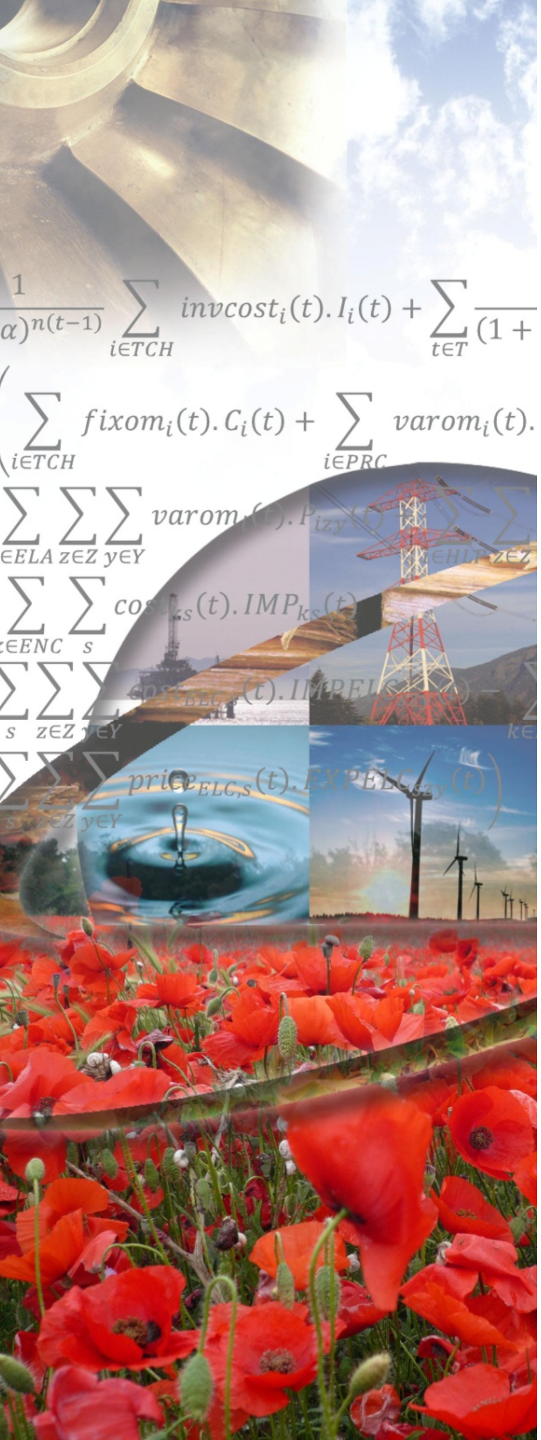


A long-term analysis of access to electricity in Africa in a climate context

Sandrine SELOSSE
MINES ParisTech/Center for Applied Mathematics
ParisTech Chair Modeling for Sustainable Development

November 12, 2013

COP 19 – Warsaw – European Pavilion

Overview

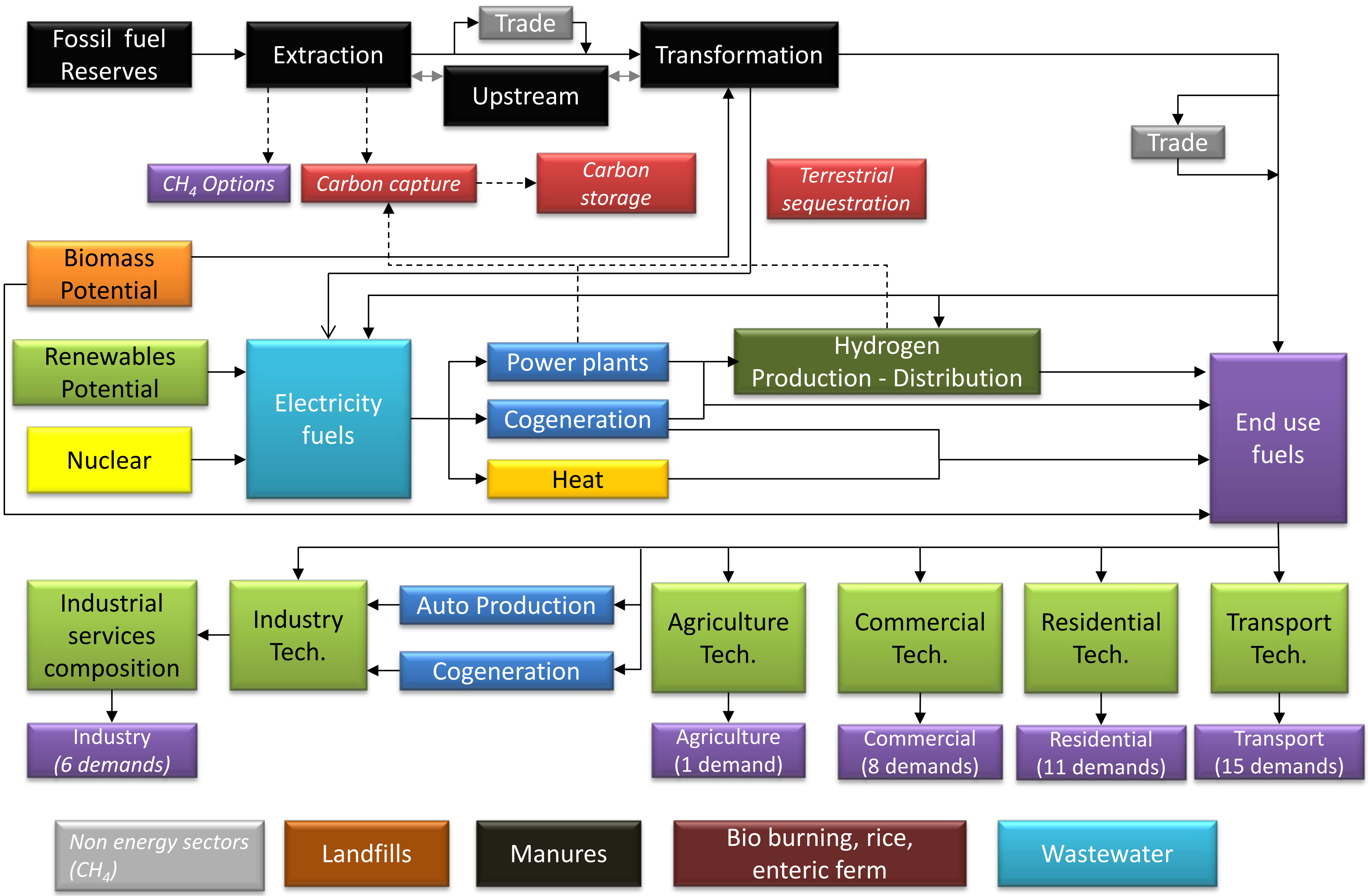
- Long term prospective studies with TIMES model
- Context of Climate issues
  - COP 15 commitments to 2020
  - UNFCCC target to 2050
- Regional focus
  - African electricity system
  - Access to electricity

Long-term prospective with TIMES model

Tools: TIAM-FR

- TIMES Integrated Assessment Model
  - ETSAP (Energy Technology Systems Analysis Program) from IEA
- Based on the concept of Reference Energy System
  - Detailed description of existing and future technologies
  - From extraction to energy services demands
- Bottom-up optimization model
  - Minimization of the total discounted cost of the system

World energy system

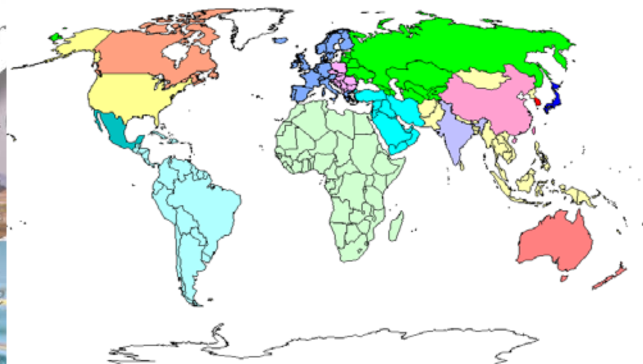


Tools: TIAM-FR

- TIMES Integrated Assessment Model
  - ETSAP (Energy Technology Systems Analysis Program) from IEA
- Based on the concept of Reference Energy System
  - Detailed description of existing and future technologies
  - From extraction to energy services demands
- Bottom-up optimization model
  - Minimization of the total discounted cost of the system

Characteristics of TIAM-FR

- World integrated model in 15 regions



AFR	Africa
AUS	Australia and New Zealand
CAN	Canada
CHI	China
CSA	Central and South America
EEU	Eastern Europe
FSU	Former Soviet Union
IND	India

JPN	Japan
MEX	Mexico
MEA	Middle-East
ODA	Other Developing Asia
SKO	South Korea
USA	United States of America
WEU	Western Europe

- Time horizon: 2005-2050

- GHG emissions and climate module
  - CO_2, CH_4 and N_2O
  - Atmospheric concentration, temperature change and radiative forcing

Climate scenarios analysis: GHG reduction cases

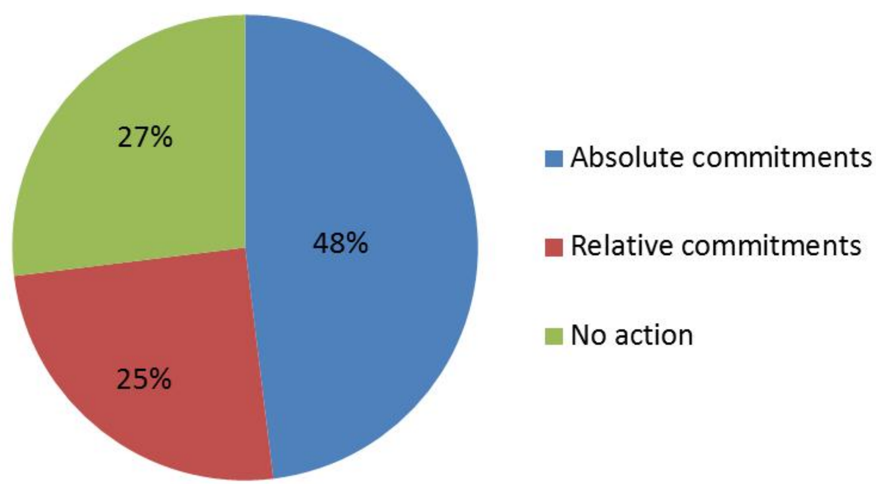
Political ambitions by 2020

- 5 groups of countries
  - Absolute commitments
  - Relative commitments
  - Political actions and support to a global agreement
  - Support without action (61 countries, essentially least advanced)
  - No association or no communication (51 countries, a majority of oil-producing countries)

Scenarios of emissions reduction by 2020

- 3 groups of countries
  - Absolute commitments: **AUS, CAN, JPN, EEU-WEU, FSU, USA**
  - Relative commitments: **CHI, IND, MEX, SKO**
  - No constraint: **AFR, CSA, MEA, ODA**

GHG emissions in 2005



Regional scenario of GHG emission reduction: low targets by 2020

Region	Reduction by 2020	Reference year	Target
Group 1: Absolute targets			
AUS	5%	2000	Absolute target
CAN	17%	2005	
JPN	25%	1990	
FSU	15%	1990	
USA	17%	2005	
WEU+EEU	20%	1990	
Group 2: Relative targets			
CHI	40%	GDP 2020	Carbon intensity
IND	20%	GDP 2020	Carbon intensity
MEX	30%	2020	BAU
SKO	30%	2020	BAU

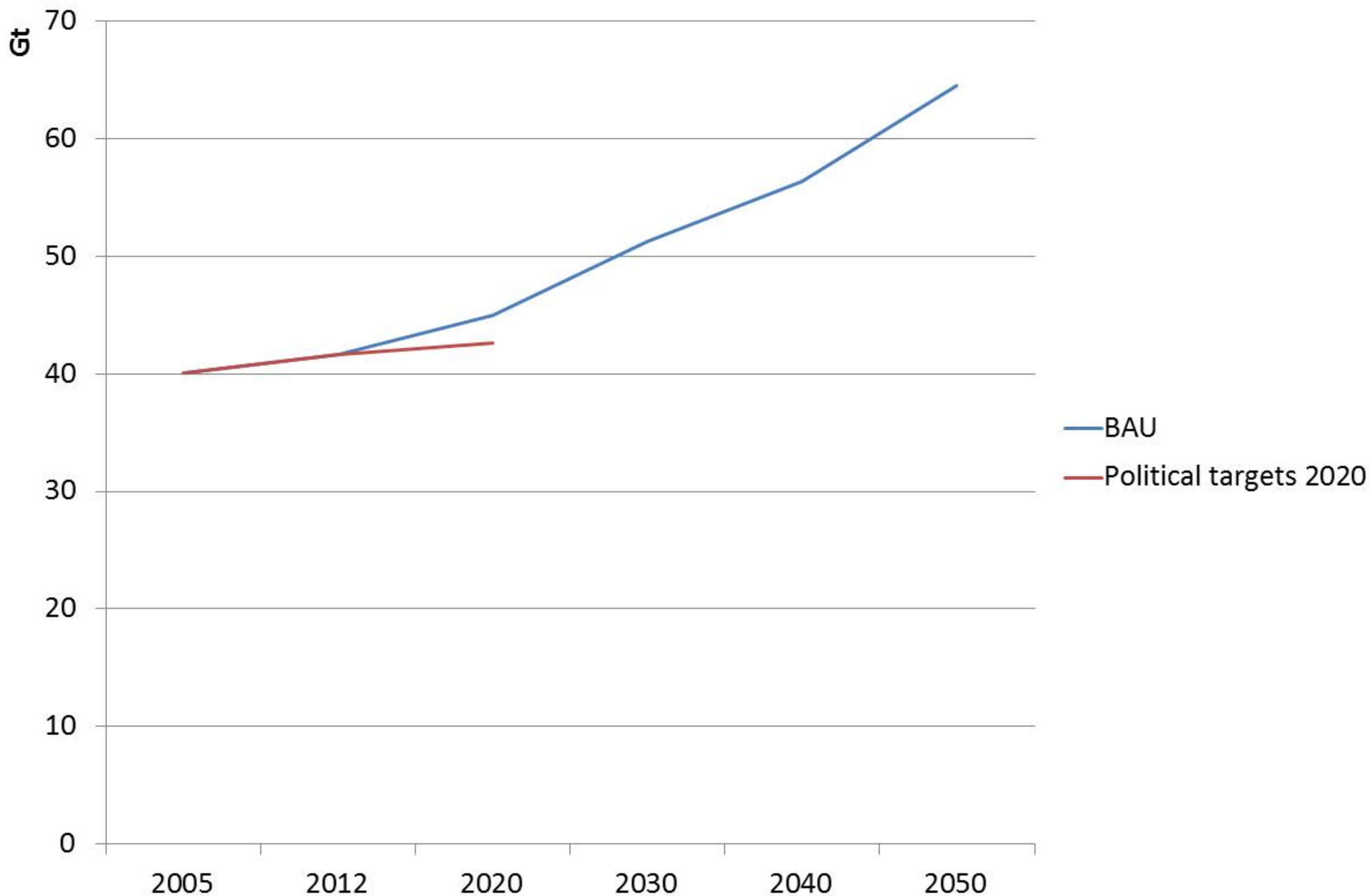
Regional scenario of GHG emission reduction: low targets by 2020

Region	Gt CO2eq 2005	Gt CO2eq 2020	Evol 2005-2020
Group 1: Absolute targets			
AUS	0.742	0.657	-11.4%
CAN	1.142	0.947	-17%
JPN	1.345	0.945	-29.71%
FSU	3.305	4.762	+44%
USA	7.072	5.869	-17%
WEU+EEU	5.65	4.891	-13.42%
Group 2: Relative targets			
CHI	6.917	8.965	+29.6%
IND	1.926	3.320	+72.32%
MEX	0.606	0.423	-30.15%
SKO	0.556	0.427	-23.55%

Regional scenario of GHG emission reduction: low targets by 2020

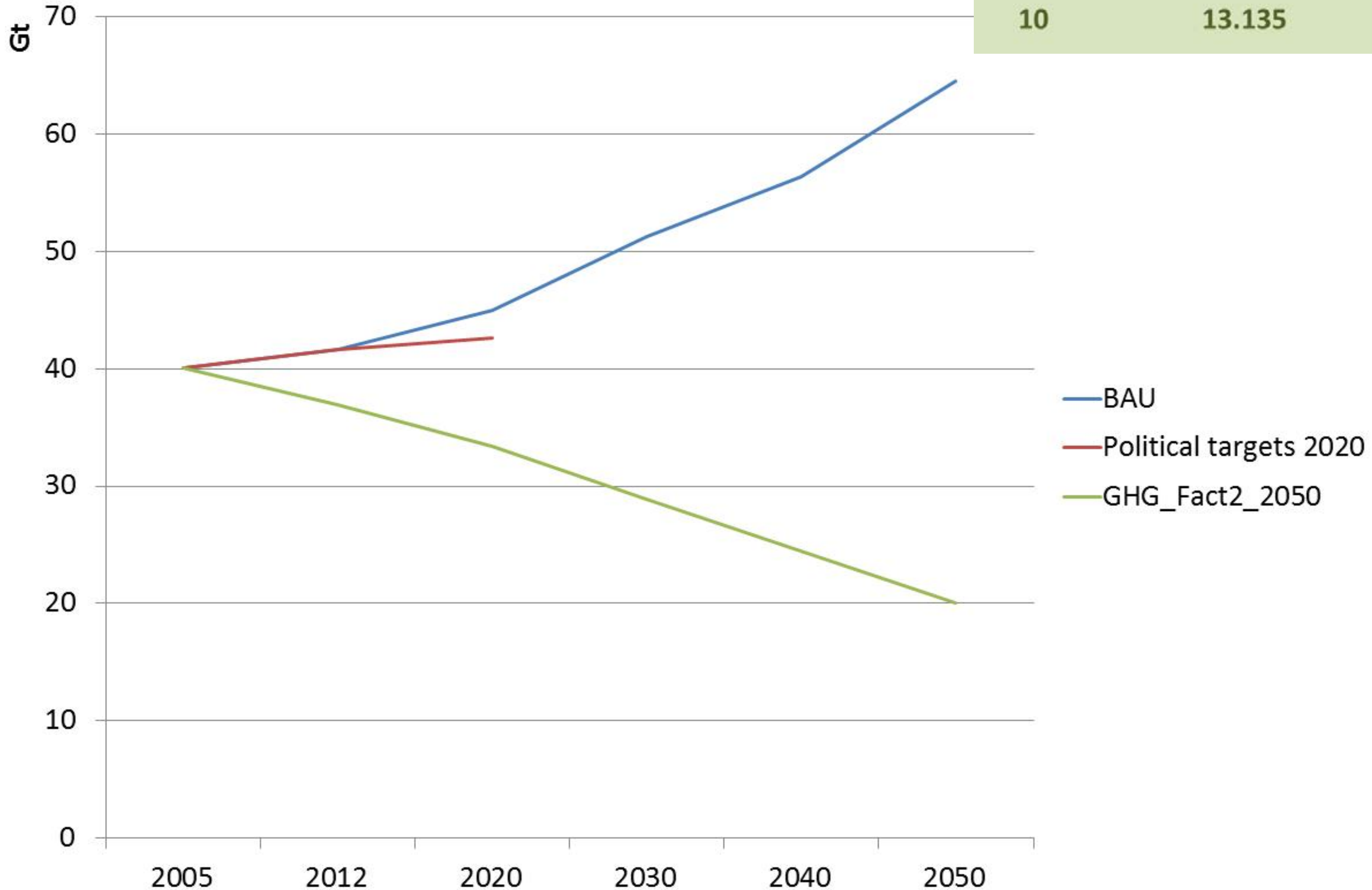
Region	Gt CO2eq 2005	Gt CO2eq 2020	Evol 2005-2020
Group 1: Absolute targets			
	19.256	18.071	-6.15%
Group 2: Relative targets			
	10	13.135	+31.28%

World GHG emissions

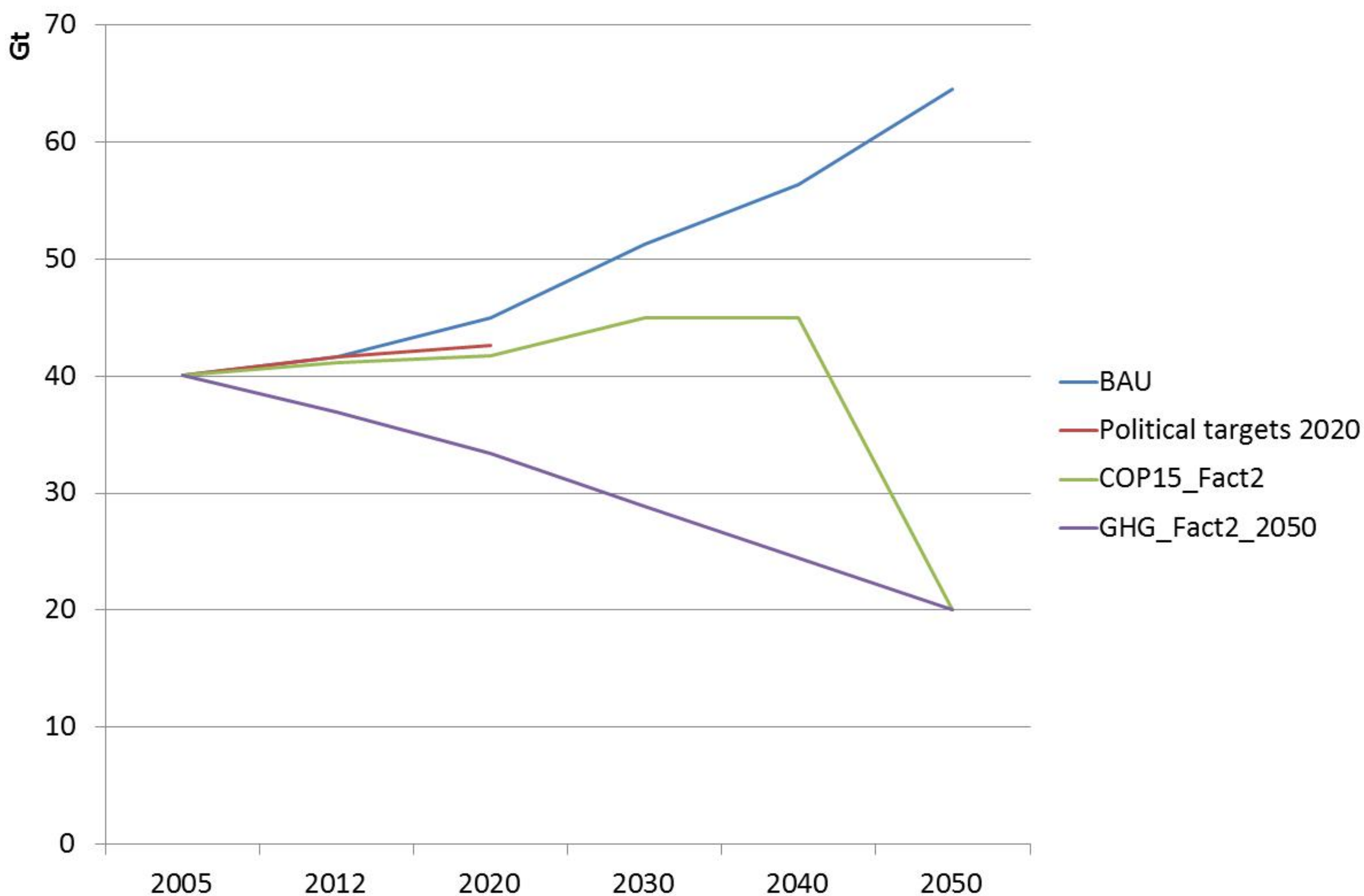


Is a GHG factor 2 by 2050 in line with the 2020 targets?

Gt CO2eq 2005	Targets 2020	Level 2020 (Fact2)
Group 1: Absolute targets		
19.256	18.071	14.531
Group 2: Relative targets		
10	13.135	9.964



Is a GHG factor 2 by 2050 in line with the 2020 targets?



Is a GHG factor 2 in 2050 reachable without the participation of developing countries?

- 3 Groups
  - Absolute, Relative and No Action
- Factor 2 with fix level of GHG emissions from 2005 to 2050 for No action and with fix objectives for Absolute and Relative by 2020
- It is not possible to reach the target
  - The contribution of developing countries is a necessary condition to reach an ambitious climate objective

Regional focus:
Impact on the African system

African energy context

- More than 60% of the African population has not access to commercial energy and use firewood

➢ So, the expected growth of the population and development in Africa will lead to **increased energy needs**

- **The natural resources are important**
  - Fossil fuels or renewables potential
  - Renewables, largely untapped, should be promote

But significantly different from one region to another

- **Different economic and energy realities within Africa**
  - North Africa and South Africa: 75% of the energy consumed
  - Sub-Saharan Africa: ¾ of the population

Heuraux 2010	Population (millions; 2009)	GDP per capita (US $)	Conso. Elec per capita (kWh)	Conso. Elec (GWh)
AFRICA	**1 030**	**1 380**	**474**	**446 150**
North	169	2 665	1 039	138 325
Sub-Saharan	810	525	136	105 825
South	50	5 720	4 008	202 000

- **Energy resources and potential: unequally distributed**
  - North Africa: abundant oil and gas and CSP potential
  - Sub-saharan Africa: hydro potential
  - South Africa: coal

Heuraux 2010	Installed capacities (GW)		Potential and reserves			
	TOTAL	Hydro	Hydro (GW)	Gas (Gm3)	Coal (Mt)	Oil (Mbl)
AFRICA	**114**	**24**	**201,3**	**14 893**	**55 519**	**125 000**
North	43	5	7,2	8 079	73	60 900
Sub-Saharan	30	17	192,6	6 795	1 446	64 100
South	41	2	1,5	19	54 000	-

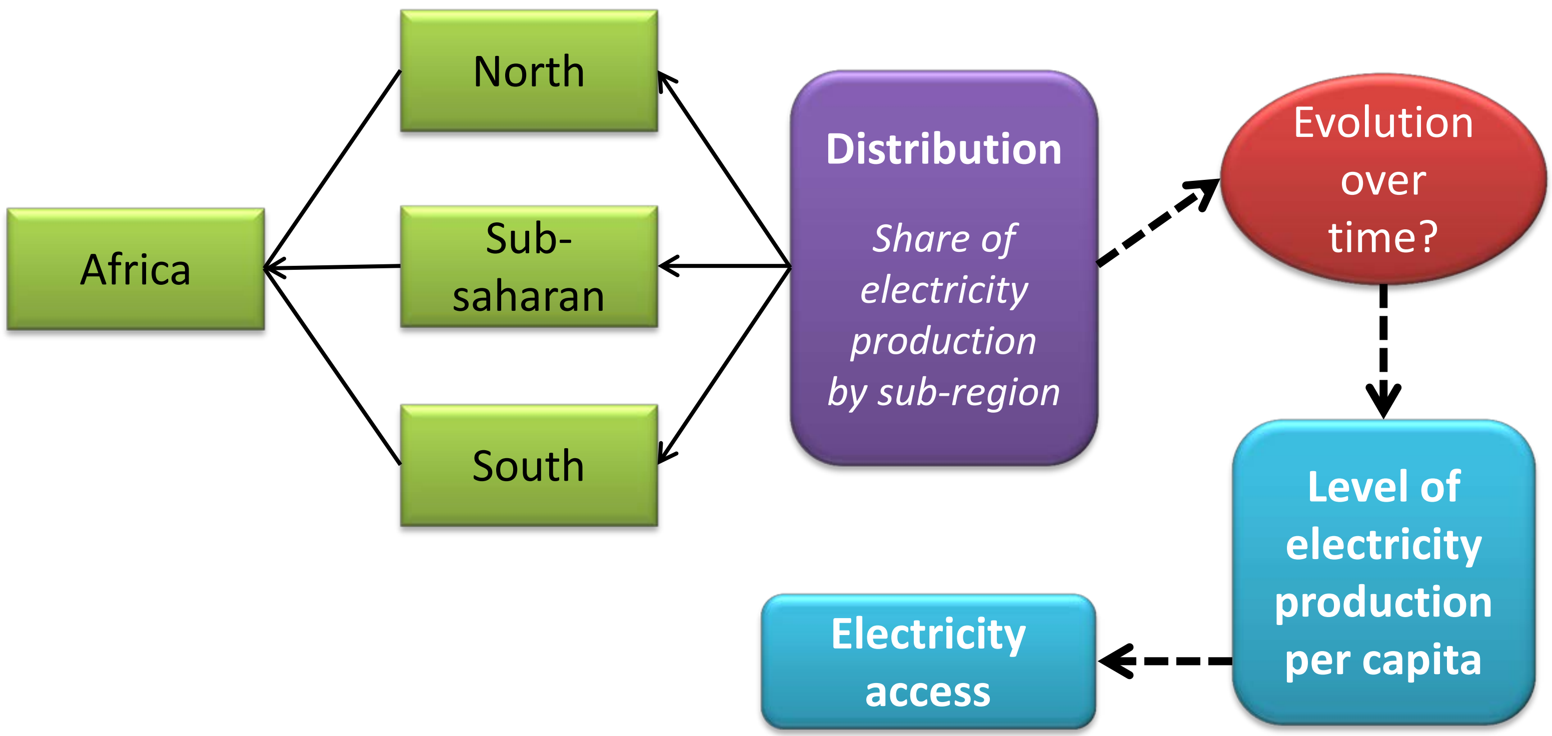
Modelling context: modification in TIAM-FR

- Implementation of 3 power sub-sectors in Africa
  - North Africa AFR1
  - Sub-Saharan Africa AFR2
  - South Africa AFR3

- Calibration of the electricity sector
  - Base year source: IEA Statistics, 2011 Edition, Energy statistics of non-OECD countries
  - Time horizon: Potential of resources by sub-sector
  - Time horizon: Scenarios of sub-regional distribution of African electricity on the time period: electricity production per capita

Contrasted levels of evolution of the electricity access

- Sub regional distribution on the time horizon is based on the level of electricity production per capita
  - Electricity access



Same speed access to electricity

2005	Production per capita (kWh/capita)	Distribution of the electricity production by sub-region (%)
North Africa	1,231	36%
Sub-saharan Africa	164	21%
South Africa	4,930	43%
AFRICA	601	100%

Region	Speed	GR
AFR1	1	46.7%
AFR2	1	46.7%
AFR3	1	46.7%

2050	Production per capita (kWh/capita)	Distribution of the electricity production by sub-region (%)
North Africa	1,805	36%
Sub-saharan Africa	241	32%
South Africa	7,229	32%
AFRICA	639	100%

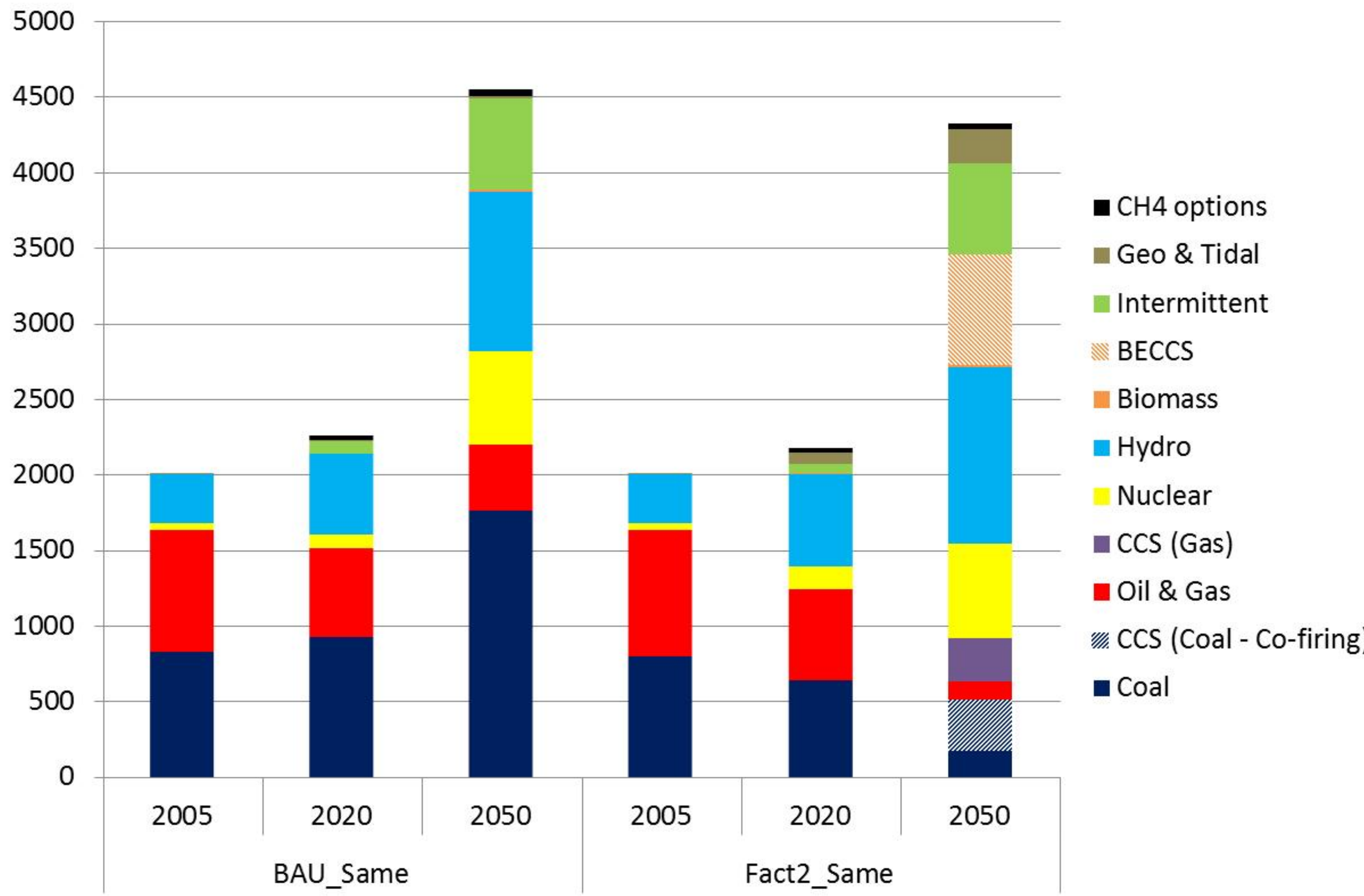
Contrasted speed access to electricity

2005	Production per capita (kWh/capita)	Distribution of the electricity production by sub-region (%)
North Africa	1,231	36%
Sub-saharan Africa	164	21%
South Africa	4,930	43%
AFRICA	601	100%

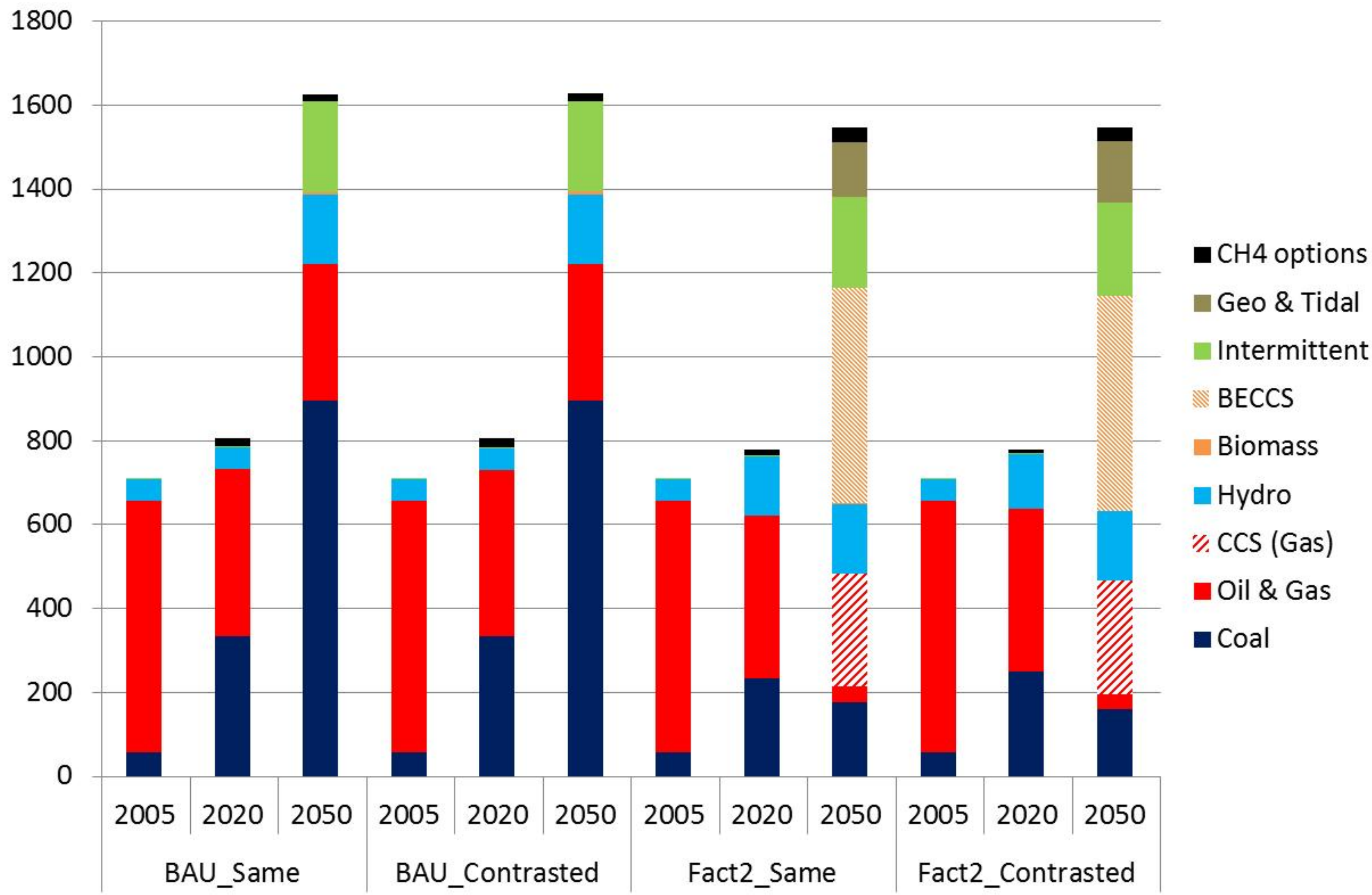
Region	Speed	GR
AFR1	0.75	46.7%
AFR2	1	62.3%
AFR3	0.5	31.2%

2050	Production per capita (kWh/capita)	Distribution of the electricity production by sub-region (%)
North Africa	1,806	36%
Sub-saharan Africa	266	35%
South Africa	6,469	29%
AFRICA	639	100%

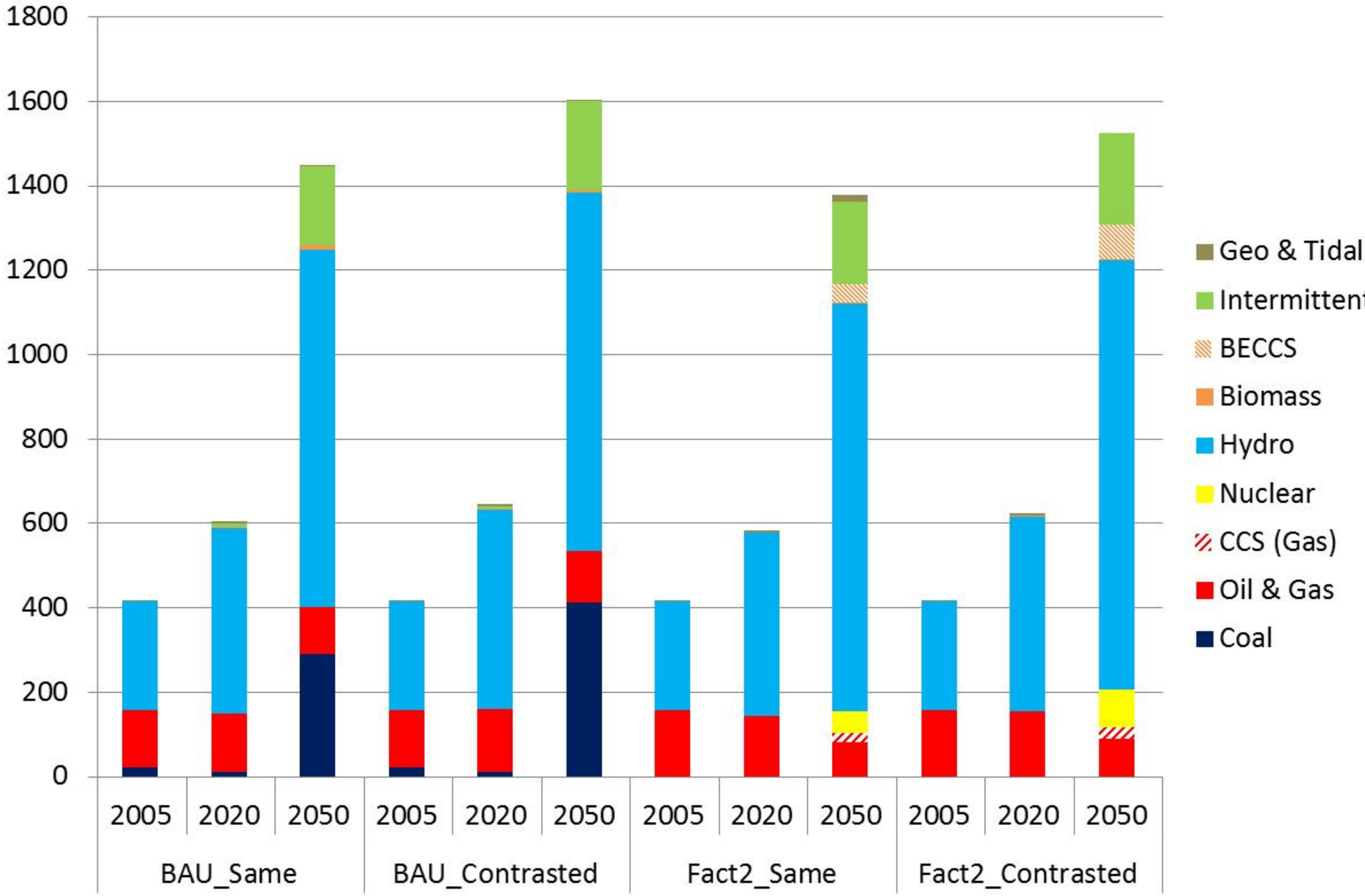
Electricity production (PJ) – Africa BAU & Climate scenarios



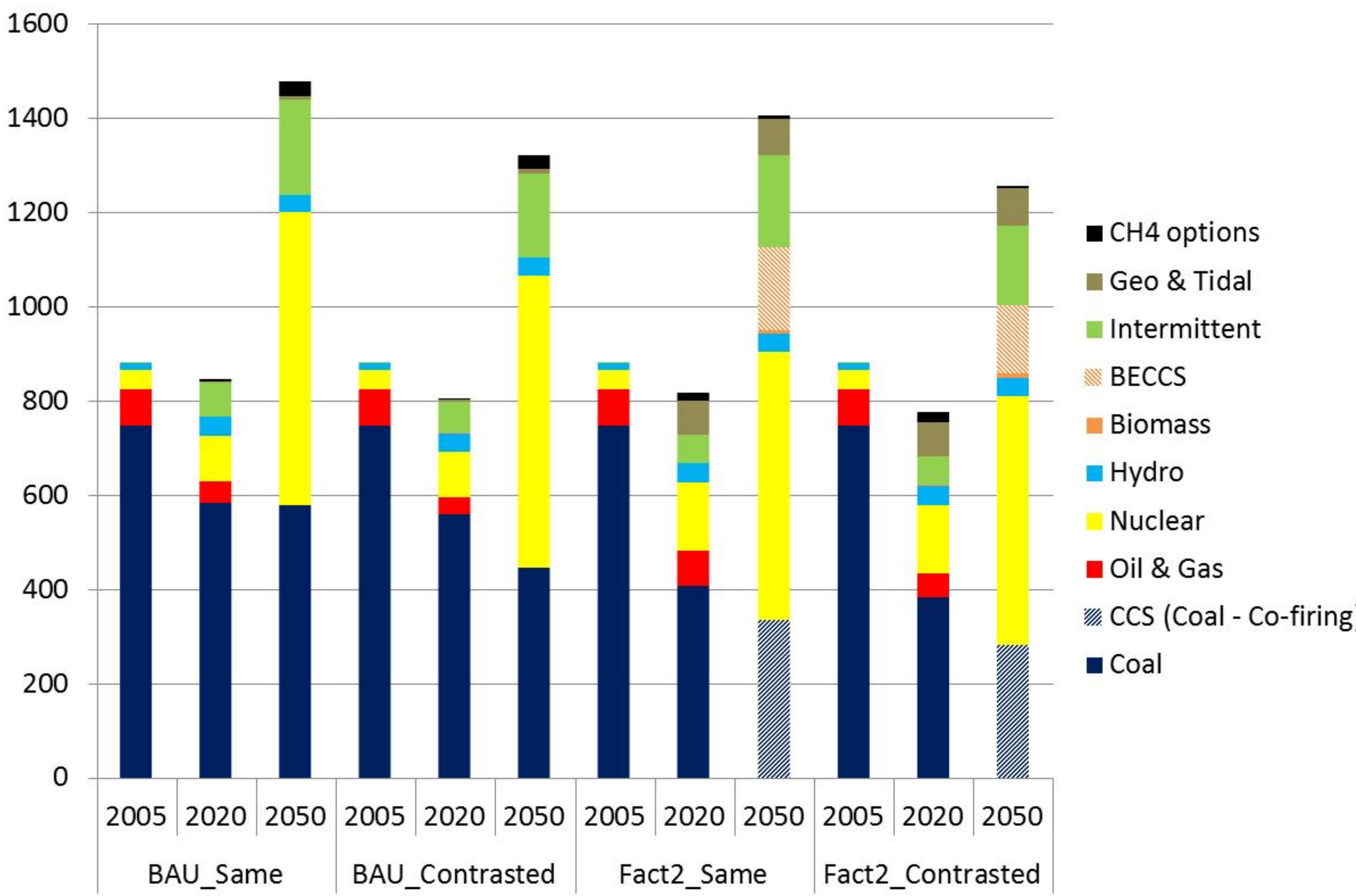
Electricity production (PJ) – North Africa BAU & Climate scenarios



Electricity production (PJ) – Sub-saharan BAU & Climate scenarios



Electricity production (PJ) – South Africa
BAU & Climate scenarios

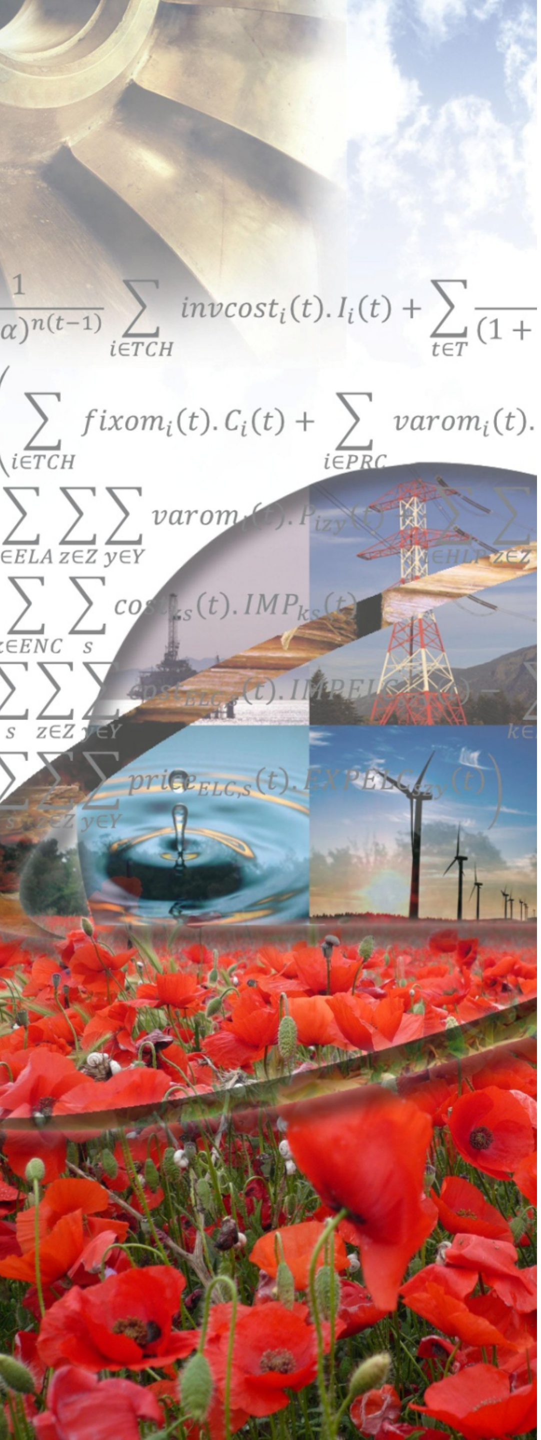


Intelligent and fair solutions to GHG emissions reductions?

- Den Elzen and Höhne (2008): a reduction between 15% and 30% by 2020 by comparison with BAU…
  - BAU_{2020}: 3 Gt-$CO2_{eq}$
  - $Fact2_{2020}$: 1.79 Gt-$CO2_{eq}$

  41%

- Economical rationality
  - Priority of development
  - Access to energy: need fo electricification (in a massive and accelerated way)
  - Electricity costs
- Technological choices
  - Potential of renewables : solar without funded projects?
  - Large scale development of CCS? Of BECCS?
    Food competition with biomass, deforestation
  - Smart solutions to reduce losses in distribution, peak demand, etc.



Centre for Applied Mathematics

Thank You!

Is a GHG factor 2 by 2050 in line with the 2020 targets?

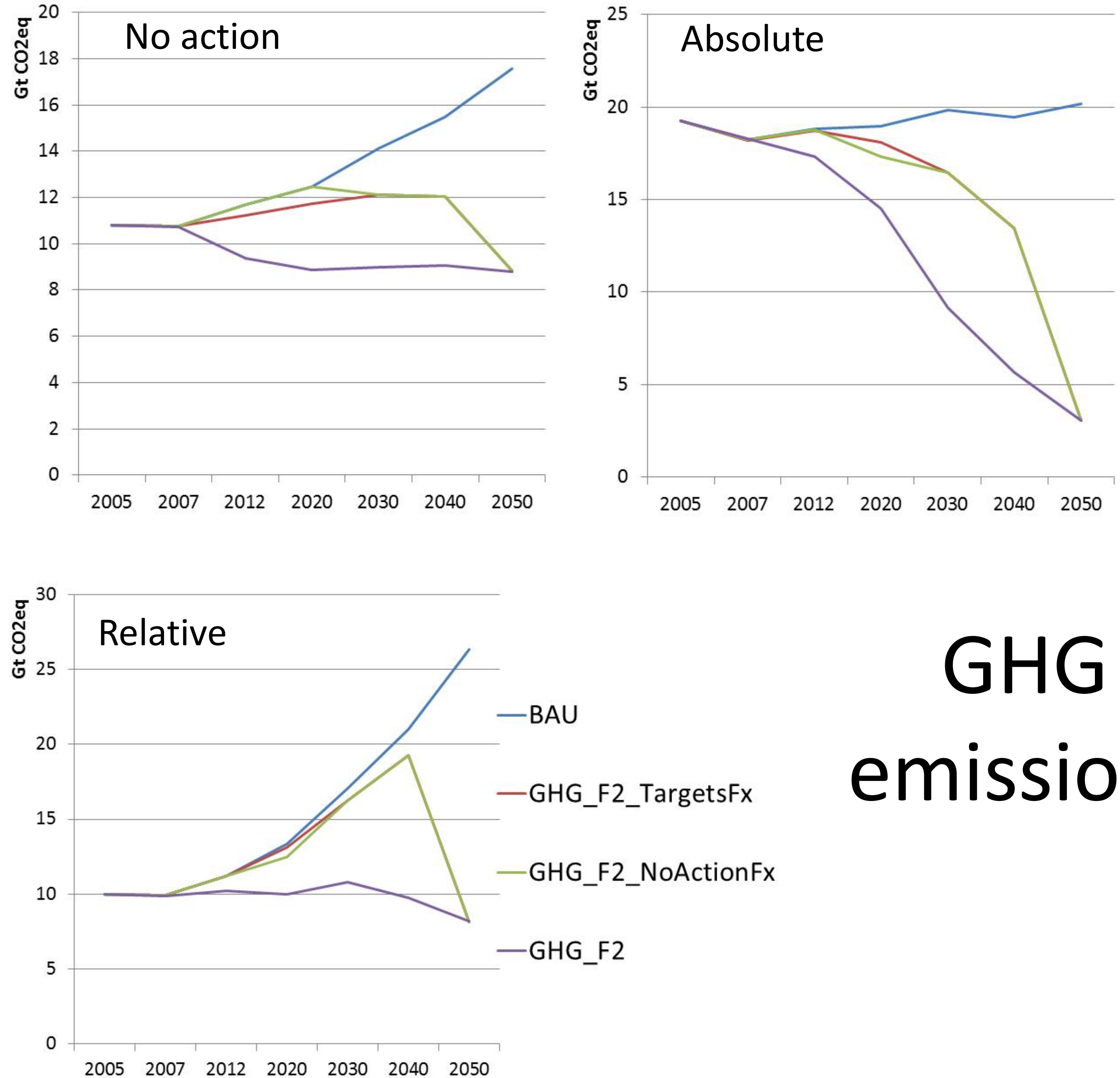
Region	Gt CO2eq 2005	Targets 2020	Level 2020 (Fact2)
Group 1: Absolute targets			
	19.256	**18.071**	**14.531**
Group 2: Relative targets			
	10	**13.135**	**9.964**

Is a GHG factor 2 in 2050 compatible with the 2020 targets?

Region	Gt CO2eq 2005	Targets 2020	Level 2020 (Fact2)
Group 1: Absolute targets			
AUS	0.742	0.657	0.371
CAN	1.142	0.947	0.651
JPN	1.345	0.945	1.051
FSU	3.305	4.762	2.80
USA	7.072	5.869	5.515
WEU+EEU	5.65	4.891	4.143
Group 2: Relative targets			
CHI	6.917	8.965	7.062
IND	1.926	3.320	1.987
MEX	0.606	0.423	0.415
SKO	0.556	0.427	0.500

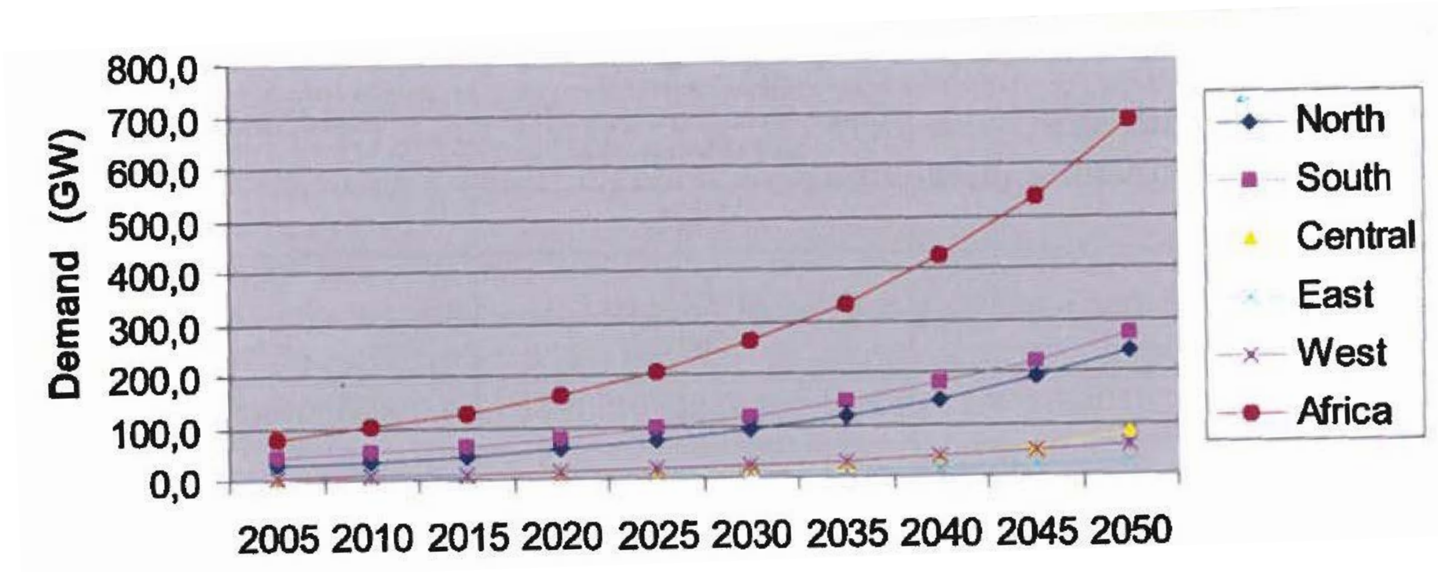
Comparative analysis (1)

- 3 Groups
  - Absolute, Relative and No Constraint
- Different objectives
  - Factor 2: world GHG emissions divided by 2 in 2050 (**GHG_F2**)
  - Factor 2 with fix level of GHG emissions from 2005 to 2020 for No constraint (**GHG_F2_NoActionFx**)
  - Factor 2 with fix objectives for Absolute and Relative (**GHG_F2_TargetsFx**)



GHG emissions

Important expected increase of the electricity consumption : North and South Africa

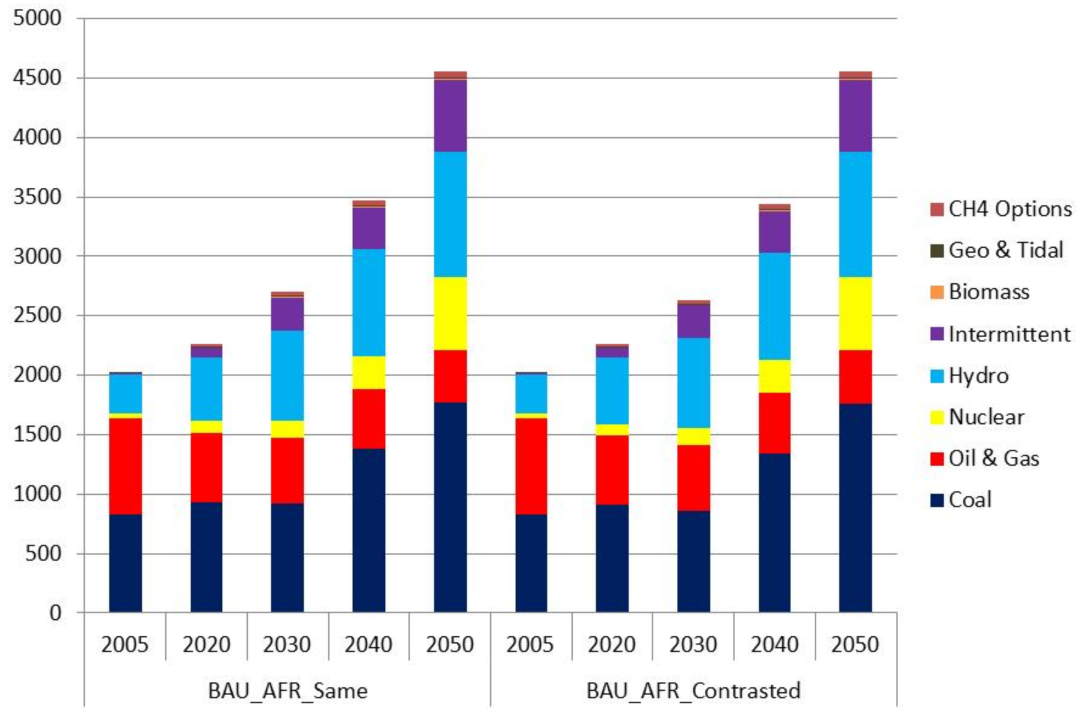


Source: WEC, 2007 according 2004 data

- Different impacts on the electricity mix according to sub-regions

Annex

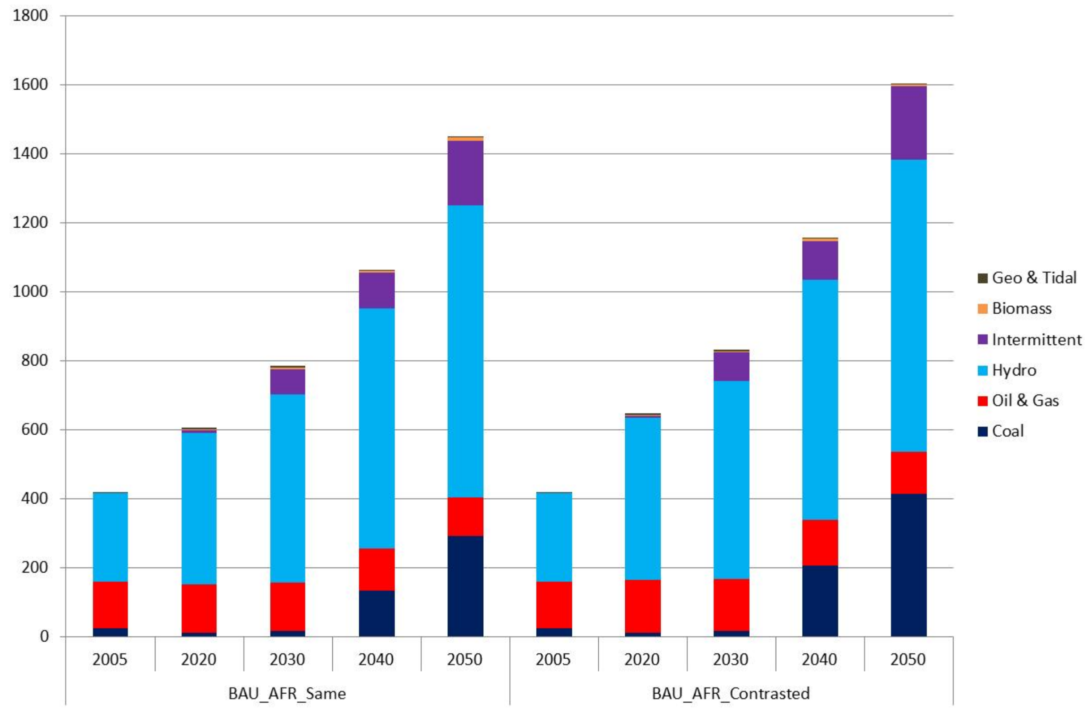
Electricity production (PJ) - AFRICA



Share (%)	Period	Coal	Oil & Gas	Nuclear	Hydro	Intermittent
BAU_AFR_Same	2005	41	40	2	16	0
	2020	41	26	4	24	4
	2030	34	21	5	28	10
	2040	40	15	8	26	10
	2050	39	10	14	23	13
BAU_AFR_Contrasted	2005	41	40	2	16	0
	2020	40	26	4	25	3
	2030	32	21	5	29	10
	2040	39	15	8	26	10
	2050	39	10	14	23	13

Annex

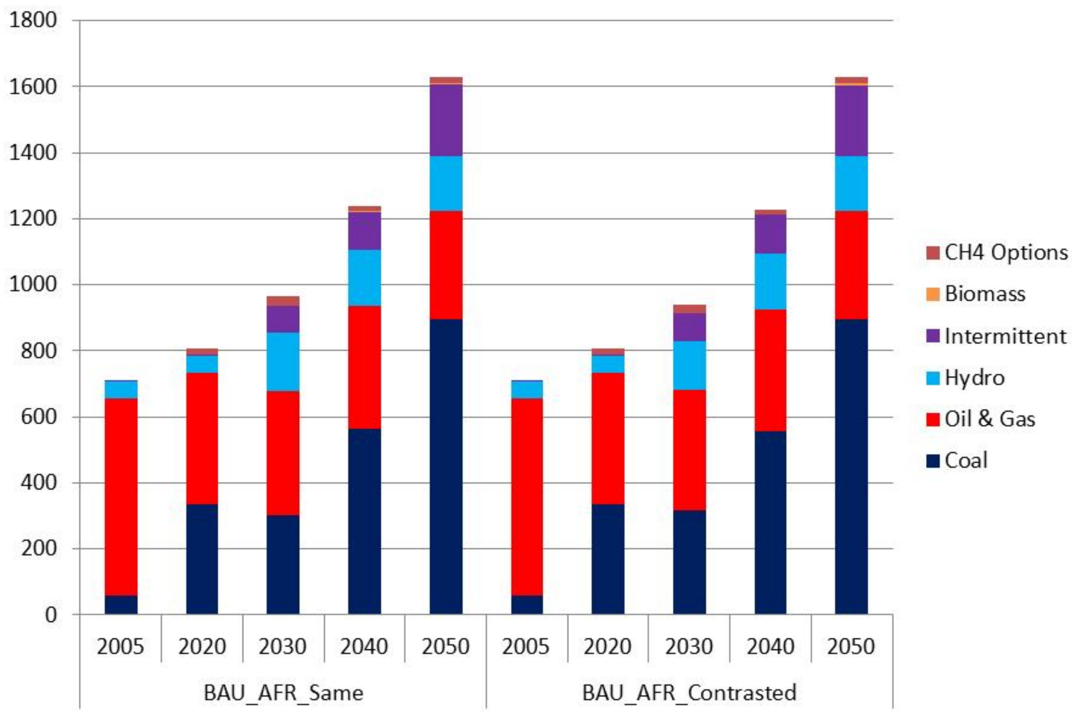
Electricity production (PJ) – North Africa



Scenario	Period	Coal	Oil & Gas	Hydro	Intermittent
BAU_AFR_Same	2005	8	84	7	0
	2020	42	49	6	0
	2030	31	39	18	9
	2040	45	30	14	9
	2050	55	20	10	13
BAU_AFR_Contrasted	2005	8	84	7	0
	2020	41	49	6	0
	2030	34	39	16	9
	2040	45	30	14	10
	2050	55	20	10	13

Annex

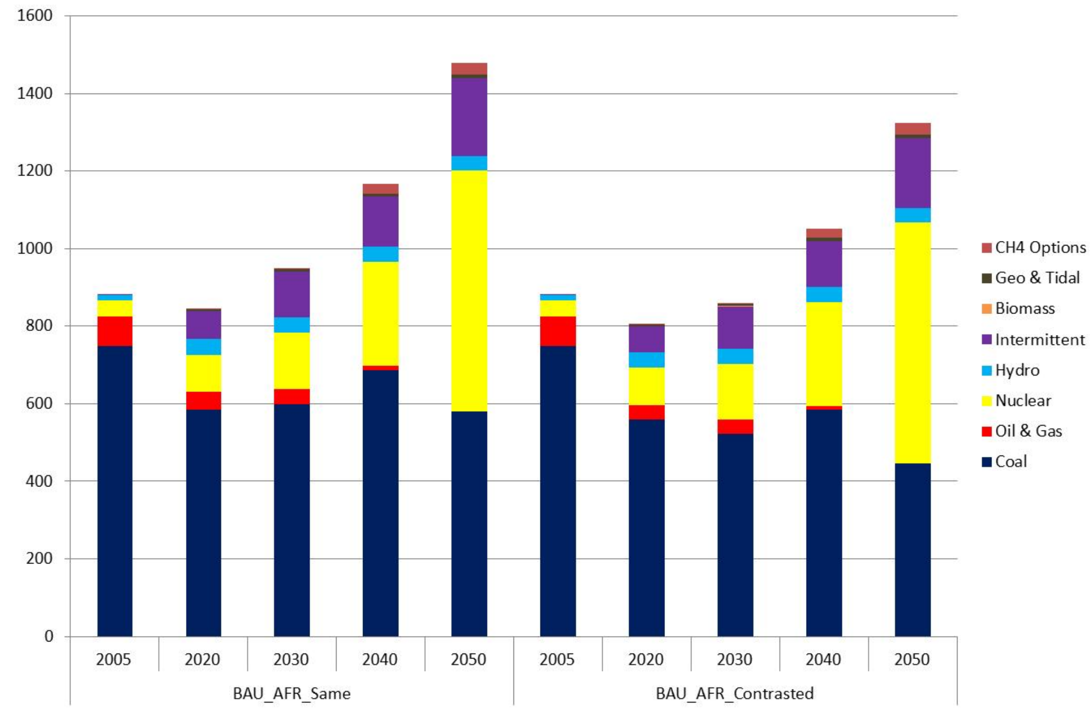
Electricity production (PJ) – Sub-saharan Africa



Scenario	Period	Coal	Oil & Gas	Hydro	Intermittent
BAU_AFR_Same	2005	6	32	61	0
	2020	2	23	72	1
	2030	2	18	70	9
	2040	13	12	66	10
	2050	20	8	58	13
BAU_AFR_Contrasted	2005	6	32	61	0
	2020	2	23	73	1
	2030	2	18	69	10
	2040	18	12	60	10
	2050	26	8	53	13

Annex

Electricity production (PJ) – South Africa

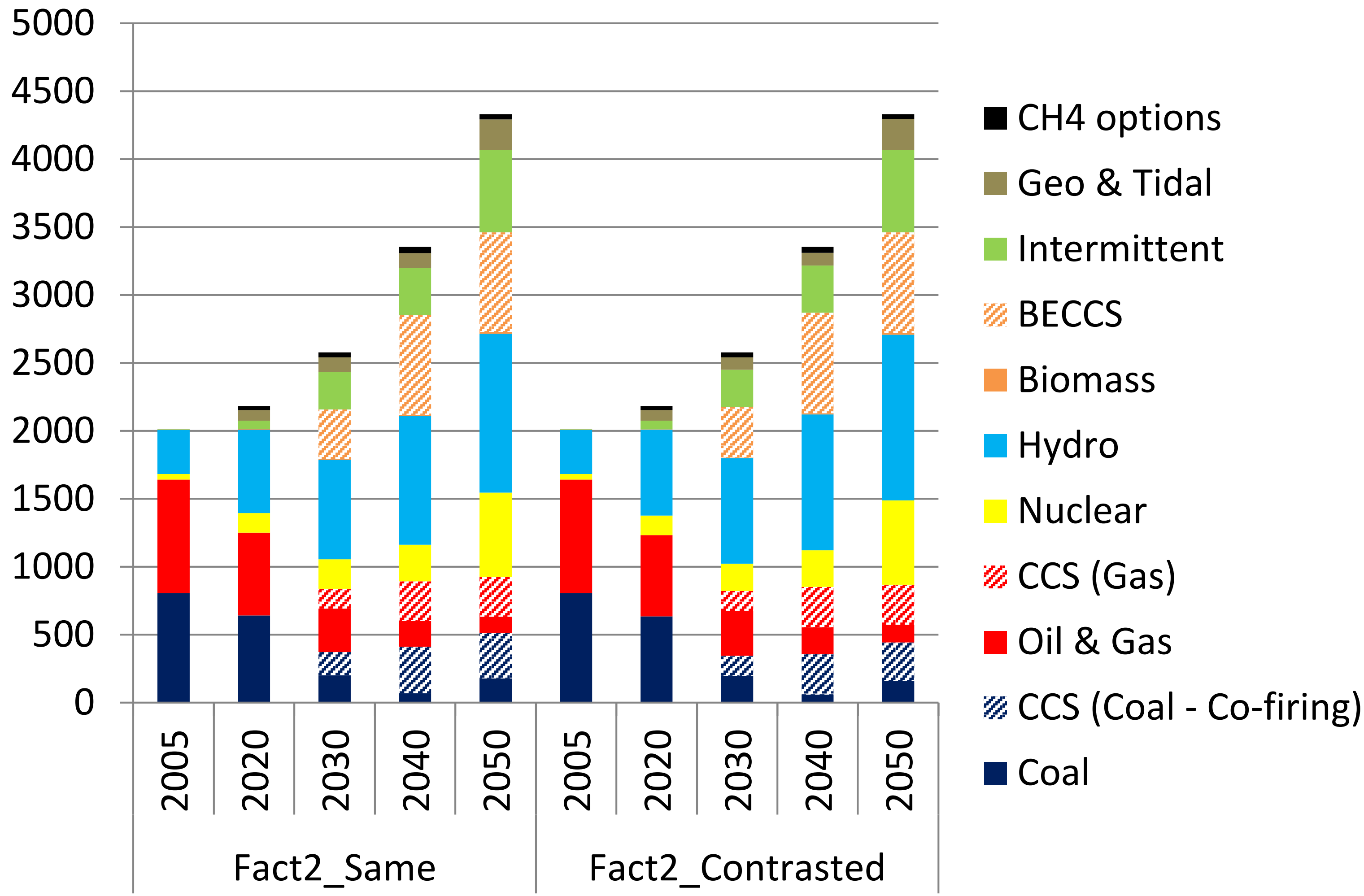


Scenario	Period	Coal	Oil & Gas	Nuclear	Hydro	Intermittent
BAU_AFR_Same	2005	85	9	5	2	0
	2020	69	5	11	5	8
	2030	63	4	15	4	12
	2040	59	1	23	3	11
	2050	39	0	42	3	14
BAU_AFR_Contrasted	2005	85	9	5	2	0
	2020	70	5	12	5	8
	2030	61	4	17	5	13
	2040	56	1	26	4	11
	2050	34	0	47	3	14

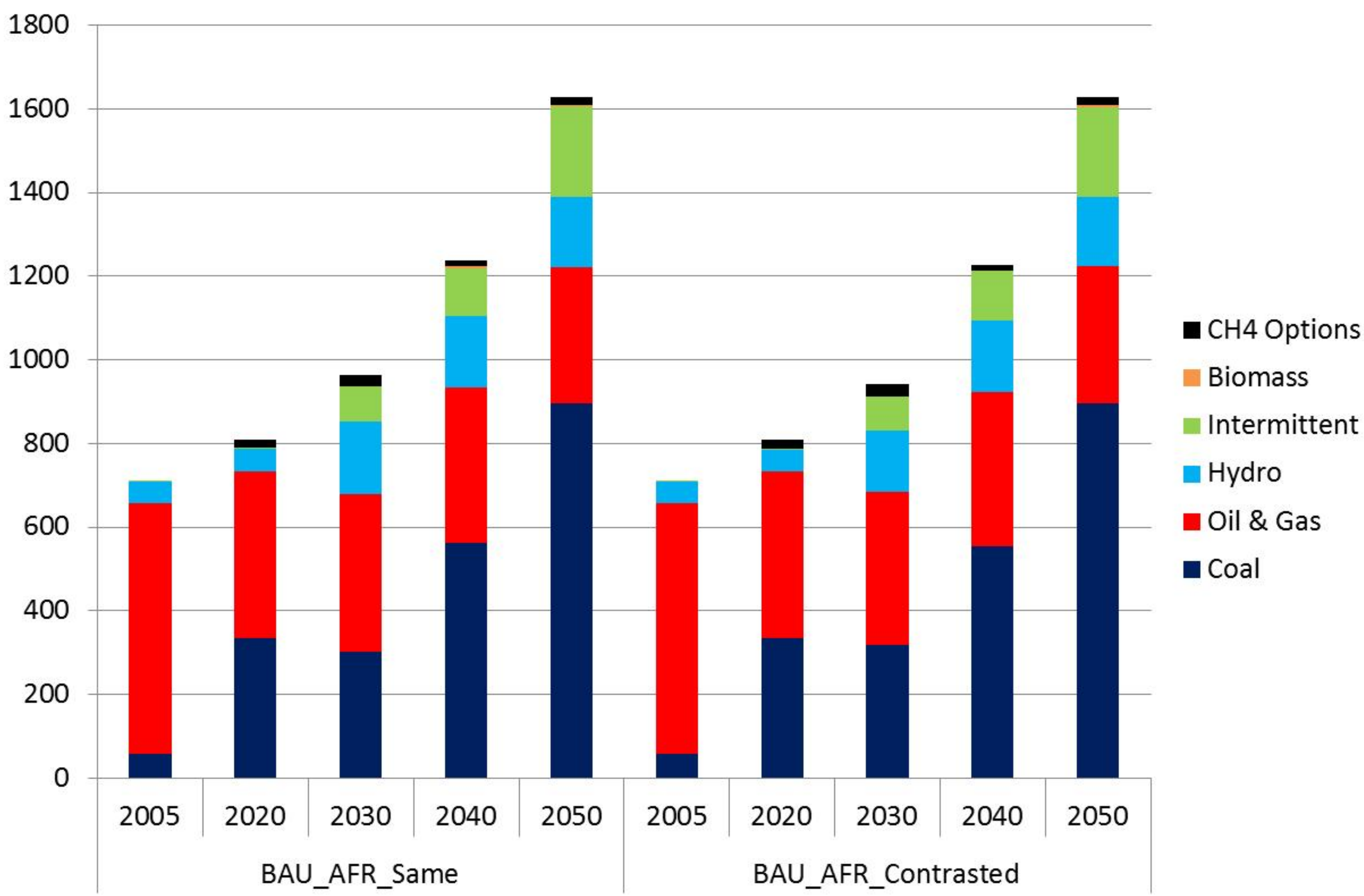
Electricity production (PJ) – AFRICA

Climate constraint scenario

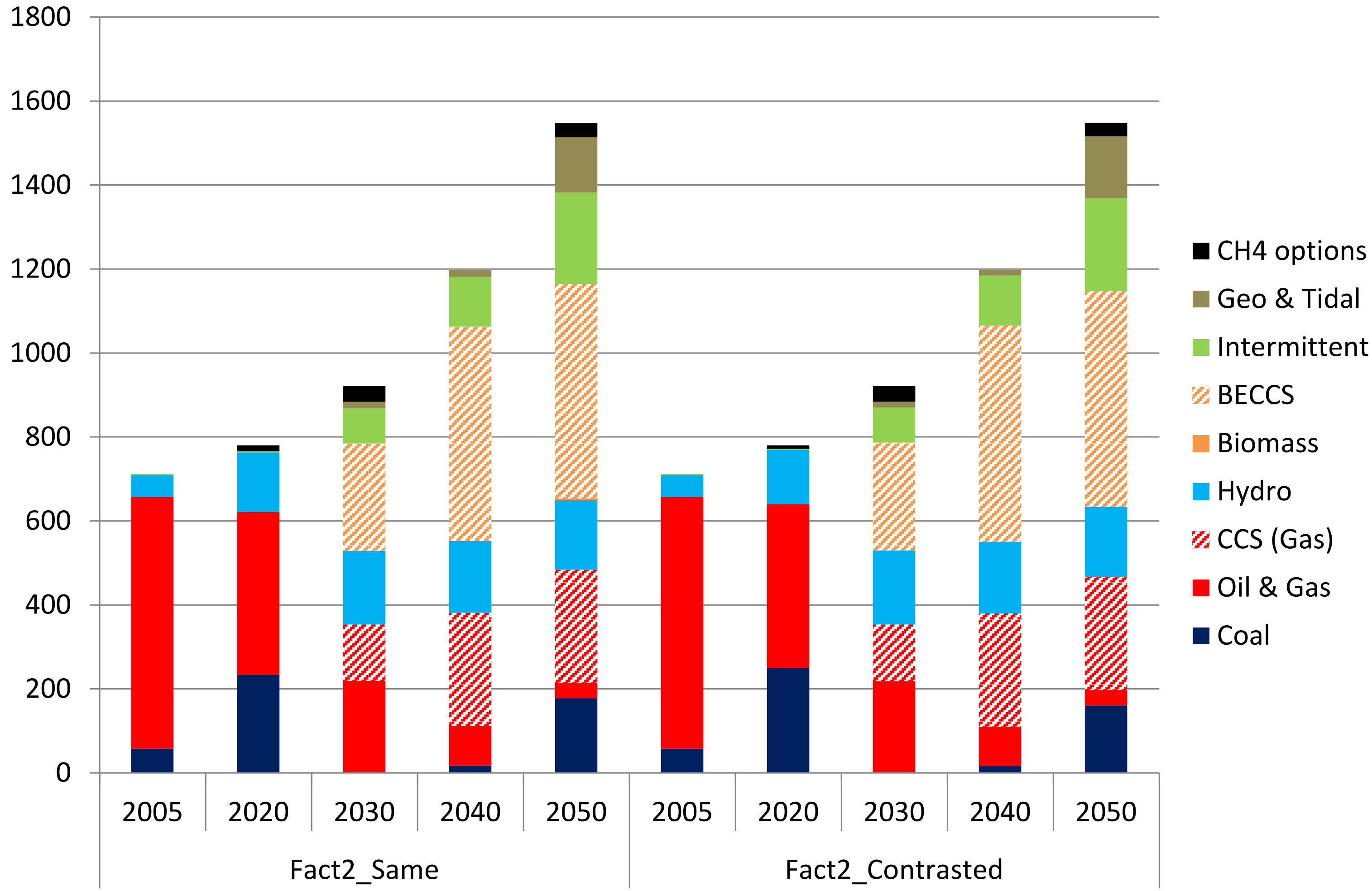
Annex



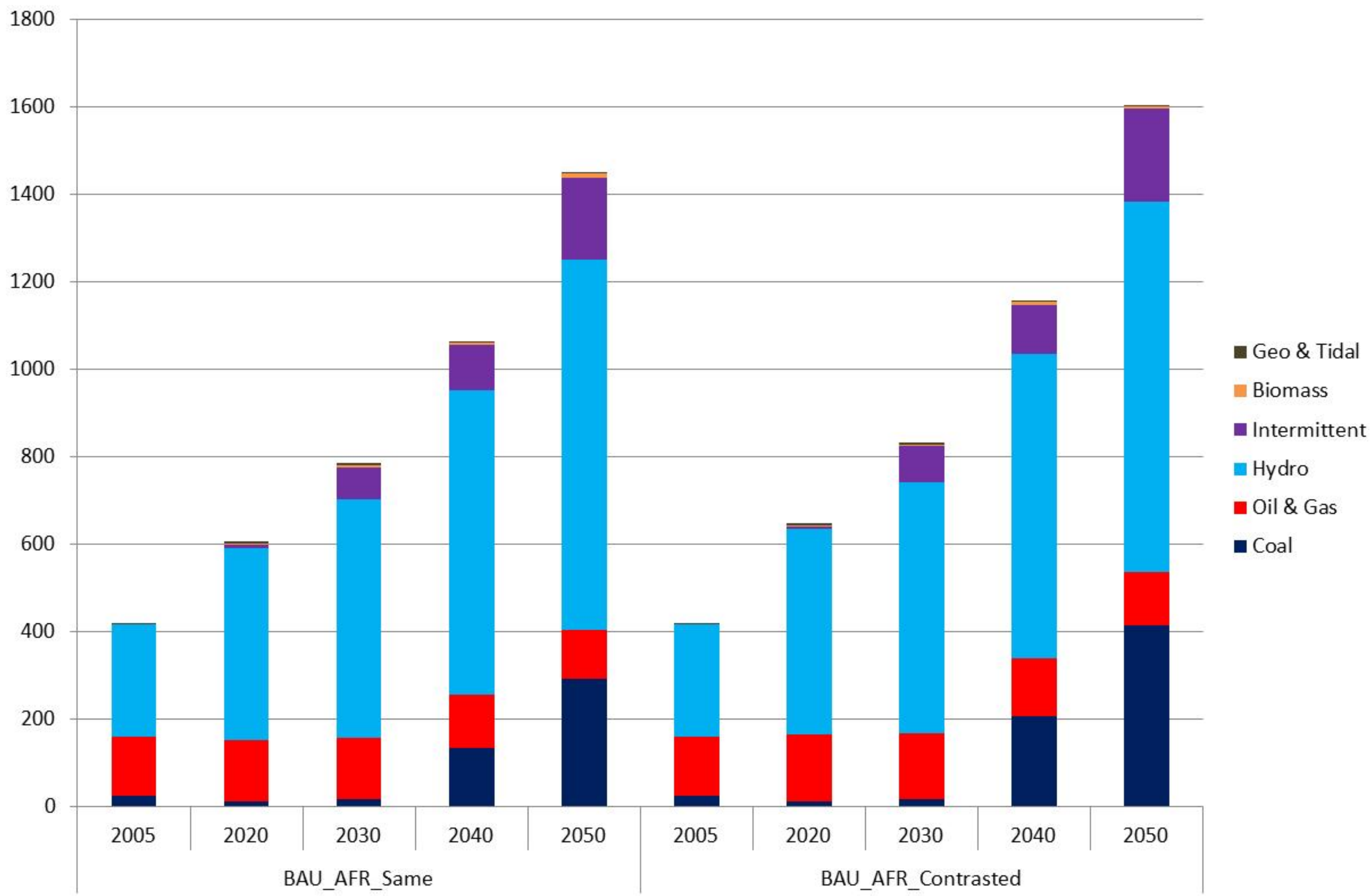
Electricity production (PJ) North Africa



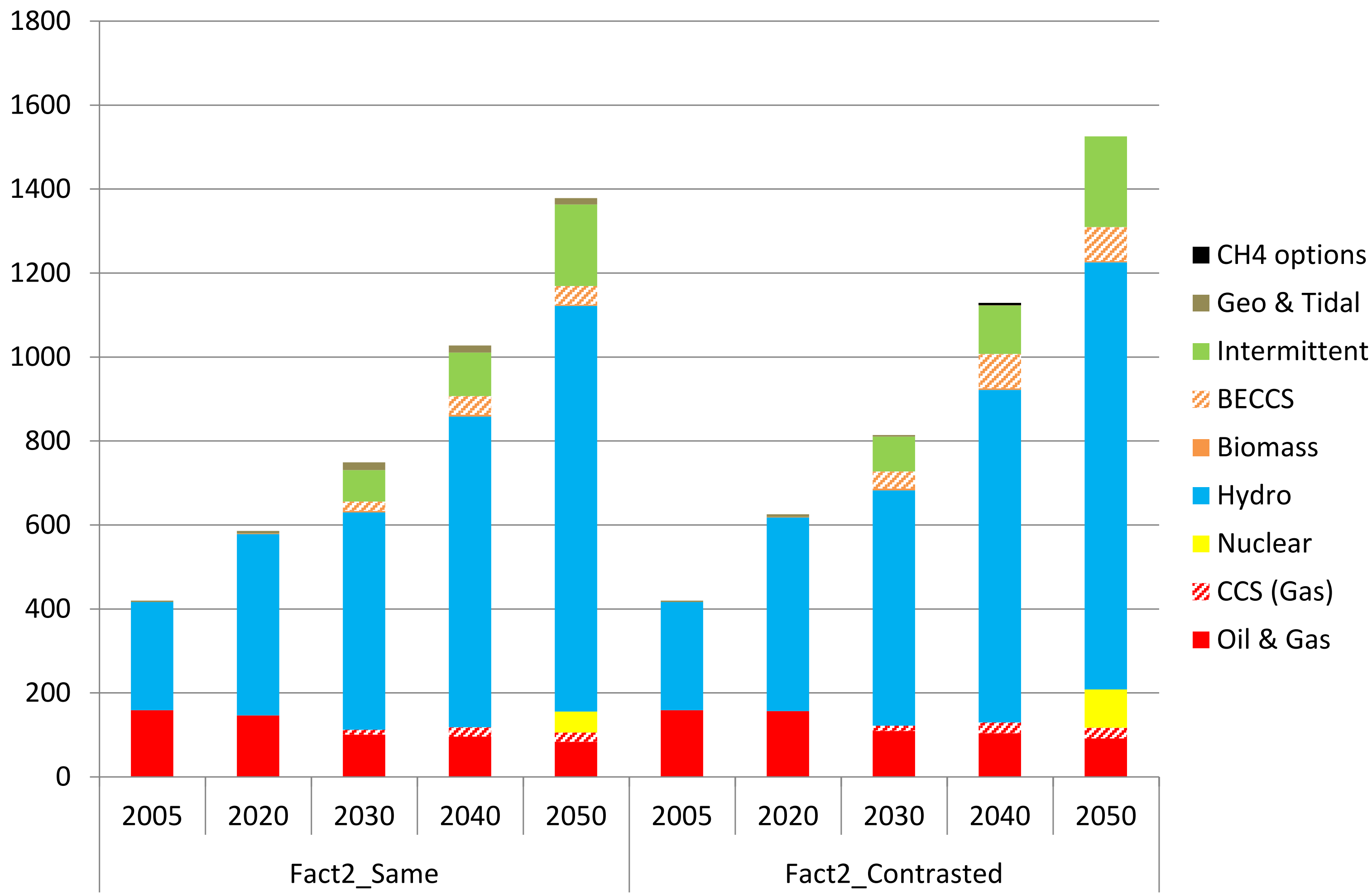
Electricity production (PJ) – North Africa Climate constraint scenario



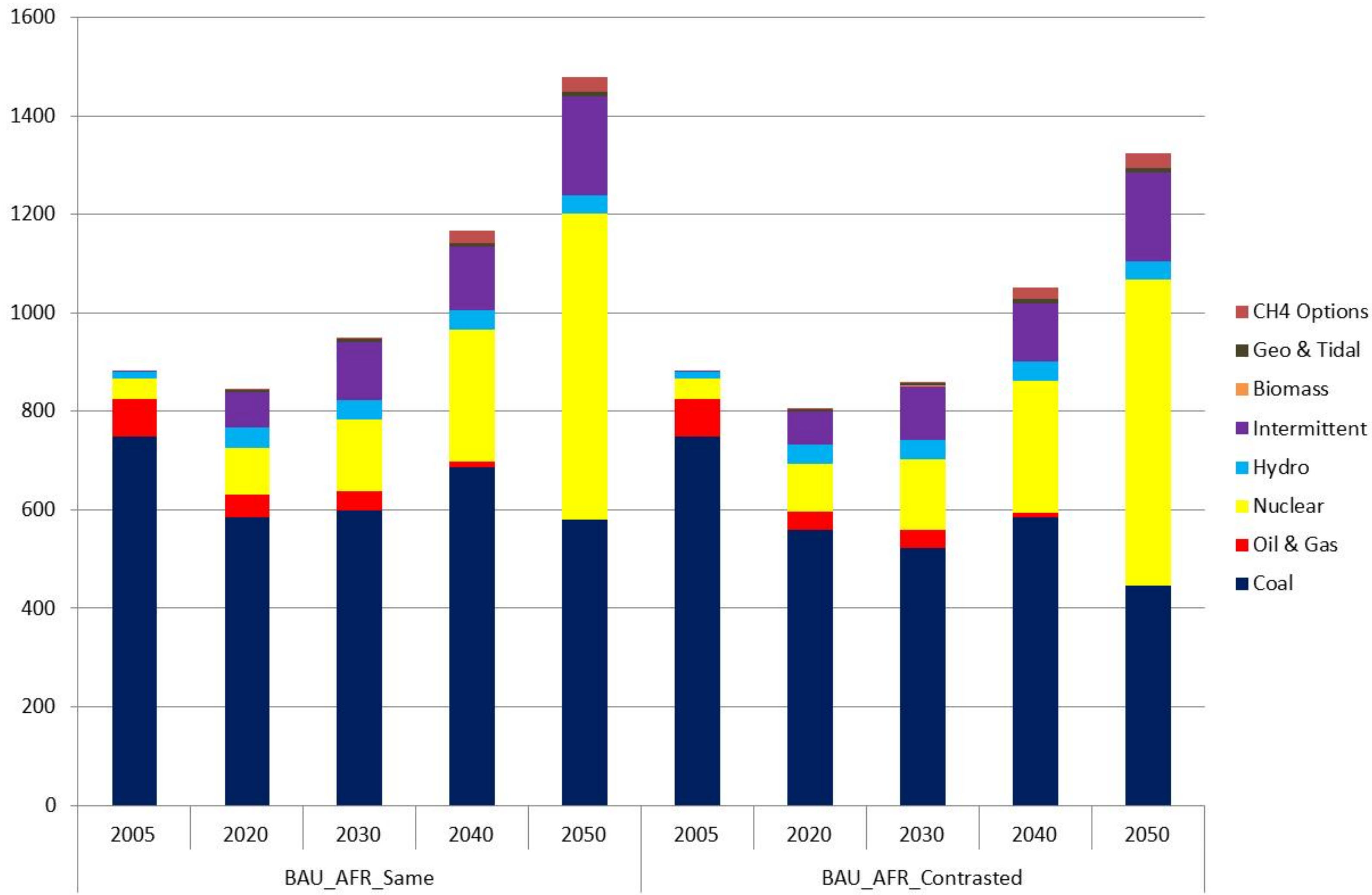
Electricity production (PJ) Sub-Saharan Africa



Electricity production (PJ) – Sub-saharan Climate constraint scenario



Electricity production (PJ) South Africa



Electricity production (PJ) – South Africa Climate constraint scenario