Biofuels, Land Use Change and Climate Change Mitigation

Some Insights from Global CGE Model Simulations

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Quantifying and Managing Land Use Effects of Bioenergy

Campinas, Brazil

September 19-21, 2011

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Presentation Outline

- Introduction/motivation
- Brief overview of the model/data
- Policies simulated
- Impacts on Land Use Change
- Impacts on Climate Change Mitigation
- Conclusions

General Background – World Bank Studies on Biofuels

Study type	Issues analyzed or investigated
Background or review study	Biofuels: markets, targets and impacts
	Advanced biofuel technologies: status and barriers
	Second generation biofuels: economics and policies
	Are there any surplus grains to produce biofuels?
Partial equilibrium modeling	Quantifying the role of biofuels in the global food crisis
General equilibrium modeling	Biofuels, land-use change and food supply
	Biofuels and climate change mitigation
	Biofuels, global income distribution and poverty
	Biofuel subsidies and import duties
	World oil price and biofuels
	Carbon tax and biofuels

Motivation – Land-use Change & Climate Change Mitigation Study

- One of the stated rationales to promote biofuels in most countries is its potential role in climate change mitigation

- Do biofuels help mitigate climate change? A long ongoing debate in the literature

- When emissions from indirect land-use change are accounted for the answer is uncertain, perhaps depends on what timeframe an analysis considers

  Searchinger et al. (2008) - 167 years
  Fargione et al. (2008) - 48 years (corn ethanol in the US); over 300 years (Amazonian rainforest for soybean), over 400 years (tropical peat land rainforest for palm-oil in Indonesia or Malaysia)
  Danielsen et al. (2009)] - 75 to 93 years

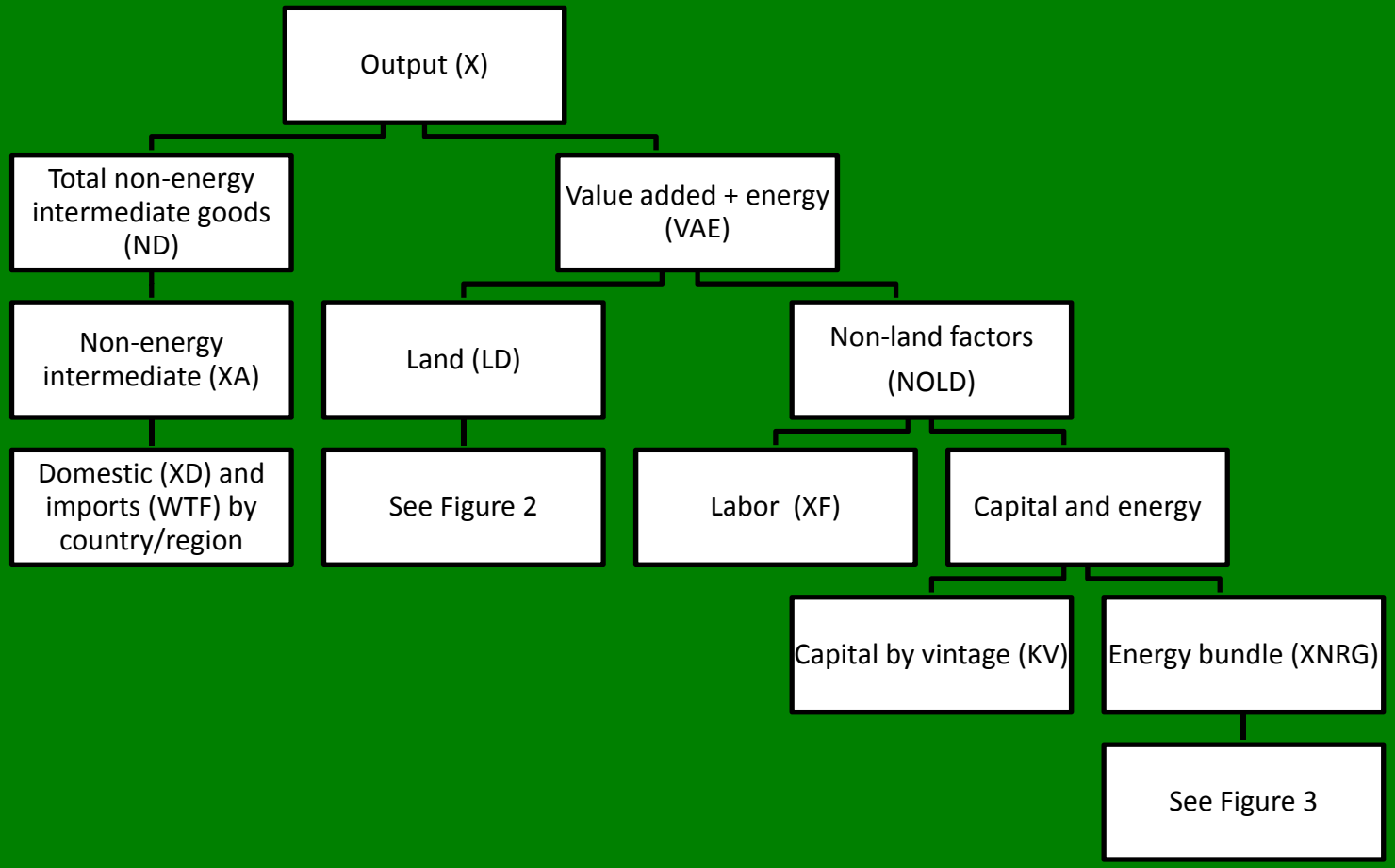
- Several studies have been carried out recently, but results do not seem converging
- Our study aims to contribute to help understand the effects of large-scale expansion of biofuels on land use and GHG emissions at global as well as national/regional levels

Methodology

- Multi-sector, multi-region, global recursive dynamic CGE model
- The model is flexible enough to accommodate new regions/countries or sectors and is calibrated with GTAP database
- Nested CES and CET functional forms to represent production behavior and land supply, respectively
- Detailed representation of land-use and biofuel sectors
- Representation of bilateral and international trade

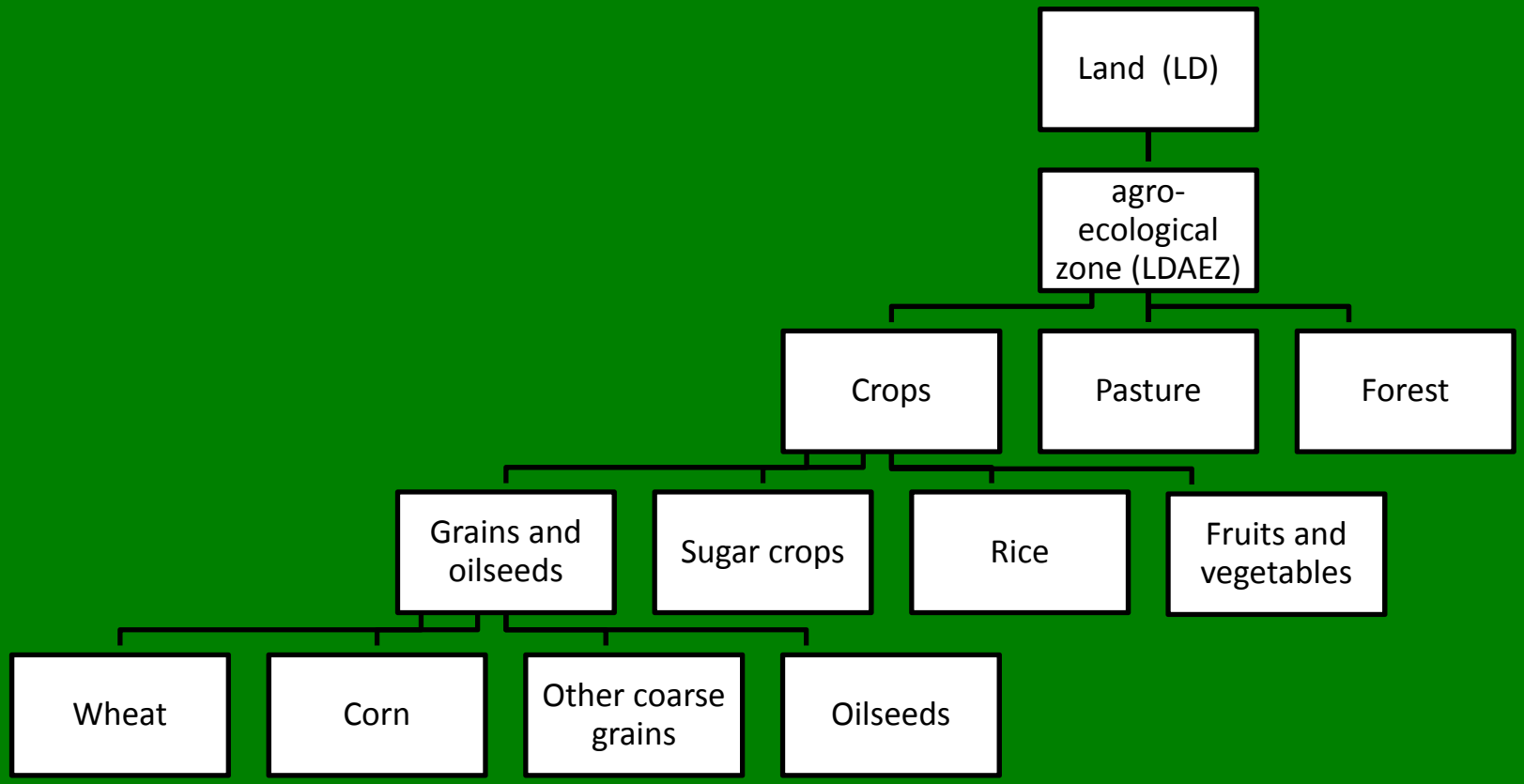
Methodology (Continue …..)

Figure 1: Nested CES structure of the model for production sectors



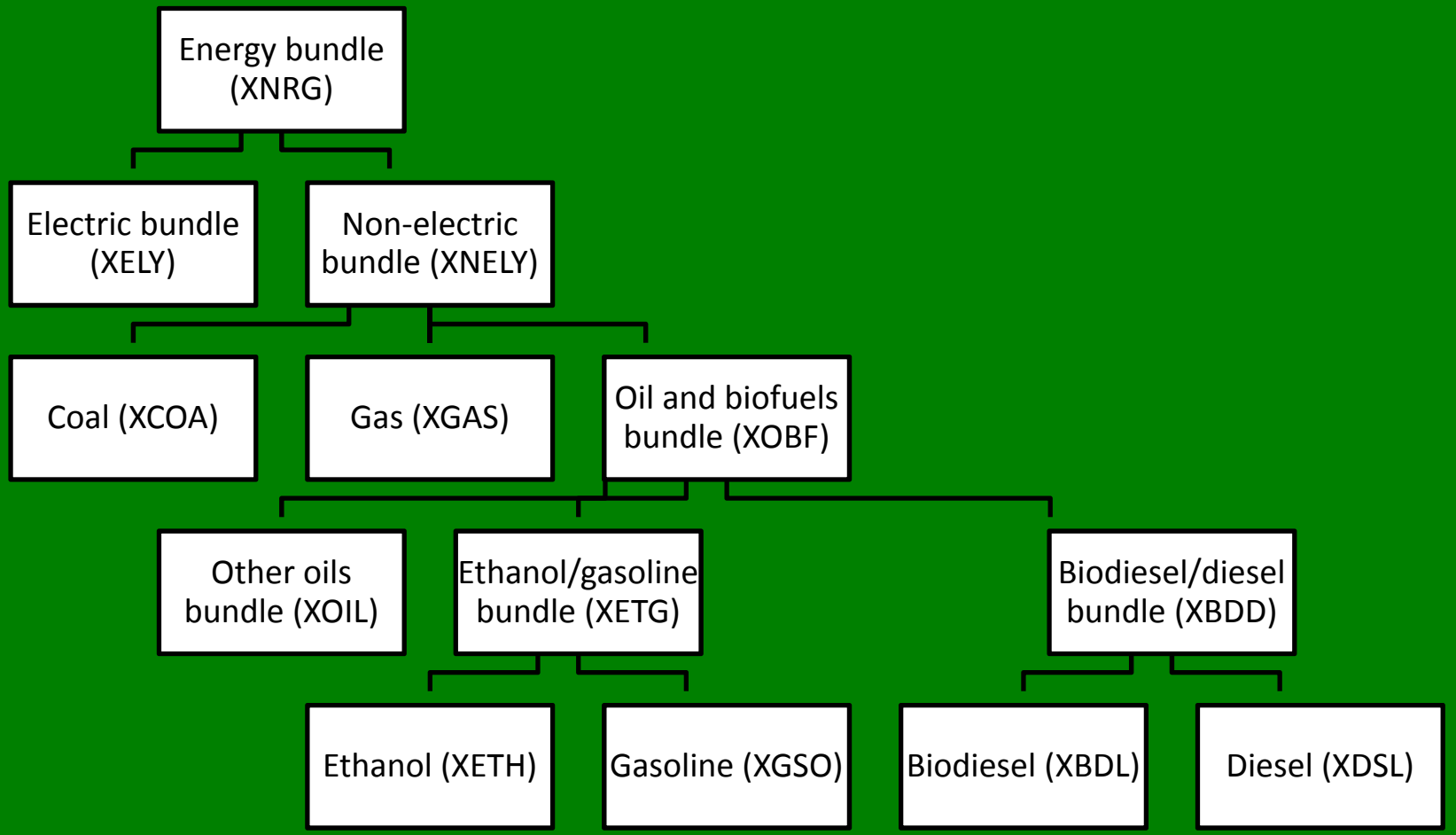
Methodology (Continue …..)

Figure 2: Nested CET structure for land supply



Methodology (Continue …..)

Figure 3: Nested CES structure of the model for energy demand



Data & Parameters

- Data are coming from the GTAP (Global Trade Analysis Project) database (Purdue University, Indiana)

- The database provides SAMs and international trade (bilateral flows, trade barriers)

- Database version 7.1
  - Year 2004
  - 112 countries/regions
  - 57 sectors

Regional and Sectoral Representation

1	Paddy rice
2	Sugar (cane & beet)
3	Vegetables, fruit
4	Wheat
5	Corn
6	Other cereal grains
7	Oilseeds
8	Livestock
9	Sugar Ethanol
10	Corn Ethanol
11	Grains Ethanol
12	Biodiesel
13	Processed food
14	Forestry
15	Coal
16	Crude oil
17	Natural gas
18	Other mining
19	Gasoline
20	Diesel
21	Refined oil
22	Chemicals
23	Other manufacturing
24	Electricity
25	Gas distribution
26	Construction
27	Transport services
28	Other services

1	Australia and New Zealand
2	Japan
3	Canada
4	United States
5	France
6	Germany
7	Italy
8	Spain
9	UK
10	Rest of EU & EFTA
11	China
12	Indonesia
13	Malaysia
14	Thailand
15	Rest of East Asia & Pacific
16	India
17	Rest of South Asia
18	Argentina
19	Brazil
20	Rest of LAC
21	Russia
22	Rest of ECA
23	MENA
24	South Africa
25	Rest of Sub-Saharan Africa

- Computational limitations require aggregation of countries/regions and sectors

(GTAP: 112 regions & 57 sectors

or 112 57 = 6,384 equations for 1*

variable only defined on 2 dimensions)

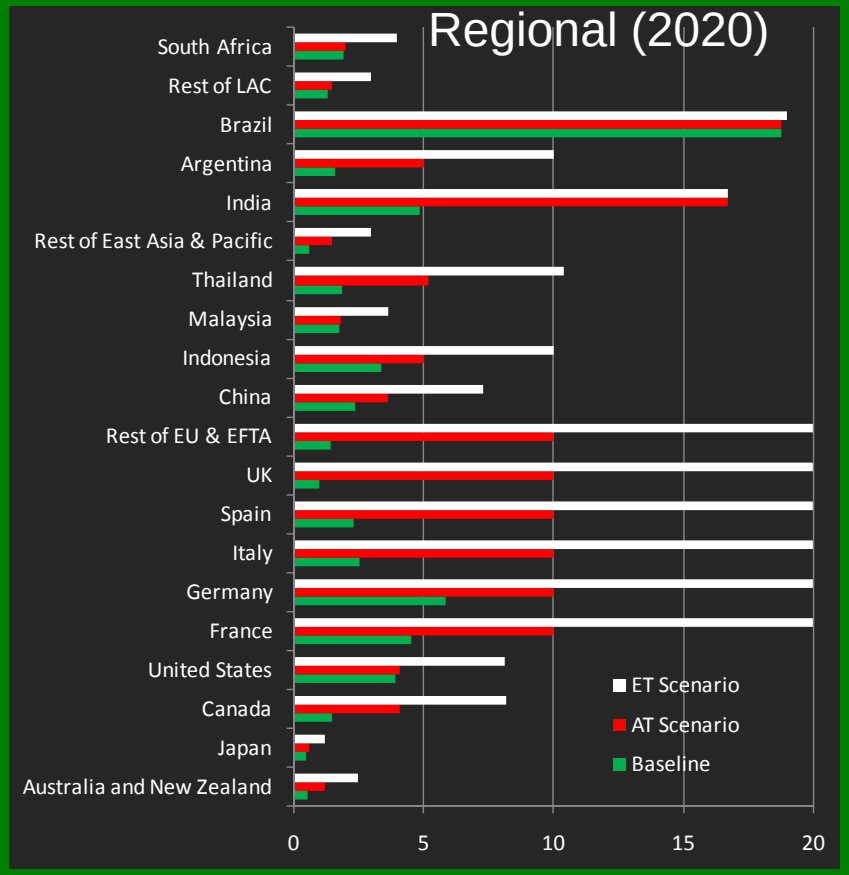
- Focus on main countries/regions producer of biofuels

- Keep as much detail as possible for agriculture (especially biofuel feedstocks) and for energy sectors

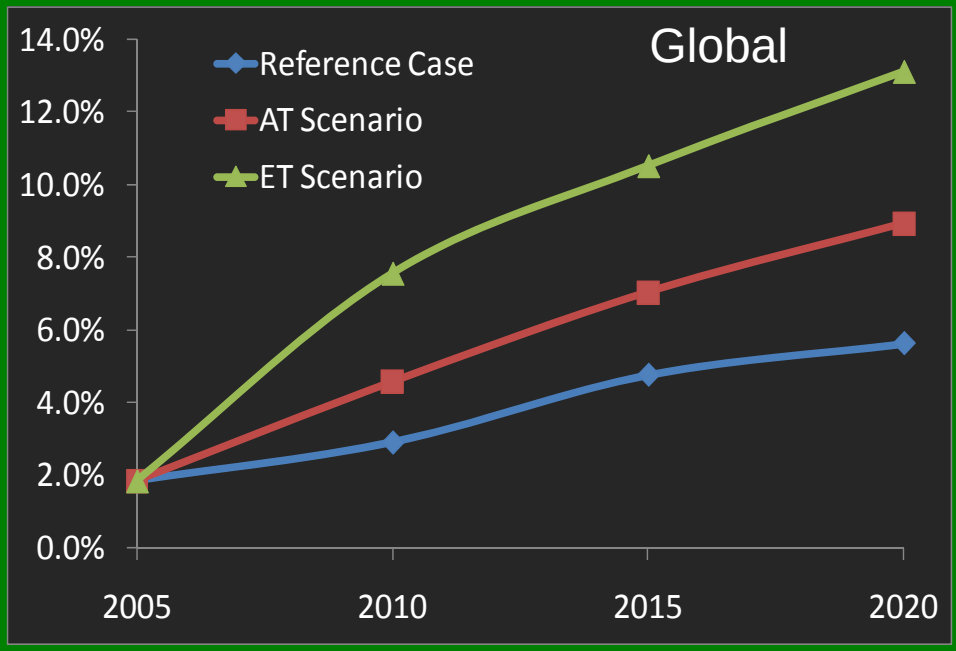
Base Year, Baseline and Scenarios

- Base year: 2004
- Baseline or reference case: A business as usual scenario for 2009-2020 period. It includes policies already in place (e.g., already introduced mandates, subsidies)
- The model is calibrated in such a way that key variables (e.g., oil prices, population, GDP, investments, etc.) retain the historical values for 2004-2009 period
- Two scenarios for biofuel targets:
  - Announced Targets (AT) scenario: all the announced biofuel targets are fully implemented by 2020, starting 2009
  - Enhanced Targets (ET) scenario: all the announced biofuel targets are doubled (except for India – extremely high announced target) and fully implemented by 2020, starting 2009
- Biofuel targets are achieved by introducing direct subsidies to biofuels, the subsidies are financed through an increase of gasoline and diesel tax (government revenue neutrality)

Biofuel Expansion Scenarios



Biofuel penetration



The expansions are modeled as change in biofuels' share in total liquid fuel consumption in road transportation (also defined as biofuel penetration)

Brazil's targets are very close to BAU scenarios; India's announced target is already high, therefore we did not consider doubling of it for India in the 'enhanced target ' scenario

Subsidies and Taxes Required for Meeting Biofuel Targets

Country/Region	Target (%)		Subsidy Rate (%)		Tax Rate (%)	
	AT	ET	AT	ET	AT	ET
Australia and New Zealand	1.23	2.46	36.40	57.71	0.13	0.34
Japan	0.60	1.20	14.80	45.68	0.05	0.19
Canada	4.10	8.20	48.88	68.11	0.50	0.91
United States	4.07	8.14	1.01	28.21	0.04	0.77
France	10.00	20.00	58.33	74.55	1.05	1.80
Germany	10.00	20.00	43.25	65.01	0.95	1.91
Italy	10.00	20.00	65.29	78.38	0.81	1.30
Spain	10.00	20.00	60.99	75.11	0.64	1.48
UK	10.00	20.00	73.14	82.90	0.44	1.06
Rest of EU & EFTA	10.00	20.00	75.60	84.82	0.65	0.97
China	3.65	7.30	18.20	47.22	0.37	1.34
Indonesia	5.00	10.00	19.24	49.16	0.41	1.52
Malaysia	1.81	3.62	1.59	39.31	0.02	0.60
Thailand	5.20	10.40	51.58	73.69	0.91	1.80
Rest of East Asia & Pacific	1.49	2.98	42.00	57.77	0.19	0.38
India	20.00	20.00	58.37	58.92	4.14	4.22
Rest of South Asia	-	-	-	-	-	-
Argentina	5.00	10.00	52.10	70.32	0.86	1.53
Brazil	11.77	23.54	-	2.76	-	0.93
Rest of LAC	1.48	2.96	16.30	44.58	0.10	0.39
Russia	-	-	-	-	-	-
Rest of ECA	-	-	-	-	-	-
MENA	-	-	-	-	-	-
South Africa	2.00	4.00	0.93	10.05	0.03	0.68
Rest of Sub-Saharan Africa	-	-	-	-	-	-

Impacts on Biofuel Production

Global Results in 2020

	2010 Production	Ratio to 2010 production			Ratio to Baseline	
	(Billion Liter)	Baseline	AT	ET	AT	ET
Biofuel	103.8	3.43	6.6	10.8	1.9	3.1
Ethanol	85.7	3.42	6.2	9.3	1.8	2.7
Biodiesel	18.1	3.58	10.4	24.0	2.9	6.7

Even under the baseline scenario, production of biofuels could increase by more than 3 times over the next decade

Production of biofuels could increase approximately 7 and 11 times over the next decade under AT and ET scenarios, respectively

Production of biofuels would be 2 and 3 times higher under AT and ET scenarios as compared to that in baseline scenario in 2020

Impacts on Biofuel Production

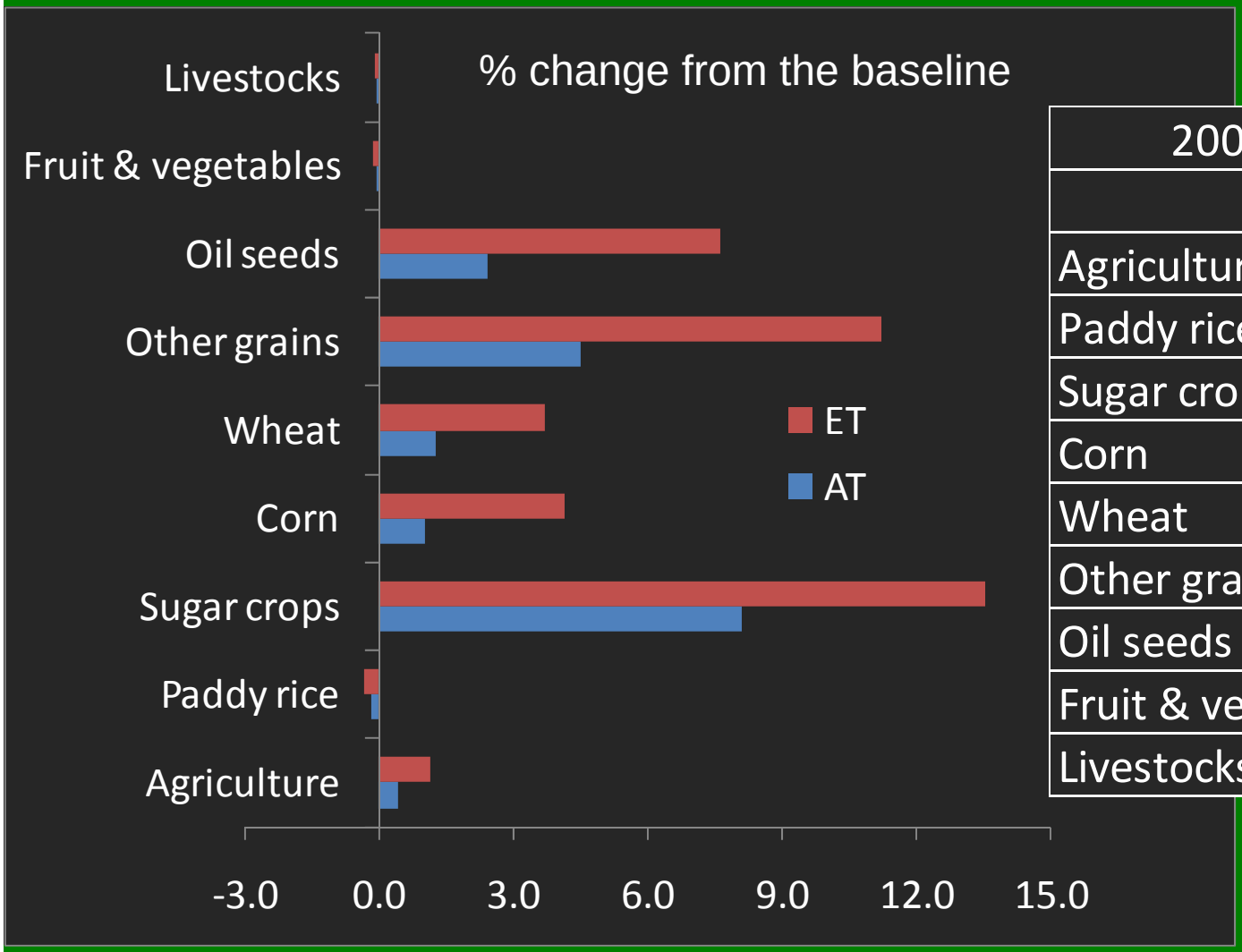
Country/Regional Results in 2020

Country/Region	AT		ET	
	US$ Billions	%	US$ Billions	%
Australia and New Zealand	0.0	20.1	0.3	132.4
Japan	0.0	4.9	0.1	27.4
Canada	0.2	38.3	0.8	156.2
United States	0.3	1.4	1.0	4.9
France	7.4	259.3	19.3	674.0
Germany	3.2	105.3	10.8	356.9
Italy	2.7	315.6	7.0	829.9
Spain	2.8	364.1	7.3	954.0
UK	2.9	492.8	6.6	1112.9
Rest of EU & EFTA	5.6	528.0	14.2	1333.0
China	1.8	40.8	8.4	187.8
Indonesia	0.3	40.1	1.3	190.6
Malaysia	0.0	0.5	0.0	1.3
Thailand	0.4	79.7	1.2	274.9
Rest of East Asia & Pacific	0.1	49.3	0.3	147.3
India	4.9	246.0	4.9	247.5
Rest of South Asia	0.0	56.9	0.2	207.1
Argentina	0.1	42.2	0.6	183.4
Brazil	8.4	41.0	9.9	48.6
Rest of LAC	0.0	5.3	0.2	47.3
Russia	0.0	-1.3	-0.1	-3.0
Rest of ECA	0.0	-0.8	0.0	-2.4
MENA	0.0	-1.3	0.0	-2.9
South Africa	0.0	0.7	0.0	0.9
Rest of Sub-Saharan Africa	0.0	0.5	0.0	-1.5

Brazil, France, India would realize the relatively higher production of biofuels; while biofuel production increase is caused by international trade in Brazil, the increase in other countries is driven by domestic targets

Countries which do not have biofuel targets could experience decrease in production due to increased export demand for their biofuel feedstock, but the reductions are negligible

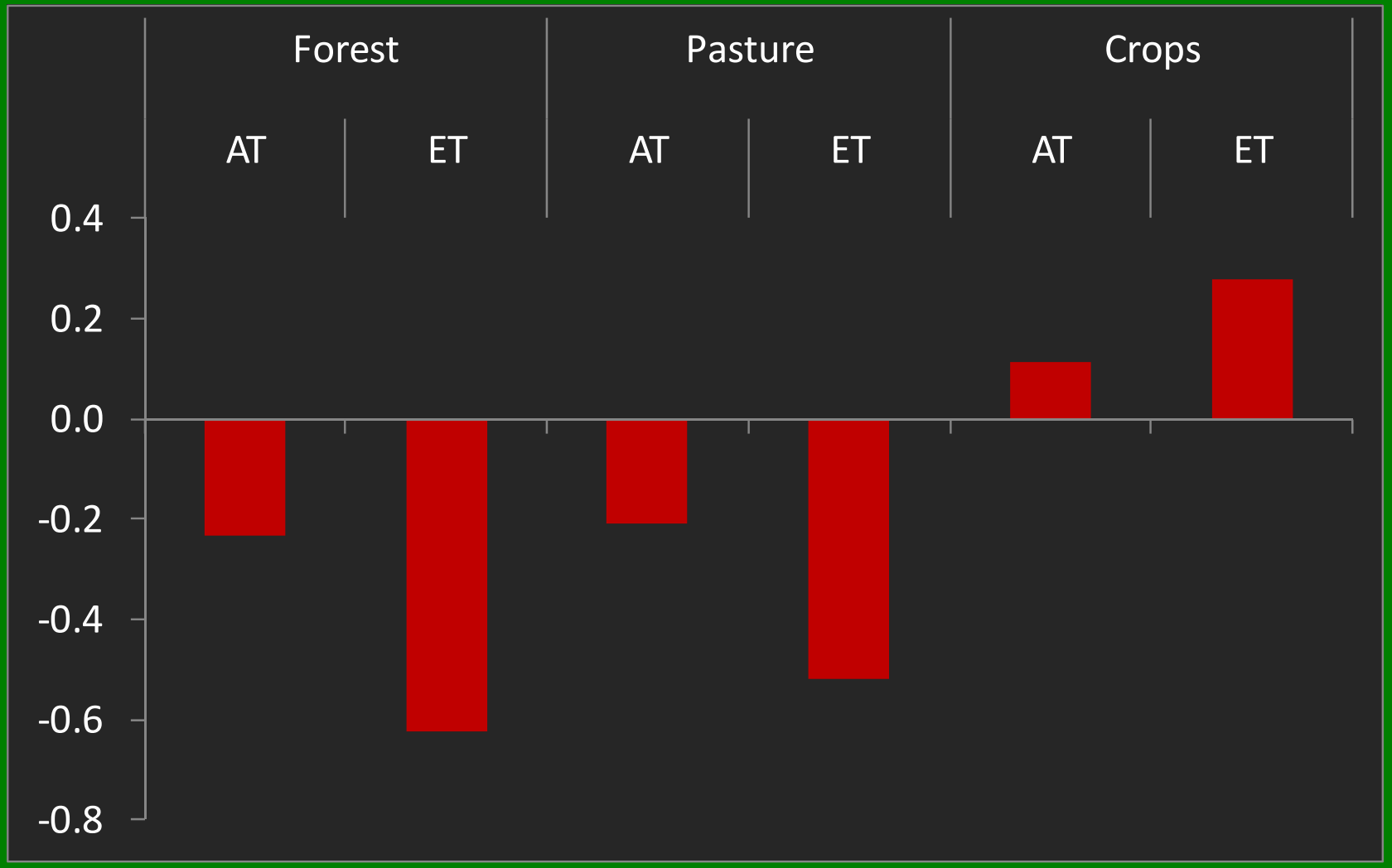
Impacts on Agricultural Production in 2020



2004 Billion US$		
	AT	ET
Agriculture	14.6	38.3
Paddy rice	-0.2	-0.5
Sugar crops	5.8	9.7
Corn	1.4	5.5
Wheat	1.9	5.6
Other grains	3.0	7.5
Oil seeds	4.3	13.6
Fruit & vegetable	-1.0	-1.8
Livestocks	-0.6	-1.3

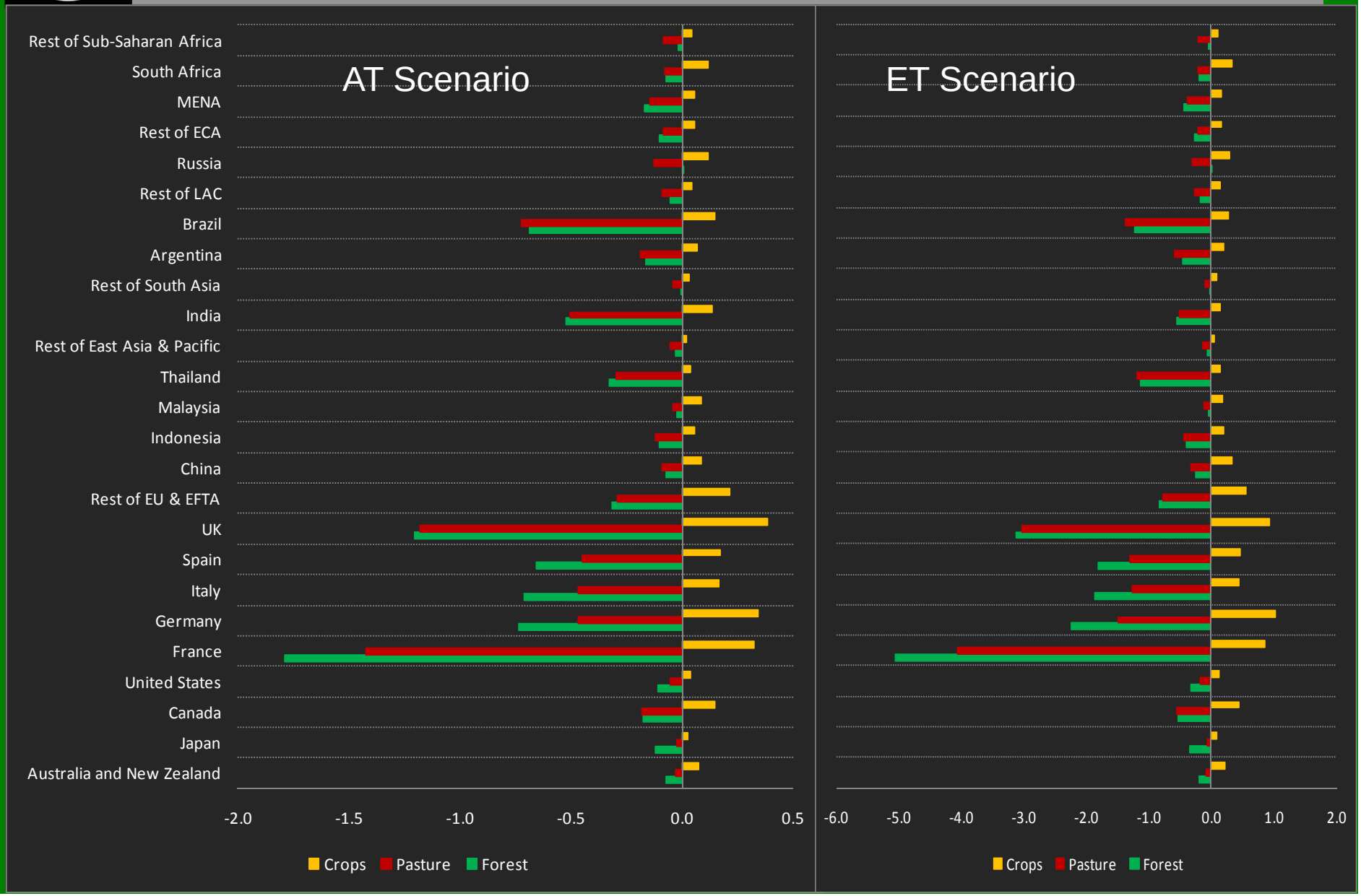
Impacts on Global Land Use

(% change from the baseline in 2020)



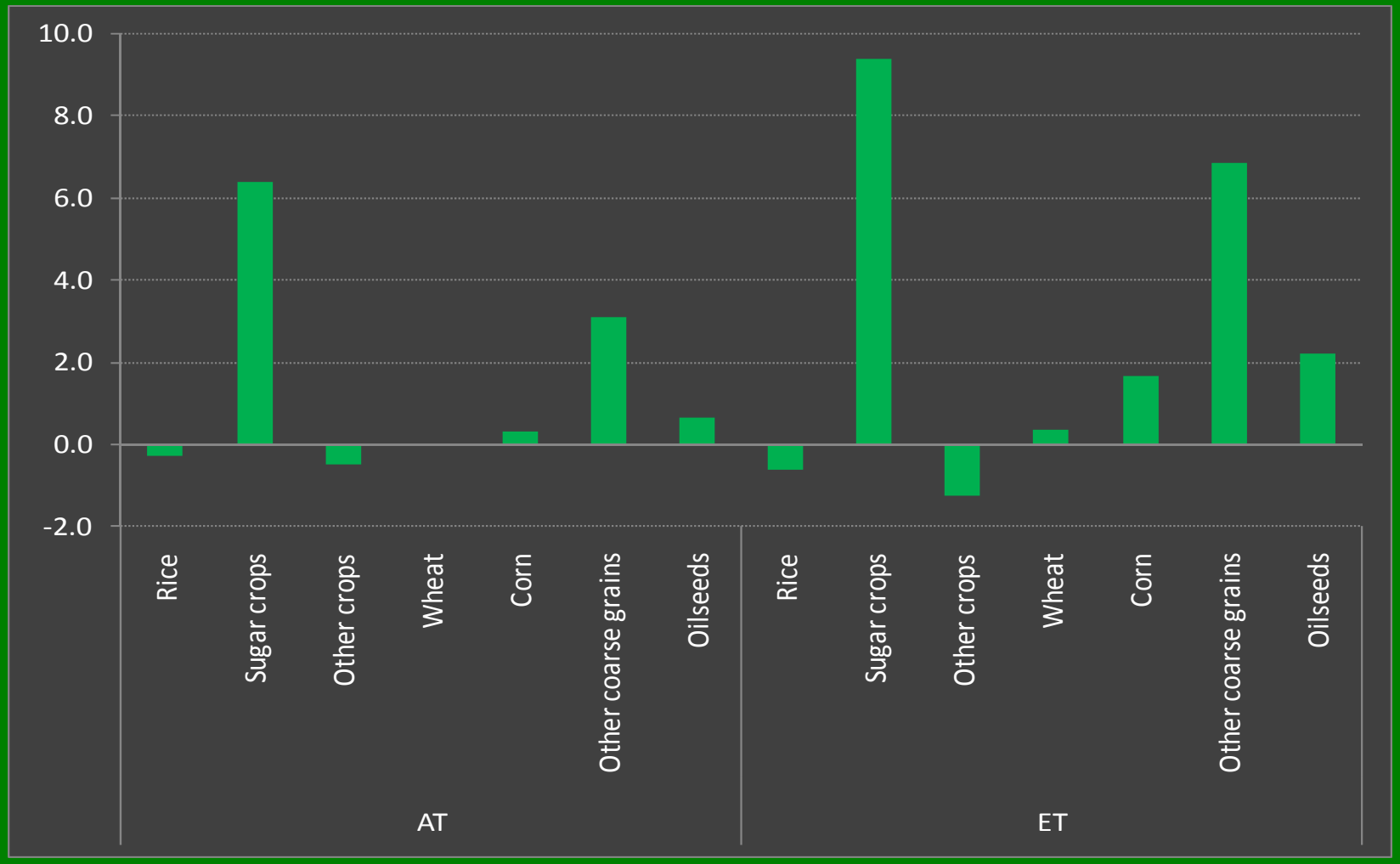
Impacts on Land Use by Country

(% change from the baseline in 2020)



Impacts on Land-Use – Crop Type

% change in global crop lands relative to baseline in 2020 by crop type



Impacts on Land Use (Continue)

% change relative to baseline in 2020 by country and crop type

Country/Regions	Rice		Sugar crops		Other crops		Wheat		Corn		Other coarse grains		Oilseeds	
	AT	ET	AT	ET	AT	ET	AT	ET	AT	ET	AT	ET	AT	ET
Australia and New Zealand	-0.1	-0.5	0.0	0.5	0.0	-0.2	0.4	1.7	0.4	2.4	0.3	1.0	1.3	3.3
Japan	-0.2	-0.6	0.2	1.2	0.0	0.0	0.3	1.3	0.0	0.8	0.5	1.3	0.4	1.1
Canada	0.0	0.0	-0.2	-0.7	-0.3	-1.3	-0.1	0.1	2.4	10.0	0.2	0.4	0.5	0.9
United States	-0.1	-0.4	-0.2	-0.5	-0.1	-0.5	0.4	1.5	0.3	1.4	0.2	0.4	0.5	1.3
France	-3.4	-9.6	36.9	72.7	-2.9	-8.4	0.6	0.2	-3.0	-8.1	3.0	5.5	17.5	46.5
Germany	0.0	0.0	-0.6	-1.3	-1.0	-3.4	3.1	6.7	-1.1	-1.6	3.7	8.2	11.1	34.0
Italy	-0.7	-2.0	-0.9	-2.2	-0.8	-2.2	-0.6	-1.0	-1.5	-3.5	-0.5	-1.0	8.6	20.5
Spain	-1.1	-3.1	-0.7	-1.8	-0.8	-2.4	-0.2	-0.1	-1.4	-2.5	25.6	59.3	0.3	0.8
UK	0.0	0.0	11.0	24.8	-2.4	-6.1	-5.2	-11.2	0.0	0.0	44.6	83.8	3.9	10.9
Rest of EU & EFTA	-0.4	-0.9	1.5	3.7	-0.5	-1.4	0.6	1.6	-1.5	-3.4	6.3	15.4	5.0	13.2
China	-0.1	-0.5	0.0	-0.2	-0.1	-0.8	0.2	0.0	2.6	11.5	-0.6	-3.8	-0.5	-2.5
Indonesia	-0.1	-0.7	5.5	22.1	-0.2	-0.9	0.0	0.0	-0.1	-0.5	0.0	0.0	0.0	0.0
Malaysia	0.2	0.3	0.1	0.2	0.0	-0.1	0.0	0.0	0.0	0.0	0.7	1.7	0.2	0.6
Thailand	-0.6	-2.5	14.1	42.9	-0.6	-2.5	0.0	0.0	0.1	0.7	-0.4	-2.3	-0.5	-2.9
Rest of East Asia & Pacific	-0.1	-0.2	2.1	5.8	0.0	0.0	0.1	0.7	0.5	2.4	0.3	0.8	0.2	0.5
India	-1.1	-1.1	12.4	12.5	-1.4	-1.4	-0.9	-1.0	-0.9	-0.8	-0.8	-0.9	-1.0	-1.0
Rest of South Asia	0.0	-0.2	0.7	2.3	0.0	-0.1	0.1	0.4	0.1	0.5	0.2	0.1	0.7	2.1
Argentina	0.0	-0.6	-0.4	-1.2	-0.1	-0.6	-0.1	-0.3	0.8	3.6	-0.2	-0.5	0.0	-0.1
Brazil	-1.4	-2.5	13.9	15.8	-1.7	-2.7	-2.0	-2.4	-1.9	-2.9	-1.6	-2.4	0.0	2.2
Rest of LAC	-0.1	-0.4	0.0	0.4	0.0	-0.1	0.1	0.6	-0.1	0.0	-0.1	-0.3	1.2	3.6
Russia	-0.1	-0.4	0.0	-0.1	0.1	0.2	0.0	0.0	0.0	0.2	0.1	0.3	1.1	2.8
Rest of ECA	-0.1	-0.4	0.1	0.1	0.0	-0.1	0.1	0.5	0.2	0.8	0.3	0.7	1.2	2.7
MENA	-0.3	-0.6	0.2	0.3	0.0	-0.2	0.3	1.2	0.7	2.5	0.3	0.7	0.7	1.6
South Africa	0.0	0.0	0.2	0.2	0.1	0.2	0.9	2.7	-0.1	0.0	0.6	1.4	0.2	0.6
Rest of Sub-Saharan Africa	0.0	-0.1	0.1	0.3	0.1	0.1	0.6	2.0	-0.1	-0.1	-0.1	-0.3	0.1	0.4

Land for rice decreases in almost all countries; land for other biofuel feedstocks increases in most countries

Comparisons of impacts on agricultural outputs and land-use

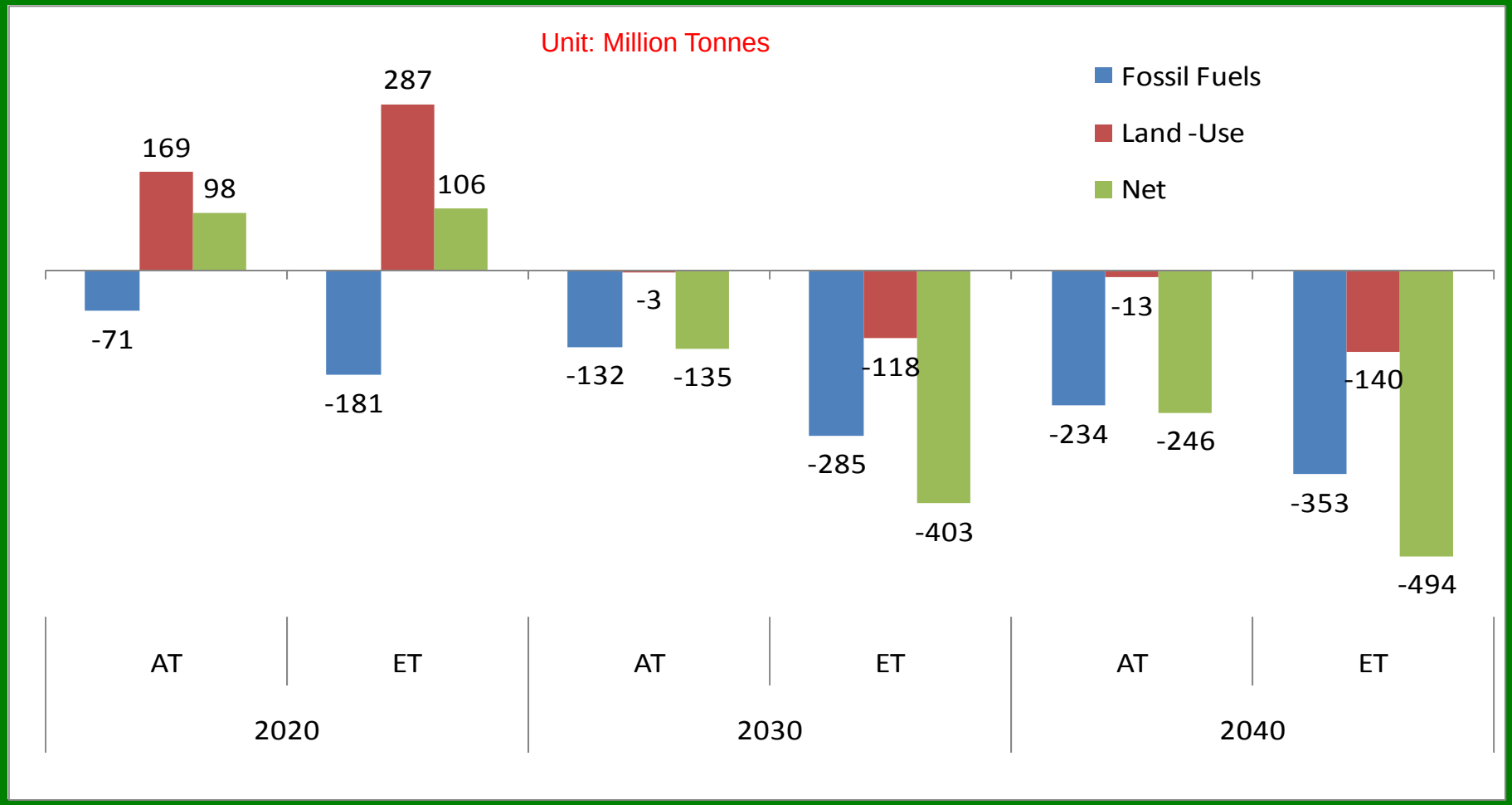
- Expansion of biofuels to meet EU mandates, AL-Riffai et al. (2010) finds, approximately 9% increase in sugar crops; less than 2% increase of oil seeds and less than 0.5% increase of corn and wheat (corresponding values in our studies are, approximately, 10%, 2.3% and 1%).

- Fischer et al. (2009) finds that expansion of biofuels to meet the existing targets could increase production of cereals from 2.7% to 5.4% depending on their scenarios in 2020.

- Al-Riffai et al. (2010) show, at the global level, that crops land would increase by 0.07% (0.15% in our study), while forest land would be unchanged (-0.3%) and pasture land would decrease by 0.01% (0.2% in our case).

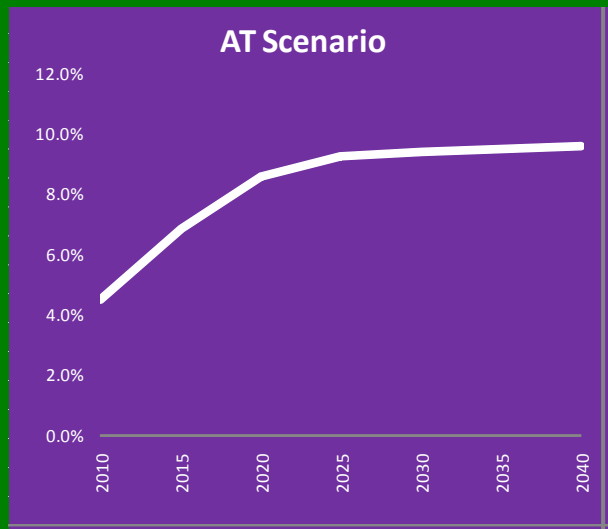
- Fischer et al. (2009) find that expansion of biofuels to meet the targets could increase total arable land by 1 to 3%, depending upon the scenarios, in 2020.

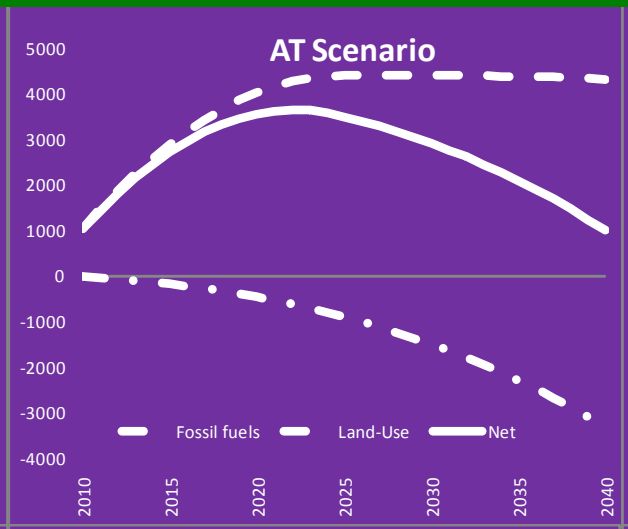
Impacts on Annual Emissions

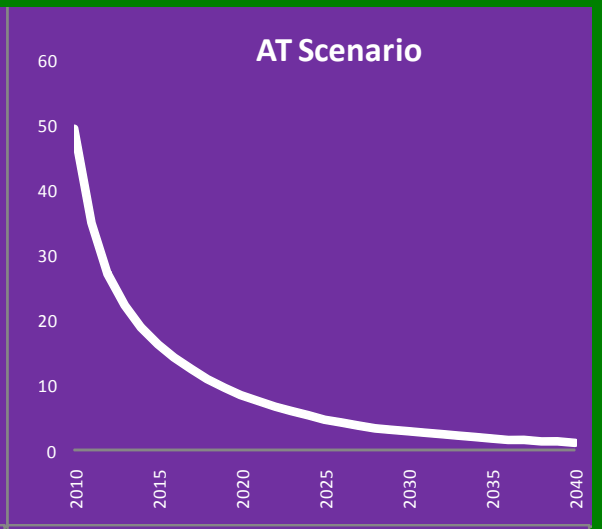


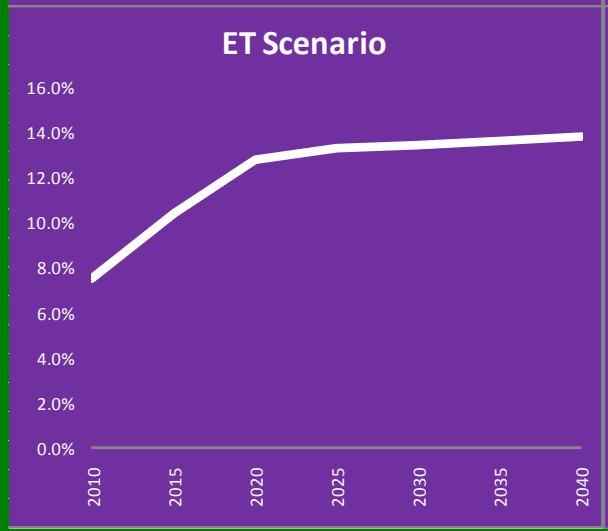
Net annual emission decreases overtime and becomes negative in 2023 despite the fact that the production of biofuels is still increasing

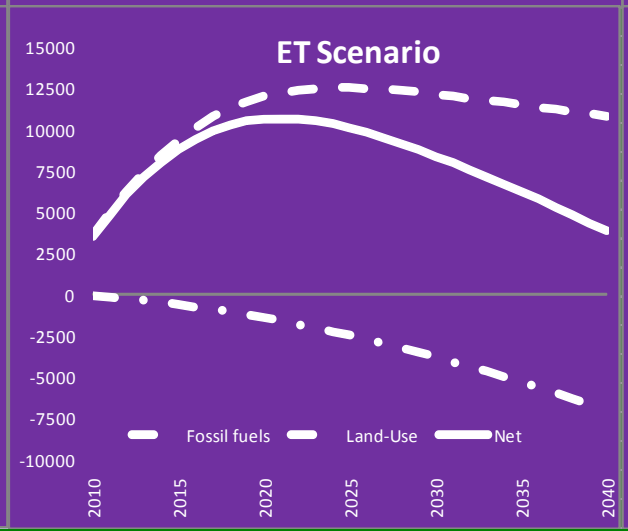
Biofuel penetration, GHG emissions and carbon payback period

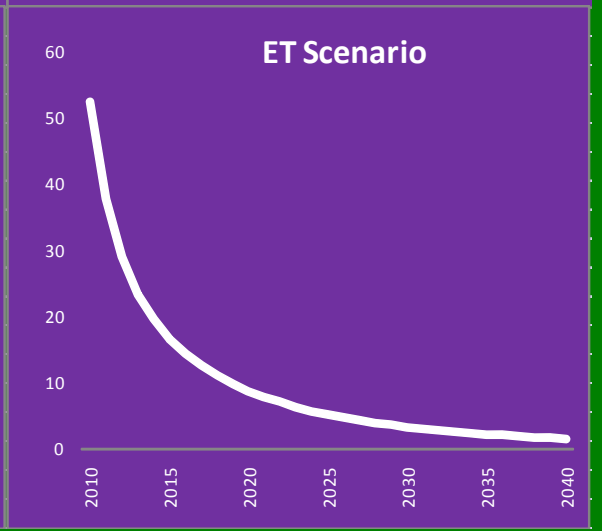










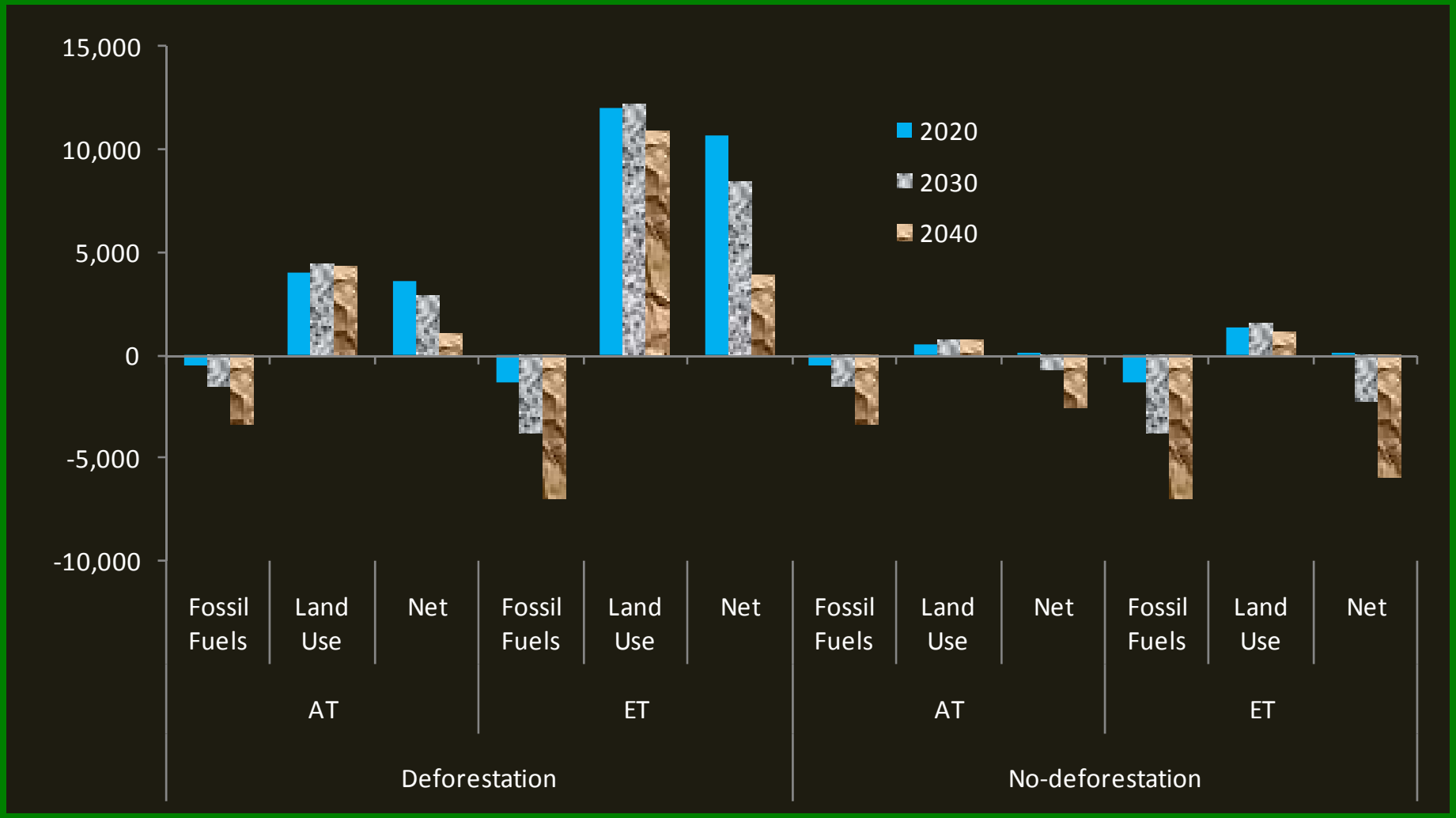


Deforested Lands as Percentage of Available Pasture Land

	AT	ET
World total	**0.2**	**0.9**
High-income	**0.4**	**1.9**
Australia & New Zealand	0.0	0.1
Japan	5.8	73.0
Canada	6.2	31.0
United States	0.1	0.5
European Union	0.5 – 2.9	1.4 - 8.7
Middle & Low-income	**0.1**	**0.7**
China	0.1	0.4
Indonesia	6.8	32.5
Malaysia	6.0	31.6
Thailand	170.8	815.8
India	5.4	14.5
Argentina	0.0	0.1
Brazil	0.9	4.4
South Africa	0.0	0.2
Rest of Sub-Saharan Africa	0.0	0.1

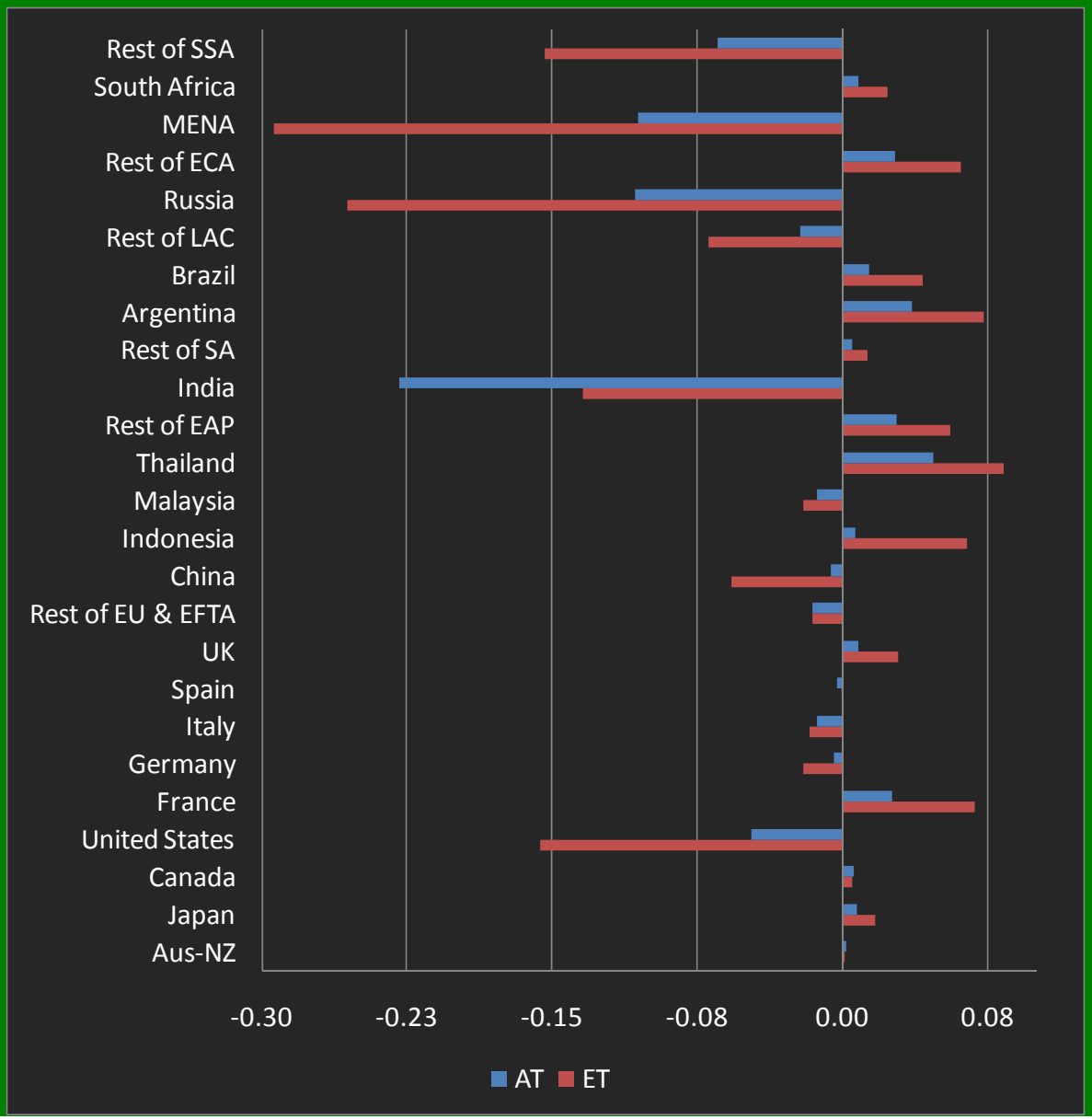
With exception of Thailand where available pasture land is very limited, deforested land represents a small fraction of the total pasture lands available

GHG emissions: Deforestation vs. No-Deforestation (Million tCO_2)



Impacts on GDP in 2020

(% change from the baseline)



Countries which have already advanced in biofuels production and produce feedstock whose price increases exhibit positive or small negative impacts

Oil producing countries such as MENA, Russia would suffer due to reduction in their oil exports which is replaced by biofuels

For sub-Saharan Africa, it is the aggregation effect, highly influenced by Nigeria

Conclusions

- Large-scale expansion of biofuels would cause significant re-allocation of lands between forest, pasture and crops leading to deforestation and pasture land conversion, particularly in countries with higher targets

- If stated (or higher) biofuel mandates and targets are implemented by 2020 using crop feedstocks, and if both forests and pasture lands are used to meet the new land demands, GHG emissions released to the atmosphere would increase until 2043

- If the use of forest lands is avoided by channeling only pasture lands to meet the demand for new lands, a net reduction of GHG emissions would occur starting from 2021, a year after the assumed full implementation of the mandates and targets

THANK YOU

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