quantities
  - Electricity: no international trade for now. Some trading will be introduced between specific pairs of regions (e.g. Canada-USA)

TIAM database in brief (2)

- Emissions (fuel consumption + process emissions)
  - CO_2, CH_4 (abatement options included)
  - N_2O (abatement options forthcoming)
- Reduction options
  - Many technology and fuel substitution possibilities in all sectors
  - Energy conservation options in end-use sectors
  - CO_2 capture from power plants, upstream processes, H_2 production
  - Geological & ocean sequestration of CO_2 calibrated to literature: saline aquifers (1), oil and gas wells (5), deep ocean (1), CBM (2)
  - Biological sequestration: afforestation options (forthcoming)
  - N_2O abatement at adipic acid (1) and nitric acid (7) plants. Forthcoming

III. CH_4 emissions and reduction options

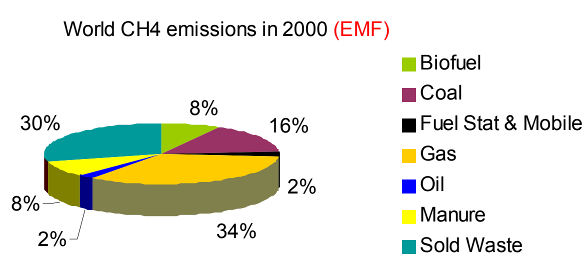
	% total CH4 emissions 2000	% modeled CH4 emissions (TIMES) 2000	Abatement technologies EMF	TIMES
Process emissions				
Manure	3.80%	8.40%	5	4*
Landfill	13.20%	29.20%	11	11
Primary oil	1.10%	2.40%	4	4
Coal mining	7.60%	16.30%	8	8
Gas production, transmission and distribution	15.10%	33.50%	35	14*
Energy emissions				
Biofuel combustion	3.60%	8.00%	**	**
Fuel combustion (stationary and mobile)	1.00%	2.20%	**	**
Total	*45.40%*	*100.00%*	*63*	*23*
Non modelled emissions (uncertain)				
Biomass burning	4.60%	na	na	na
Enteric Fermentation	29.40%	na	na	na
Rice	10.90%	na	na	na
Wastewater	9.50%	na	na	na
Total	*54.40%*	*na*	*na*	*na*

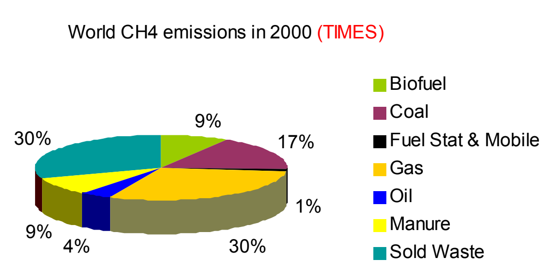
* Some EMF options not modeled due to very high cost or very small potential
** Many energy and technology substitutions.

CH_4 calibration

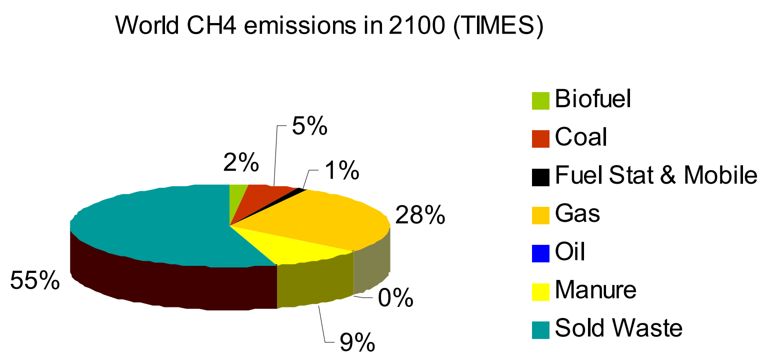
- Two new sectors: landfill, manure
- Emissions from sectors already existing in TIMES were adjusted: upstream (coal, gas, oil), fuel consumption (bio, fossil fuels)
- Emission factors provided by IPCC: were also used to adjust emissions due to fuel consumption
- 2000 emissions: are calibrated to EMF data
- Future emissions: were not "calibrated" and reflect the fact that each EMF modeler is free to define its own reference case
- Largest emitters in 2000: USA, FSU, CHI.
- Largest emitters in 2100: CHI, MEA, FSU, ODA, AFR
- Assumption: future landfill and agriculture emission growth rates after 2020 are extrapolated from the 2010-2020 growth rates proposed by EMF-22 (subject to revision)

CH_4 calibration: EMF / TIMES





CH_4 emissions: 2100



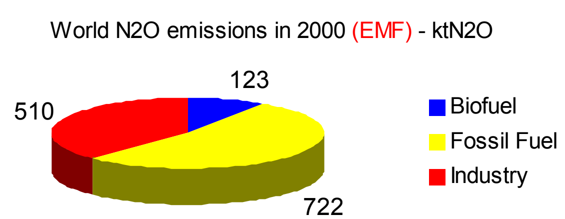
Examples of CH_4 reduction options (see annex for details)

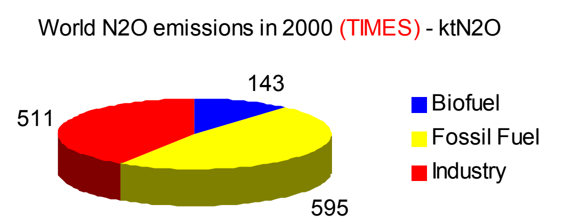
Manure (4)	Farm digesters
Landfill (11)	Flaring, Gas recovery and use, Composting, etc.
Primary oil (4)	Flaring, Gas recovery and use
Coal mining (8)	Flaring, Gas recovery and use, Catalytic oxidation
Gas production, transmission and distribution (14)	Gas use, Inspection and maintenance (leaks), Replacement of technologies (eg. Compressors, Pneumatic devices), etc.

N_2O calibration (overview – in progress)

- Two new sub-sectors: nitric acid industry, adipic acid industry
- Emissions from sectors already existing in TIMES were adjusted: fuel consumption (biofuels, fossil fuels)
- Non-included sectors: agriculture soils, manure, human sewage (no abatement options from EMF sources)
- ⇒ N2O included represents 12% of total N_2O
- 2000 emissions: are calibrated to EMF data
- Future emissions: were not "calibrated" and reflect the fact that each modeler is free to define its own reference case
- Largest emitters: USA, WEU, CHI, IND.
- Assumption: future emi growth rates from nitric and adipic industry after 2020 is extrapolated from the 2010-2020 growth rates proposed by EMF-22 (subject to revision)

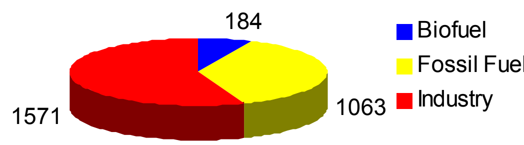
N_2O calibration: EMF / TIMES





N_2O emissions: 2100

World N2O emissions in 2100 (TIMES) - ktN2O



Examples of N_2O reduction options

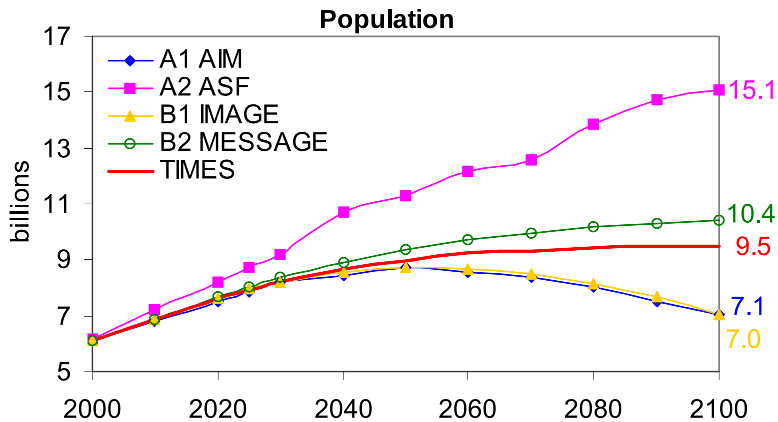
(being tested)

Adipic acid (1)	Thermal destruction
Nitric acid (7)	Different types of catalytic reduction

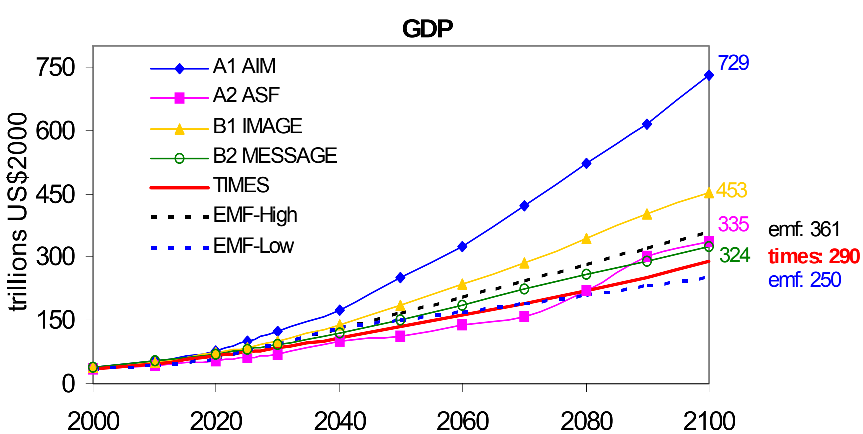
IV. Base case

- Close to the Common POLES-IMAGE (CPI) scenario, itself close to *A1* and *B2* IPCC scenarios wrt CO_2 emissions and primary energy.
- Drivers: Populations, GDP's, technical progress
- Nuclear upper bound: Slow growth until 2040, more rapid growth after 2040 (see Appendix)
- Renewables: Lower than most SRES scenarios (see Appendix)

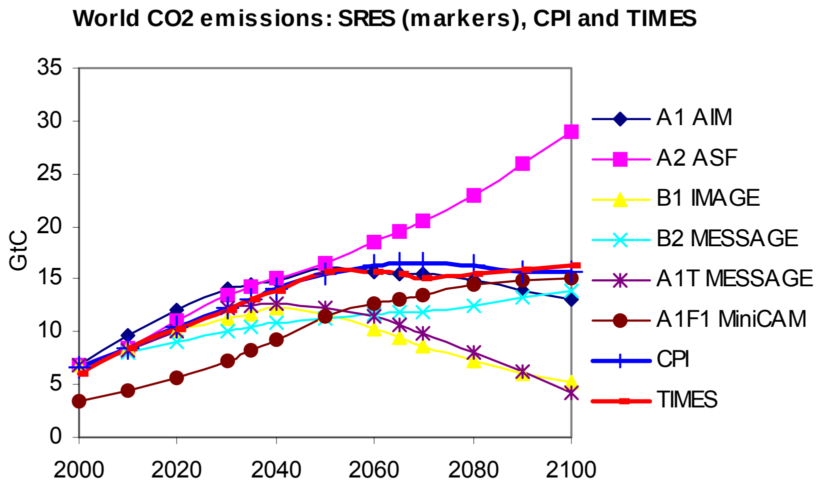
Drivers: Global population



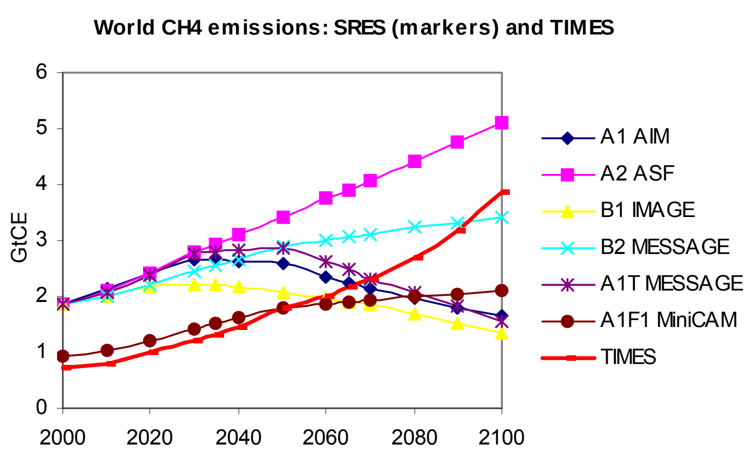
Drivers: Global GDP



Base Case: CO2 emissions



Base Case: CH_4 emissions



Remark: the comparison of TIMES vs IPCC CH4 emissions is subject to revision

VI. Alternate scenarios

alternate scenarios	2010		2100	
1) CO_2 tax only	10	\$/tCO_2	200	\$/tCO_2
2) CH_4 tax only	210	\$/tCH_4	4200	\$/tCH_4
3) Both taxes				
4) Both taxes, no carbon sequestering				

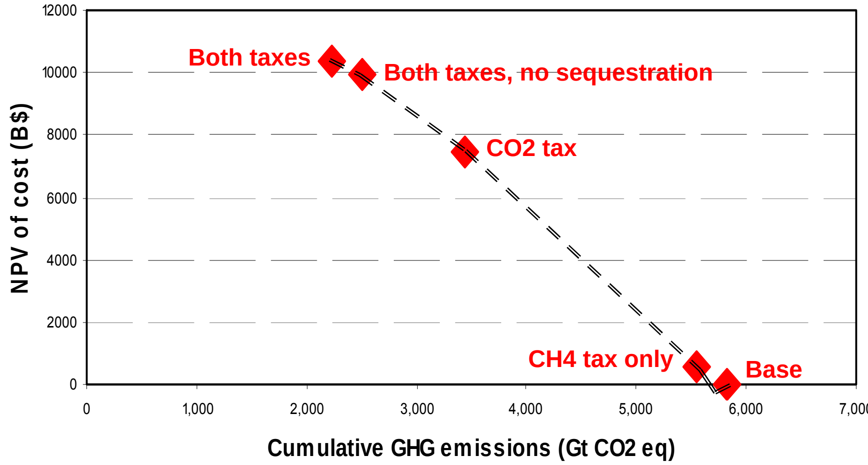
Remark: it was observed that the impacts of the two taxes are close to being additive. Therefore, we present results only for scenarios with the two taxes

Global costs (excluding taxes)

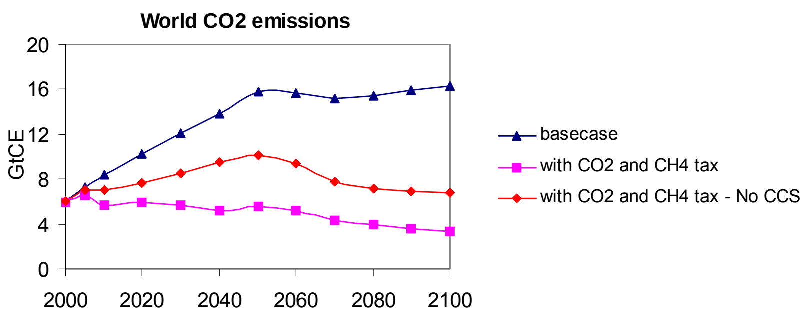
	NPV (B$)	Annualized (B$/year)
Base Case	0	0
CO_2 tax	9935	477
CH_4 tax	541	26
Both taxes	10334	496
Both taxes-no seq.	7454	358

Remarks:
1. The two taxes induce almost additive costs.
2. Global costs are all less than 1% of global GDP

Cost / Emission trade-off

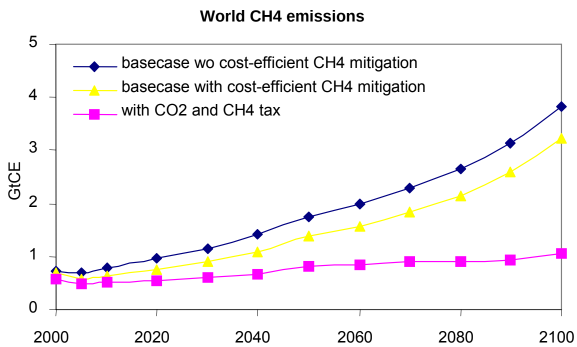


CO_2 emissions



- CO_2 emissions are divided in almost 5 compared to base case in 2100. Sequestration (forest+geological+ocean)= up to 60% of CO_2 reduction
- If sequestration is not available, total CO_2 emissions are reduced by "only" 2.4 compared to base case in 2100

CH_4 emissions



- Some no-regret CH_4 mitigation options penetrate in base case (mostly production of “cheap” gas or electricity)

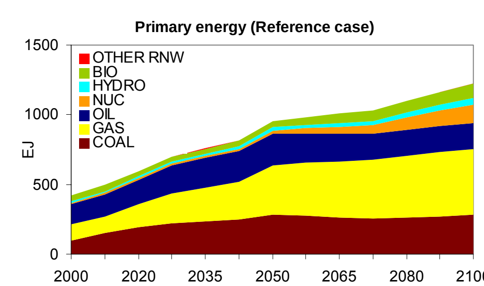
$\Rightarrow$ up to 23% of CH_4 is reduced

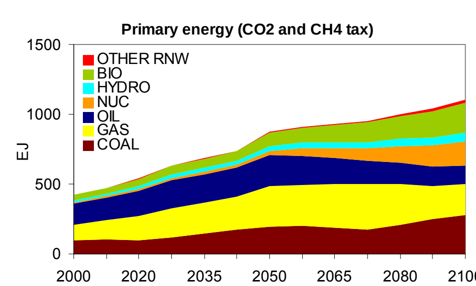
Also observed by US-EPA using MARKAL for the US

Primary energy

- Coal keeps large share when CS is available (gas and coal power plants with CO_2 capture)
- If CS is not available: renewables replace fossil power plants
- Gas: less market share after 2050
- Oil: see final energy

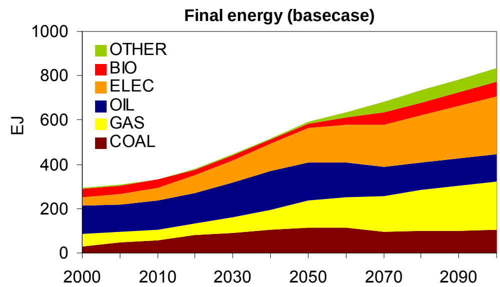
Remark: CH4 tax alone does not modify primary energy structure

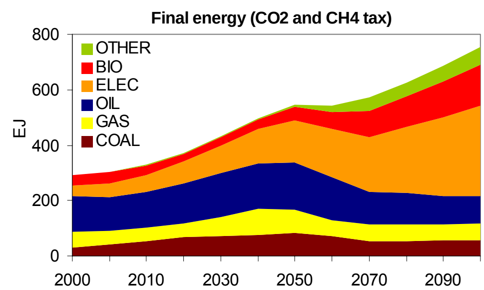




Final energy

- Substitution of fossil fuels by biomass, electricity and hydrogen, especially in IND and TRA
- Other: includes hydrogen consumed by transportation sector (hydrogen from coal and gas with CO_2 capture)
- If CCS is not available: substitution by biomass is higher, gas final consumption remains high, and hydrogen final consumption remains limited (carbon intensive without CCS)





VI. Future work (2005)

1. N_2O abatement: being completed and tested
2. Sequestration by forests: will replace current options with EMF 'scenarios'

Scenario	1	2	3	4	5	6
	5$/tC ++	10$/tC ++	10$/tC +	20$/tC +	100$/tC	75$/tC +
	MtC/yr	MtC/yr	MtC/yr	MtC/yr	MtC/yr	MtC/yr
2000	0	0	0	0	0	0
2010	85	146	142	284	967	778
2020	168	282	235	448	1,346	1,057
2030	267	424	315	562	1,253	981
2040	359	591	344	638	1,011	753
2050	466	749	363	647	683	526
2060	669	1,046	462	782	691	552
2070	920	1,434	577	938	684	582
2080	1,251	1,886	674	1,092	641	513
2090	1,673	1,779	842	1,288	735	576
2100	1,477	1,503	926	1,272	521	509
cum 2050	**13456**	**21921**	**13996**	**25798**	**52601**	**40954**
cum 2100	**73362**	**98397**	**48808**	**79525**	**85321**	**68270**

Future work (2006)

- Policies: Test with global GHG constraints
- Stochastic programming: Experiment with uncertain climate sensitivity
- Review of data: Collaboration with IER-Stuttgart
- Next EMF-22 meeting: winter 2006 (for hedging work group)

VII. Conclusions

- Work is on schedule w.r.t. to EMF-22 objectives
- Model responds as expected. No anomaly.
- New VEDA-FE version required much testing and debugging (Summer 2005). Performs well. A few features yet to be tested with TIAM: adratios, ..

Appendix

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Regions

TIMES regions	EMF regions
AFR	Africa
AUS	Australia/NZ
CAN	Canada
CHI	China
CSA	Latin America/Caribbean + Brazil
EEU	Eastern Europe
FSU	CIS + Russian Federation + Ukraine
IND	India
JAP	Japan
MEA	Middle East (inc OPEC) + Turkey
MEX	Mexico
ODA	South & SE Asia
SKO	South Korea, Rep.
USA	USA
WEU	EU-15 + Non-EU Europe

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Regional CO_2 emissions

Gt CO2	2000	2050	2100
AFR	0.7	2.9	2.8
AUS	0.4	0.7	0.6
CAN	0.5	1.0	1.5
CHI	2.8	8.3	6.0
CSA	0.9	2.6	3.4
EEU	0.6	1.6	2.1
FSU	1.8	6.2	8.6
IND	1.0	5.8	6.2
JPN	1.2	1.8	1.7
MEA	0.9	3.6	4.5
MEX	0.4	0.8	0.8
ODA	1.4	6.5	6.5
SKO	0.5	2.7	2.9
USA	5.9	8.1	7.6
WEU	3.5	5.1	4.5
Total	22.3	57.8	59.6

GtC-eq	2000	2050	2100
AFR	0.18	0.80	0.75
AUS	0.11	0.18	0.16
CAN	0.13	0.26	0.41
CHI	0.77	2.26	1.64
CSA	0.23	0.72	0.93
EEU	0.17	0.45	0.56
FSU	0.50	1.69	2.34
IND	0.27	1.59	1.68
JPN	0.32	0.48	0.47
MEA	0.26	0.98	1.21
MEX	0.10	0.23	0.22
ODA	0.37	1.77	1.77
SKO	0.12	0.75	0.79
USA	1.60	2.20	2.08
WEU	0.95	1.40	1.23
Total	6.09	15.75	16.27

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Regional CH_4 emissions

Mt CH4	2000	2050	2100
AFR	7.9	28.0	90.6
AUS	1.9	5.9	24.2
CAN	3.5	5.5	18.3
CHI	17.3	73.6	245.7
CSA	7.8	31.2	50.8
EEU	5.0	8.5	11.3
FSU	26.6	98.6	119.1
IND	5.6	11.7	21.1
JPN	0.6	0.2	0.2
MEA	8.1	48.6	85.8
MEX	2.3	4.5	5.0
ODA	8.3	32.5	82.6
SKO	0.4	0.7	1.1
USA	20.0	25.2	19.3
WEU	11.1	11.0	11.4
Total	126.3	385.6	786.7

GtC-eq	2000	2050	2100
AFR	0.05	0.16	0.52
AUS	0.01	0.03	0.14
CAN	0.02	0.03	0.10
CHI	0.10	0.42	1.41
CSA	0.04	0.18	0.29
EEU	0.03	0.05	0.06
FSU	0.15	0.56	0.68
IND	0.03	0.07	0.12
JPN	0.00	0.00	0.00
MEA	0.05	0.28	0.49
MEX	0.01	0.03	0.03
ODA	0.05	0.19	0.47
SKO	0.00	0.00	0.01
USA	0.11	0.14	0.11
WEU	0.06	0.06	0.07
Total	0.72	2.21	4.51

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Regional N_2O emissions

Mt N2O	2000	2050	2100
AFR	0.05	0.08	0.13
AUS	0.01	0.02	0.01
CAN	0.02	0.03	0.04
CHI	0.18	0.29	0.35
CSA	0.06	0.11	0.13
EEU	0.03	0.05	0.07
FSU	0.03	0.07	0.09
IND	0.10	0.18	0.28
JPN	0.05	0.06	0.08
MEA	0.03	0.06	0.07
MEX	0.02	0.02	0.03
ODA	0.06	0.13	0.13
SKO	0.04	0.09	0.12
USA	0.29	0.38	0.77
WEU	0.26	0.32	0.34
Total	1.25	1.90	2.63

GtC-eq	2000	2050	2100
AFR	0.004	0.007	0.011
AUS	0.001	0.002	0.001
CAN	0.002	0.003	0.003
CHI	0.015	0.024	0.030
CSA	0.005	0.009	0.011
EEU	0.003	0.004	0.006
FSU	0.003	0.006	0.008
IND	0.008	0.016	0.023
JPN	0.004	0.005	0.007
MEA	0.002	0.005	0.006
MEX	0.001	0.002	0.003
ODA	0.005	0.011	0.011
SKO	0.004	0.008	0.010
USA	0.025	0.032	0.065
WEU	0.022	0.027	0.029
Total	0.106	0.160	0.223

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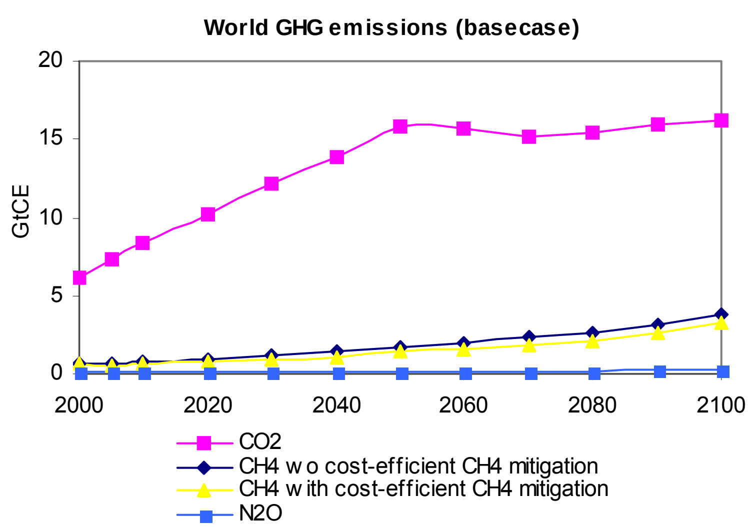
GHG emissions (in C-eq)



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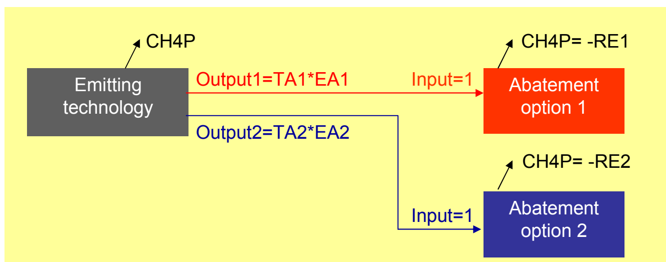
CH_4 abatement options: modeling approach

Each option is characterized by:
- Technical applicability: TA
- Economic applicability: EA
- Reduction efficiency: RE

Abatement potential =
TA * EA * RE * base emissions

Emissions to which a given option applies based on economic/infrastructure factors =
TA * EA * base emissions

➡ Free competition between options could not be modelled given lack of data from EMF



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CH_4 reduction options

Manure	
ACH4MAN01	Farm Scale Digesters-A (cool climate)
ACH4MAN02	Farm Scale Digesters-A (warm climate)
ACH4MAN03	Farm Scale Digesters-B (cool climate)
ACH4MAN04	Farm Scale Digesters-B (warm climate)
Not modeled	*Centralized Digesters (cool climate)*
Landfill	
RCH4WLF01	Anaerobic digestion 1 (AD1)
RCH4WLF02	Anaerobic digestion 2 (AD2)
RCH4WLF03	Composting (C1)
RCH4WLF04	Mechanical Biological Treatment
RCH4WLF05	Heat Production
RCH4WLF06	Increased Oxidation
RCH4WLF07	Direct Gas Use (profitable at base price)
RCH4WLF08	Electricity Generation
RCH4WLF09	Direct Gas Use (profitable above base price)
RCH4WLF10	Flaring
RCH4WLF11	Composting (C2)
Primary oil	
UNCH4OIL01	Flaring instead of Venting (Offshore)
UNCH4OIL02	Flaring instead of Venting (Onshore)
UNCH4OIL03	Associated Gas (vented) Mix with Other Options
UNCH4OIL04	Associated Gas (flared) Mix with Other Options
	+ Same options for OPEC
Coal mining	
UNCH4COA01	Degasification and Pipeline Injection
UNCH4COA02	Enhanced Degasification, Gas Enrichment, and Pipeline Injection
UNCH4COA03	Catalytic Oxidation (US)
UNCH4COA04	Flaring
UNCH4COA05	Degasification and Power Production – A
UNCH4COA06	Degasification and Power Production – B
UNCH4COA07	Degasification and Power Production – C
UNCH4COA08	Catalytic Oxidation (EU)
	+ Same options for OPEC

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CH_4 reduction options (2)

Gas production, transmission and distribution	
UNCH4GAS01	P&T - Use gas turbines instead of reciprocating engines
UNCH4GAS02	Prod-D I&M (Pipeline Leaks)
UNCH4GAS03	Installation of Flash Tank Separators (Production)
UNCH4GAS04	Replace high-bleed pneumatic devices with compressed air systems (Production)
UNCH4GAS05	Replace high-bleed pneumatic devices with low-bleed pneumatic devices (Production)
UNCH4GAS06	Dry Seals on Centrifugal Compressors (P&T)
UNCH4GAS07	Catalytic Converter (P&T)
UNCH4GAS08	Portable Evacuation Compressor for Pipeline Venting (P&T)
UNCH4GAS09	Replace High-bleed pneumatic devices with compressed air systems (P&T)
UNCH4GAS10	Replace high-bleed pneumatic devices with low-bleed pneumatic devices (P&T)
UNCH4GAS11	D-D I&M (Distribution)
UNCH4GAS12	D-D I&M (Enhanced: Distribution)
UNCH4GAS13	Electronic Monitoring at Large Surface Facilities (D)
UNCH4GAS14	Replacement of Cast Iron/Unprotected Steel Pipeline (D)
	+ Same options for OPEC
Not modeled	*P&T - Compressors-Altering Start-Up Procedure during Maintenance*
	Prod-D I&M (Chemical Inspection Pumps)
	Prod-D I&M (Enhanced)
	Prod-D I&M (Offshore)
	Prod-D I&M (Onshore)
	Installation of Electric Starters on Compressors (Production)
	Installing Plunger Lift Systems In Gas Wells
	Portable Evacuation Compressor for Pipeline Venting (Production)
	Reducing the Glycol Circulation Rates in Dehydrators (Production)
	Surge Vessels for Station/Well Venting (Production)
	Fuel Gas Retrofit for Blowdown Valve
	Reducing the Glycol Circulation Rates in Dehydrators (P&T)
	P&T-D I&M (Compressor Stations)
	P&T-D I&M (Compressor Stations: Enhanced)
	P&T-D I&M (Enhanced: Storage Wells)
	P&T-D I&M (Pipeline: Transmission)
	P&T-D I&M (Wells: Storage)
	Installation of Flash Tank Separators (P&T)
	Portable Evacuation Compressor for Pipeline Venting (P&T)
	Static-Pacs on reciprocating compressors (P&T)
	Surge Vessels for Station/Well Venting (P&T)

N_2O reduction options (not yet tested)

Adipic Acid	
ICH4ADI01	Thermal Destruction
Nitric Acid	
ICH4NIT01	Grand Paroisse - High Temperature Catalytic Reduction Method
ICH4NIT02	BASF - High Temperature Catalytic Reduction Method
ICH4NIT03	Norsk Hydro - High Temperature Catalytic Reduction Method
ICH4NIT04	HITK – High Temperature Catalytic Reduction Method
ICH4NIT05	Krupp Uhde - Low Temperature Catalytic Reduction Method
ICH4NIT06	ECN - Low temperature selective catalytic reduction with propane addition
ICH4NIT07	Non-Selective Catalytic Reduction (NSCR)

Resources

			US geological survey				
COMPARISON	TIMES	IPCC	*MEAN*	*F95*	*F50*	*F5*	MERGE
TOTAL COAL (EJ)	168298	212193					261518
TOTAL GAS (EJ)	33061	36020					35294
Conventional	*18997*	*17179*	*14395*	*9001*	*13111*	*20258*	*10086*
Unconv. / Undiscov.	*16913*	*18841*					*25208*
TOTAL OIL EJ	42315	35576					20027
Conventional	*15202*	*13562*	*15768*	*9954*	*14454*	*21900*	*8828*
Unconventional	*27113*	*22014*					*11199*

- Gas and coal reserves of TIMES are consistent with other sources
- Oil reserves of TIMES are too high (non-conventional)
  BUT based on reference case results, cumulative consumption of oil up to 2100 is ~ 25000 EJ ⇒ OK

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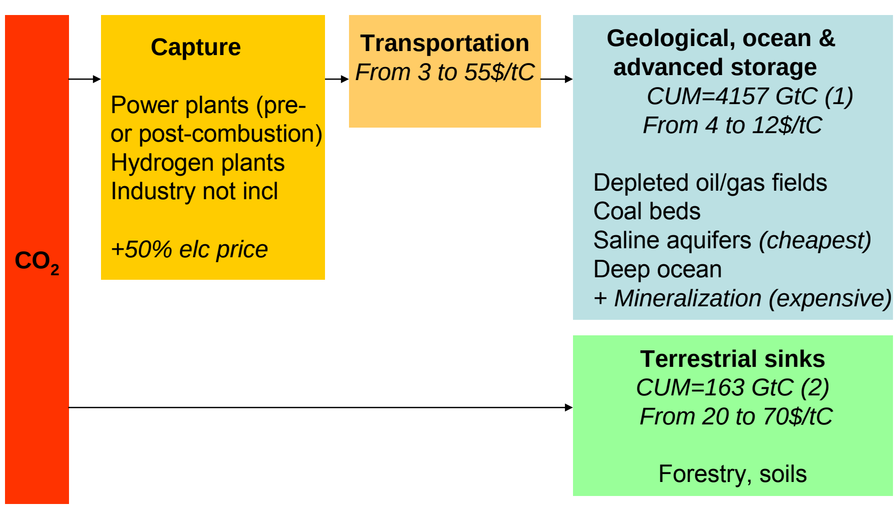
Sequestration



(1) Calibrated to literature (Kauppi and Sedjo, 2001; Herzog et al., 1997)
(2) In the range proposed by IPCC, but very uncertain
Barriers : Needs for more R&D about CCS technologies, reservoirs and biological processes, risk of leakage, permanence

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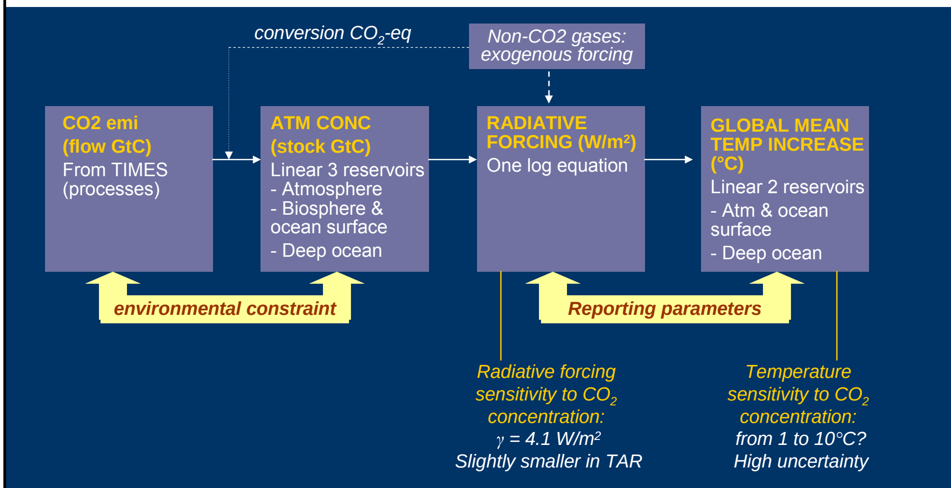
Climate model



Equations

Adapted from the model proposed by Nordhaus and Boyer (1999)

Well documented + simple

Good approximation of those obtained from more complex climate models

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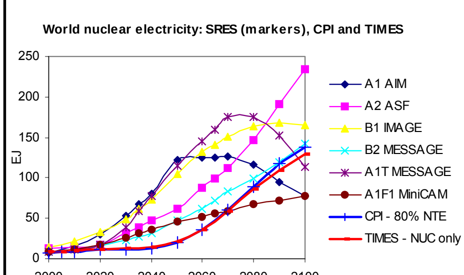
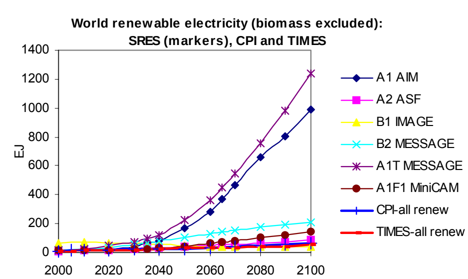
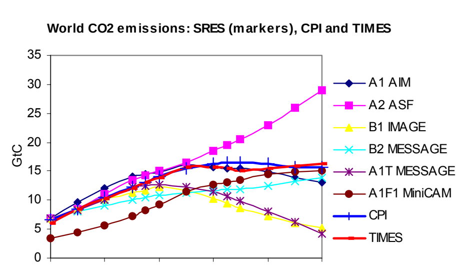
Base case energy/emission characteristics







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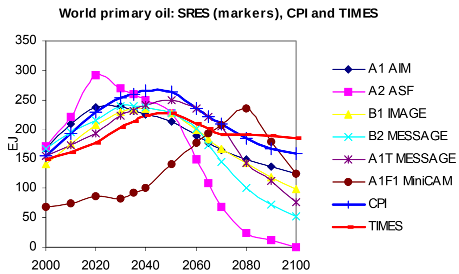
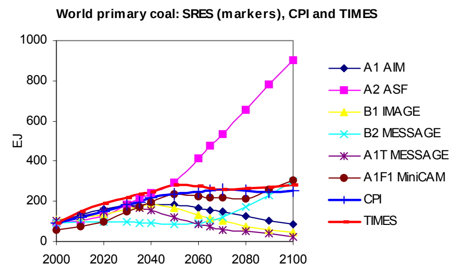
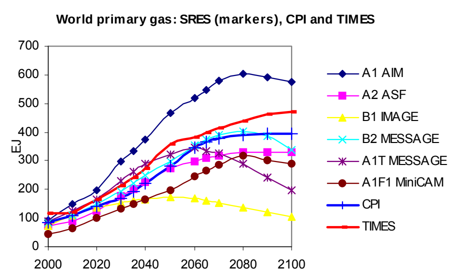
Base case energy/emission characteristics







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Preferred CH_4 abatement options

CO2 and CH4 taxes	*CUM MtCH4*
RCH4WLF03 [CH4- Composting (C1)]	1671
RCH4WLF11 [CH4- Composting (C2)]	1525
RCH4WLF07 [CH4- Direct Gas Use (profitable at base pric	1415
RCH4WLF09 [CH4- Direct Gas Use (profitable above base	1415
RCH4WLF10 [CH4- Flaring]	1411
RCH4WLF08 [CH4- Electricity Generation]	1389
RCH4WLF05 [CH4- Heat Production]	1321
UNCH4COA03 [CH4- Catalytic Oxidation (US)]	930
UNCH4COA07 [CH4- Degasification and Power Production	847
RCH4WLF06 [CH4- Increased Oxidation]	648
UNCH4COA01 [CH4- Degasification and Pipeline Injection]	427
UNCH4GAS12 [CH4- D-D I&M (Enhanced: Distribution)]	302
ACH4MAN02 [CH4- Farm Scale Digesters-A (warm climate	275
UNCH4GAS04 [CH4- Replace high-bleed pneumatic device	272
UNCH4GAS05 [CH4- Replace high-bleed pneumatic device	240
UNCH4GAS11 [CH4- D-D I&M (Distribution)]	240
UPCH4GAS01 [CH4- P&T - Use gas turbines instead of rec	200
UPCH4GAS12 [CH4- D-D I&M (Enhanced: Distribution)]	177
UNCH4GAS06 [CH4- Dry Seals on Centrifugal Compressoı	171
UNCH4GAS07 [CH4- Catalytic Converter (P&T)]	170
UNCH4COA02 [CH4- Enhanced Degasification_ Gas Enric	147
UPCH4GAS11 [CH4- D-D I&M (Distribution)]	142
RCH4WLF01 [CH4- Anaerobic digestion 1 (AD1)]	134
UNCH4GAS01 [CH4- P&T - Use gas turbines instead of rec	133
UPCH4GAS04 [CH4- Replace high-bleed pneumatic device	124
UNCH4GAS10 [CH4- Replace high-bleed pneumatic device	123
ACH4MAN04 [CH4- Farm Scale Digesters-B (warm climate	122
UPCH4GAS05 [CH4- Replace high-bleed pneumatic device	115
RCH4WLF02 [CH4- Anaerobic digestion 2 (AD2)]	114
UPCH4GAS06 [CH4- Dry Seals on Centrifugal Compressoı	104
UPCH4GAS07 [CH4- Catalytic Converter (P&T)]	103
UNCH4GAS08 [CH4- Portable Evacuation Compressor for	98
UNCH4GAS09 [CH4- Replace High-bleed pneumatic devic	88
UNCH4GAS03 [CH4- Installation of Flash Tank Separators	86
UPCH4OIL03 [CH4- Associated Gas (vented) Mix with Othe	78
UNCH4GAS02 [CH4- Prod-D I&M (Pipeline Leaks)]	78
UPCH4GAS10 [CH4- Replace high-bleed pneumatic device	70
RCH4WLF04 [CH4- Mechanical Biological Treatment]	69
UPCH4GAS08 [CH4- Portable Evacuation Compressor for	56
UNCH4OIL03 [CH4- Associated Gas (vented) Mix with Othe	52
UPCH4GAS09 [CH4- Replace High-bleed pneumatic devic	52
UPCH4OIL04 [CH4- Associated Gas (flared) Mix with Other	50
UPCH4GAS03 [CH4- Installation of Flash Tank Separators	45
UPCH4COA07 [CH4- Degasification and Power Production	33
UPCH4GAS02 [CH4- Prod-D I&M (Pipeline Leaks)]	33
UNCH4OIL04 [CH4- Associated Gas (flared) Mix with Other	33
UNCH4COA04 [CH4- Flaring]	32
UPCH4COA01 [CH4- Degasification and Pipeline Injection]	27
UPCH4OIL02 [CH4- Flaring instead of Venting (Onshore)]	17
UPCH4OIL01 [CH4- Flaring instead of Venting (Offshore)]	12
UNCH4OIL02 [CH4- Flaring instead of Venting (Onshore)]	11
UPCH4COA03 [CH4- Catalytic Oxidation (US)]	11
UPCH4COA02 [CH4- Enhanced Degasification_ Gas Enricl	10
UNCH4COA08 [CH4- Catalytic Oxidation (EU)]	9
UNCH4OIL01 [CH4- Flaring instead of Venting (Offshore)]	9
UNCH4COA06 [CH4- Degasification and Power Production	5
UNCH4COA05 [CH4- Degasification and Power Production	3
UPCH4COA04 [CH4- Flaring]	1
ACH4MAN03 [CH4- Farm Scale Digesters-B (cool climate)]	0
ACH4MAN01 [CH4- Farm Scale Digesters-A (cool climate)]	0
UNCH4GAS13 [CH4- Electronic Monitoring at Large Surfac	0
UPCH4GAS13 [CH4- Electronic Monitoring at Large Surfac	0
UNCH4GAS14 [CH4- Replacement of Cast Iron_Unprotect	0
UPCH4GAS14 [CH4- Replacement of Cast Iron_Unprotect	0

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