Projet PROSPEN 2
2017 - 2020

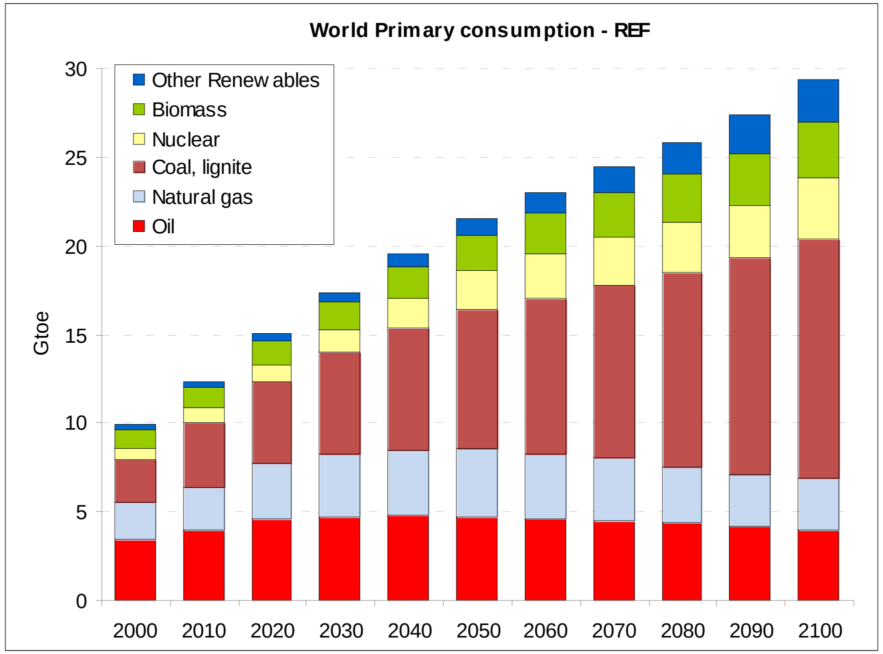
The role of gasification and methanisation in decarbonisation strategies

Gabin MANTULET,

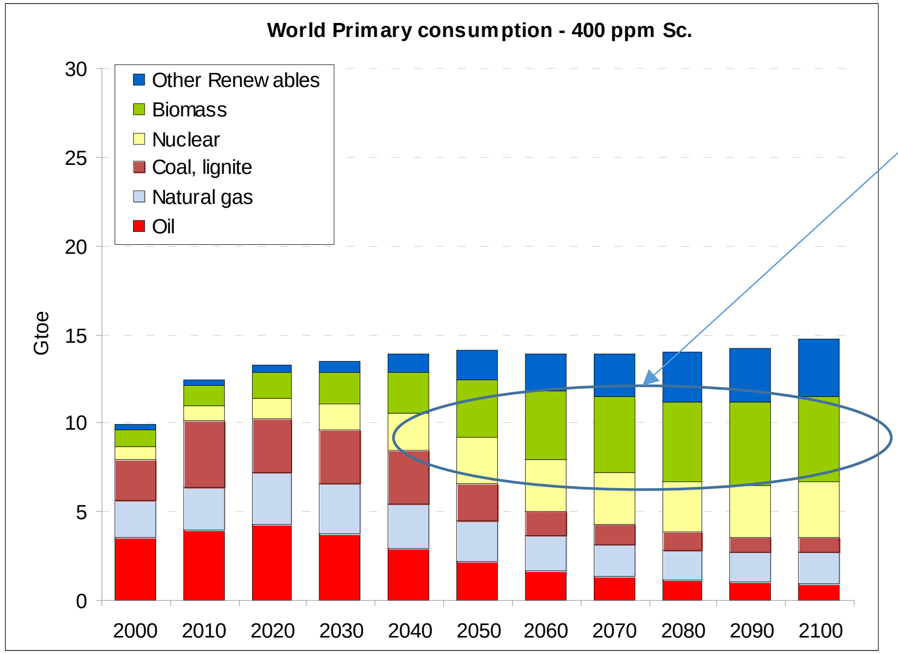
Adrien BIDAUD, Silvana MIMA

Plan

I – Energy context: decarbonisation of the energy system



POLES - Scenario Baseline



POLES - Scenario <2°C

Importance of biomass
- Renewable energy
- Various energetic path or chemical options
- Negative CO2 emissions

- The interactions of bioenergy deployment and emission reductions have been analyzed in a number of studies

Prominent role of biomass with climate policies

→ Combustion: heat and electricity

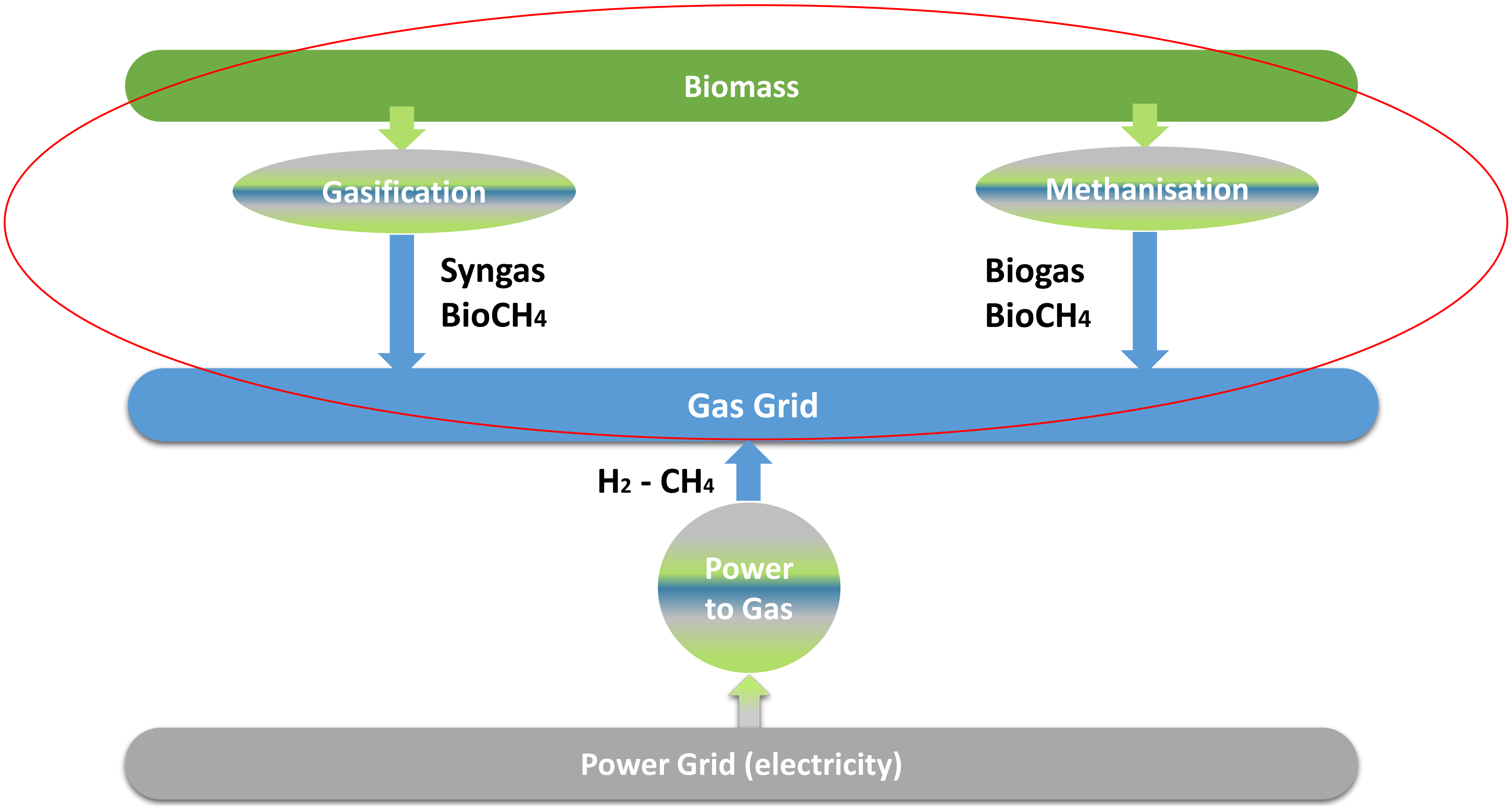
→ Biofuels

- The CARNOT study aims to complement them by performing a more detailed analysis on the availability of bioenergy technologies and their role for achieving emission limitations.

Role of new utilization of biomass linked with **green gas** vector: **gasification** and **methanisation**.

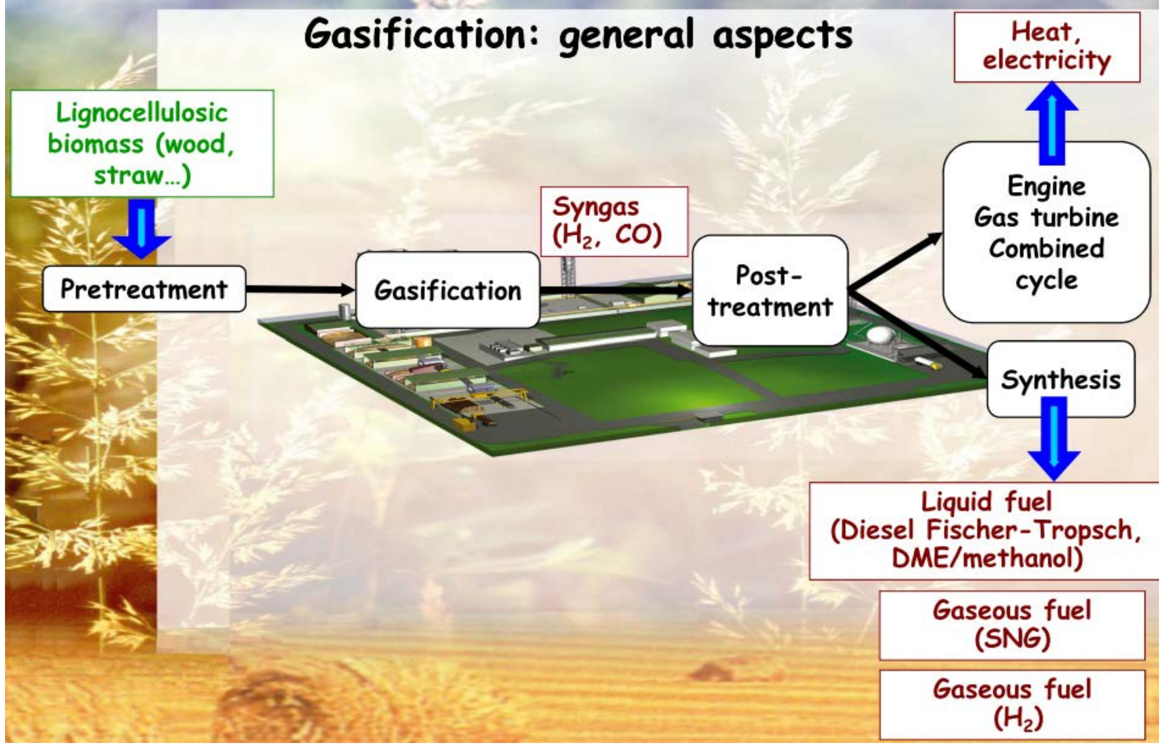
Plan

II – Green gas processes



Source: GRTgaz, projet Jupiter 1000, dec 2016

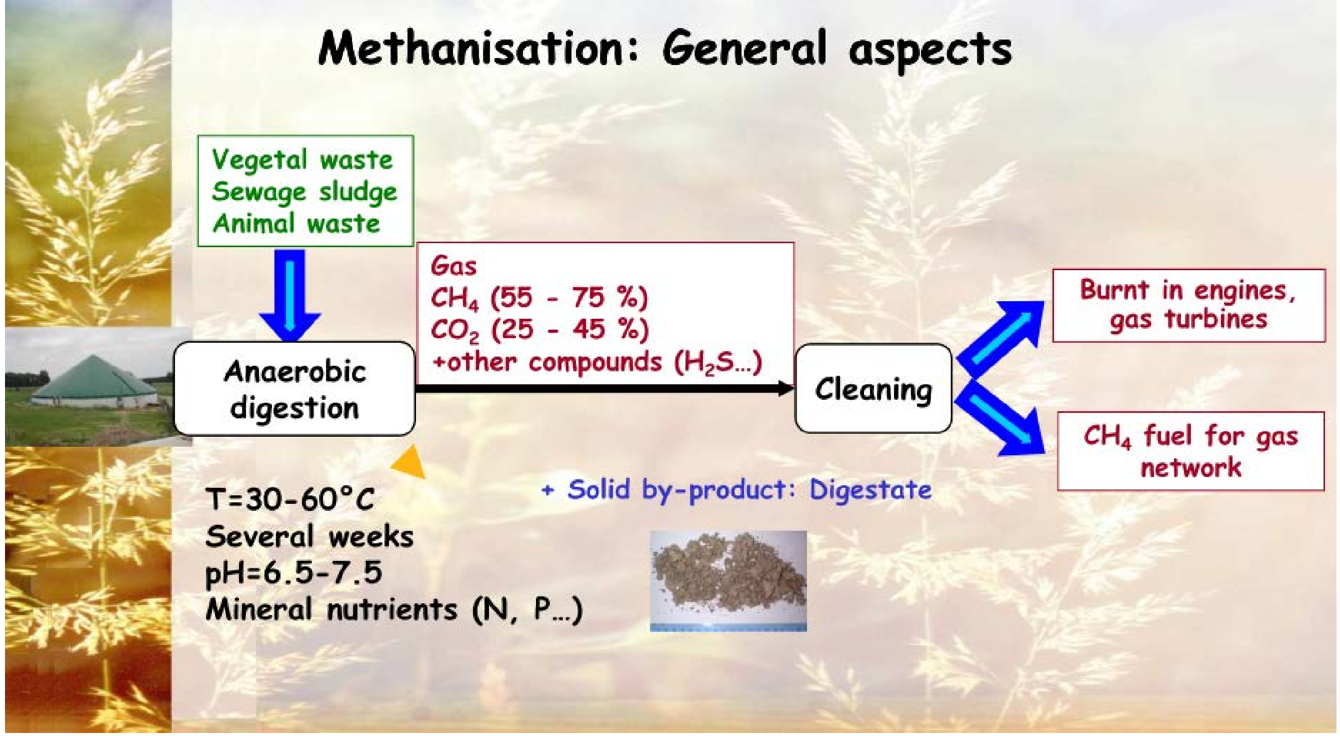
II – Gasification



Advantages	Drawbacks
Able to convert lignocellulosic biomass and solid recovered fuels: **2nd generation biomass**	**High costs** for the resource
Recovery of local resources (local lignocellulosic resource such as wood residues)	Suitable only for **medium to large scale applications**
Various final products, including fuels that are mixable with conventional fossil fuels	Field **not very organised** yet. Still **R&D issues**
The bioenergy technology with the **best energy index** = energy in fuel / total fossil energy consumed	**High competition with other use** for 2nd generation of biomass such as direct heating and building timber.

Source: Gasification process, Capucine DUPONT, « The main biomass to energy routes », CEA

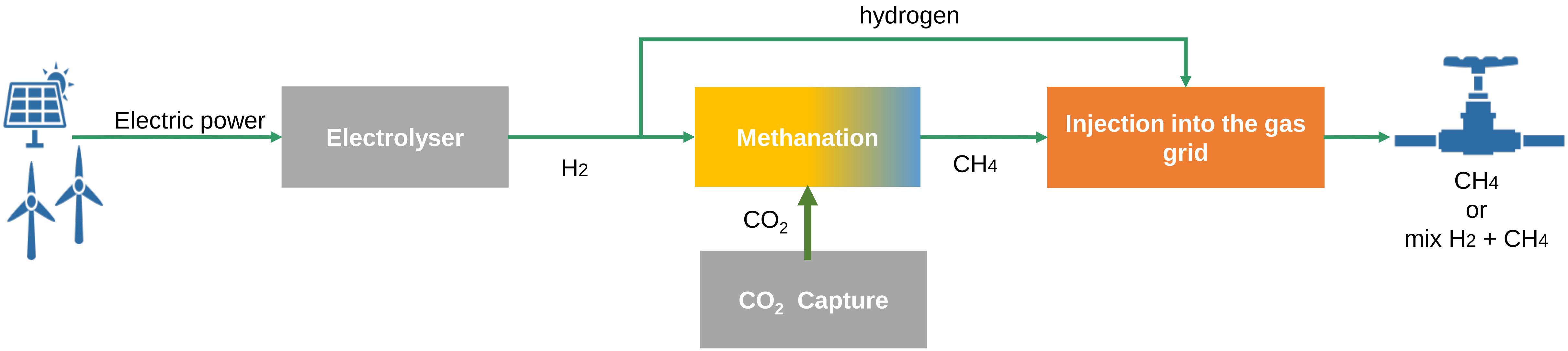
II – Methanisation



Advantages	Drawbacks
Robust and simple technology due to low temperature and pressure needed	Very **low reaction rate** (up to several weeks)
Recovery of local resources (wastes, agricultural by-products for farmers)	**Not** suitable for exclusive **2nd generation biomass** valorization (lignocellulosic)
Suitable for **wet biomass and liquids**	**Bacteria poisoning** with some biomass
Production of **CH_4** for use in **the existing pipeline**	**Severe gas cleaning mandatory** for fuel application
Recovery for by-products (the digestate can be used as soil **fertilizer**)	
Suitable for **small scale units**	

Source: Methanisation process, Capucine DUPONT, « The main biomass to energy routes », CEA

II – Power to gas

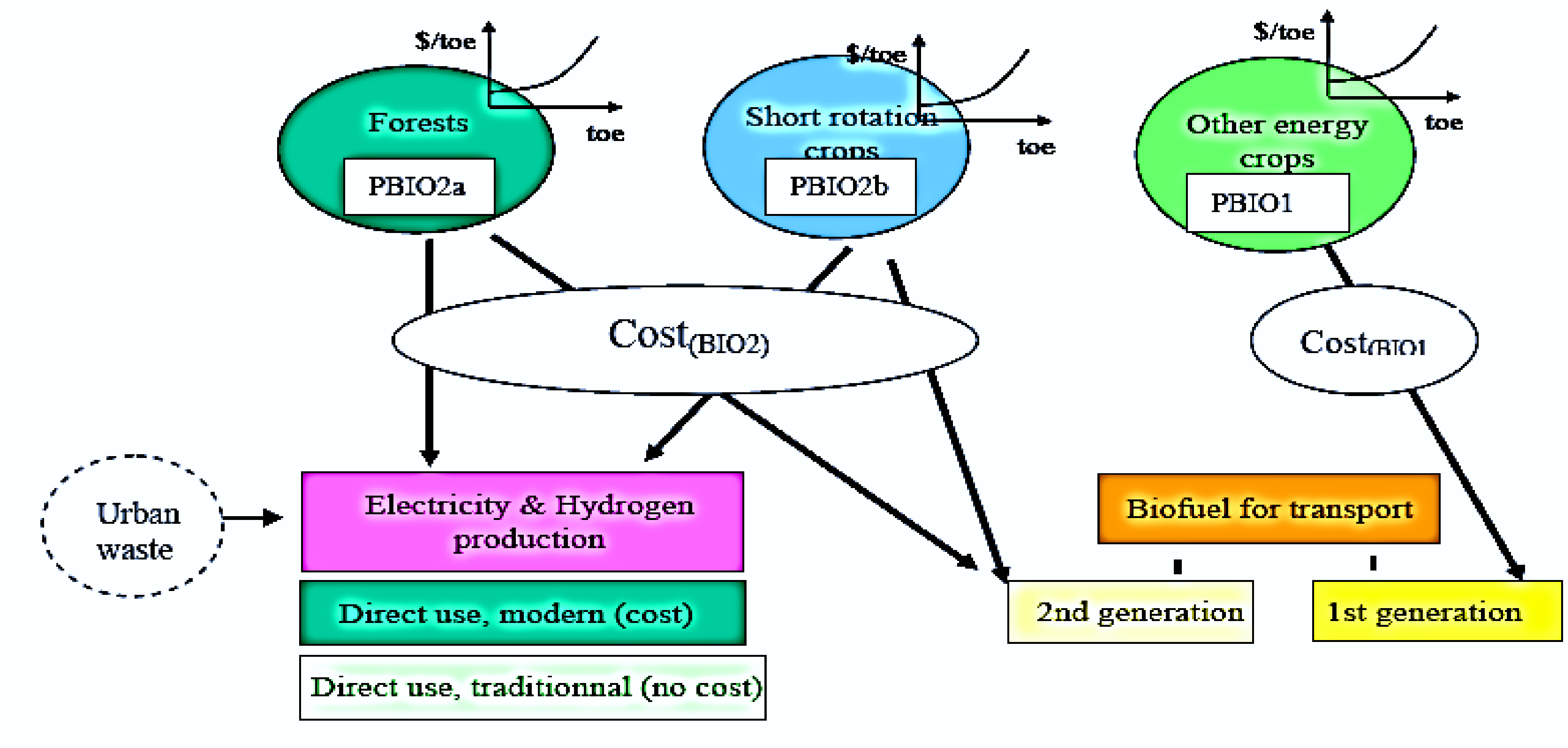


Advantages	Drawbacks
Valorization of **electricity surplus** produced by VRE	**Yields** to be improved
Large scale storage system	Yet **expensive** technology
Various valorization products, including electricity (gas to power), direct gas consumption, heat	Only at a **early R&D step**
CO_2 valorization (Carbon Capture and Use)	

Source: GRTgaz, projet Jupiter 1000, dec 2016

Plan

III – Methodology: biomass modelling in the POLES model



- Several biomass generations with different energetic valorization
- Each bio-energy feedstock is represented by a maximum potential and a marginal cost curve
- Information comes from specialist models: cost curves and potentials: GLOBIOM (default), Green-X, etc.

III – Methodology: biomass in climate constraint scenarios

1) **Scenarios**

- **Baseline** = business as usual
- **<2°C scenario** = implementation of climate policies reaching **the carbon budget 900GtCO_2**

2) **Output declined as**

- **Perimeter** (World and several countries: France, China, Brazil and USA)
- **Type of biomass** (1st and 2nd generation of biomass)
- **Final use** (electricity, heat, gas, biofuel)
- **Technologies** (gasification and methanisation)

3) **Comparison with other models from**

- International Energy Agency
- World Energy Council

Plan

I – Energy context

II – Green gas process

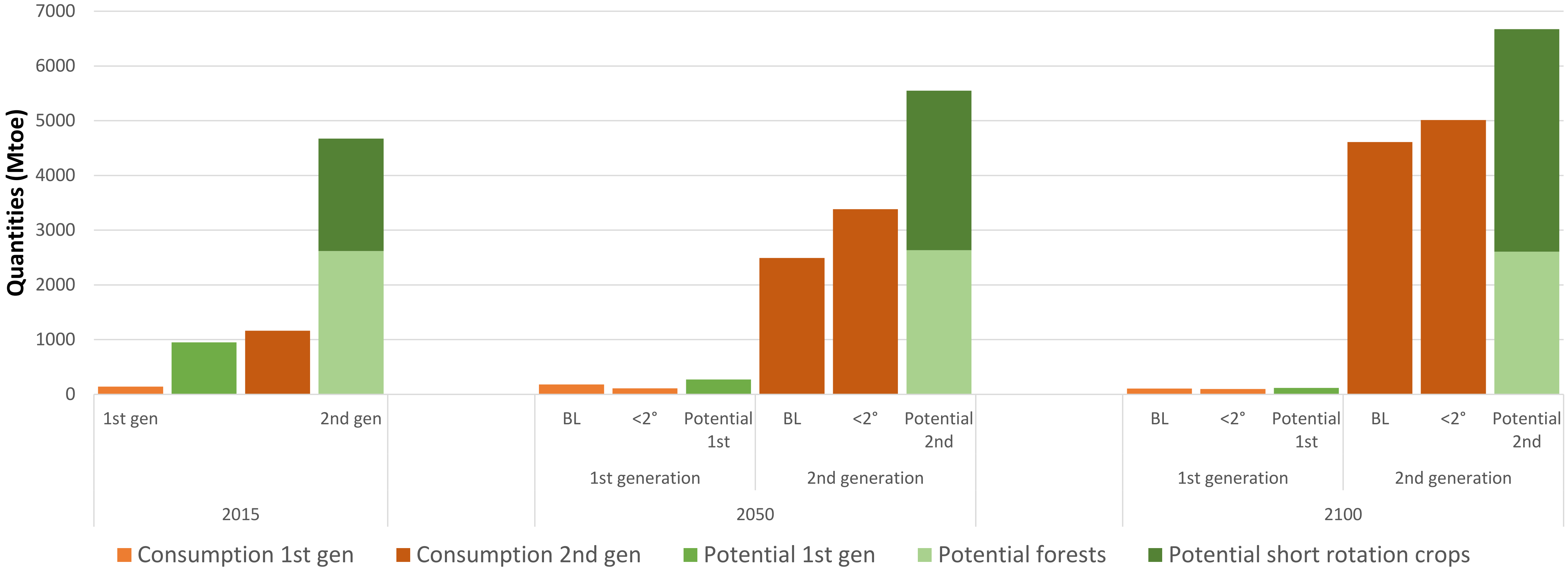
III – Methodology

IV – Modelling results

V – Scenarios comparison

VI – Conclusions and perspectives

IV – Modelling results : growth of biomass potential and consumption - World



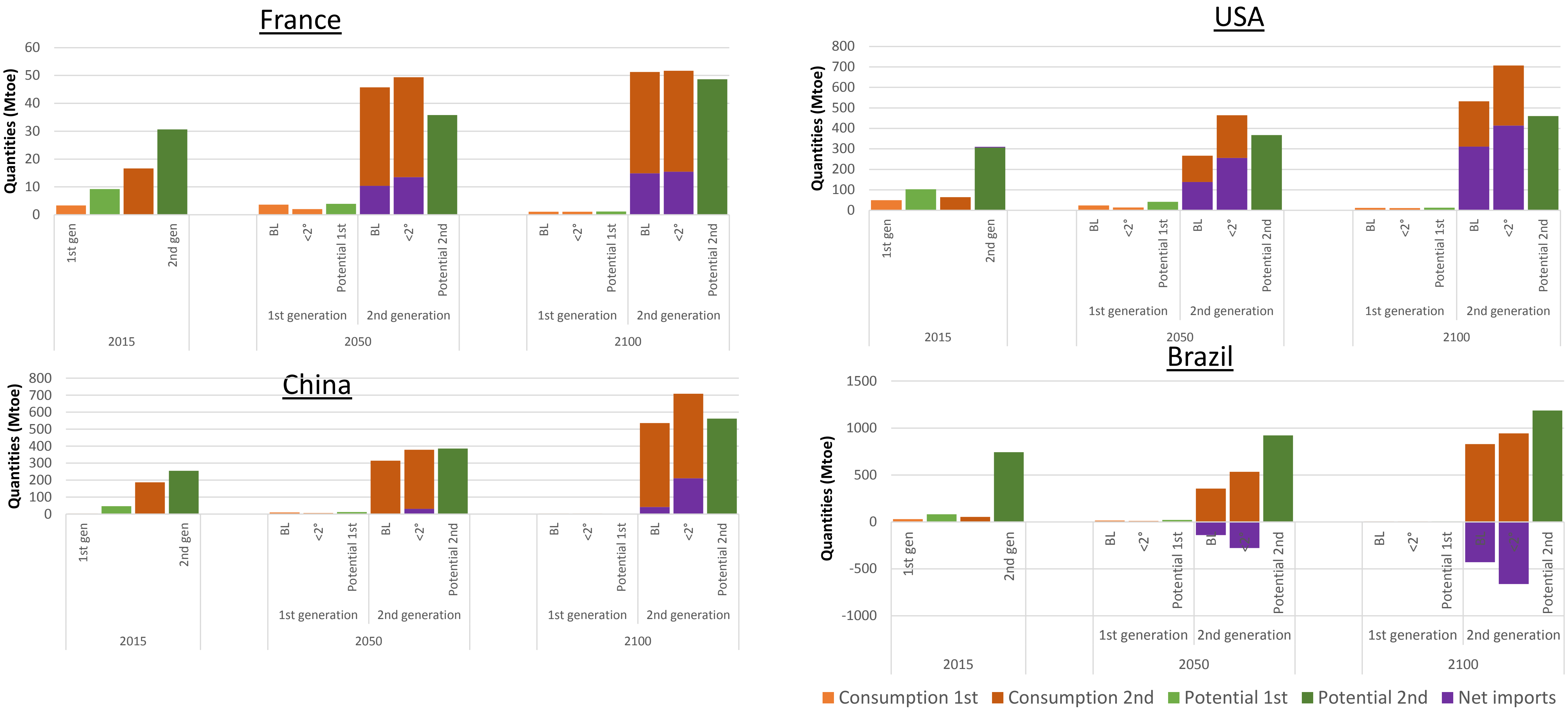
Consumption

- Decrease in 1st generation (food constraints + potential saturation)
- Linear increase in 2nd generation biomass consumption
  - Same proportion in energy mix for baseline
  - Increase proportion from 11% to 18% in climate policies scenario

Potential

- Forest potential remains constant
- Linear growth of short rotation crops potential
- Linear decrease of 1st gen potential

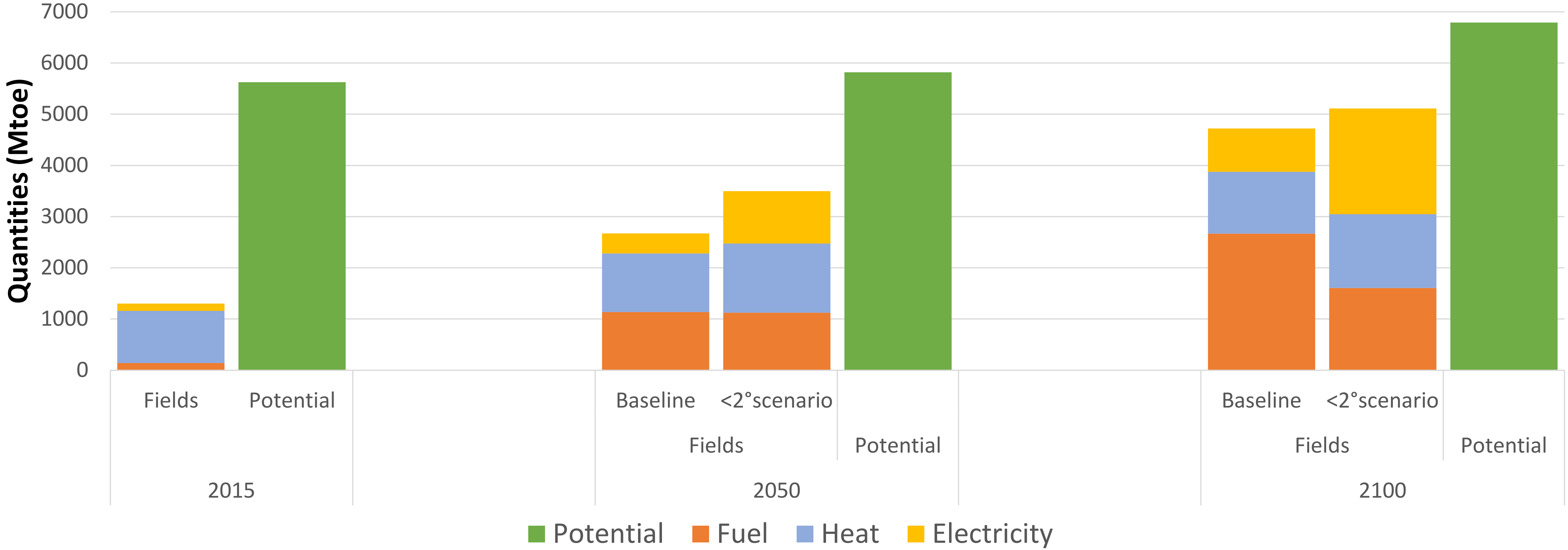
IV – Modelling results: growth of biomass potential and consumption - countries



Massive increase in consumption for many countries that overtake their country potential

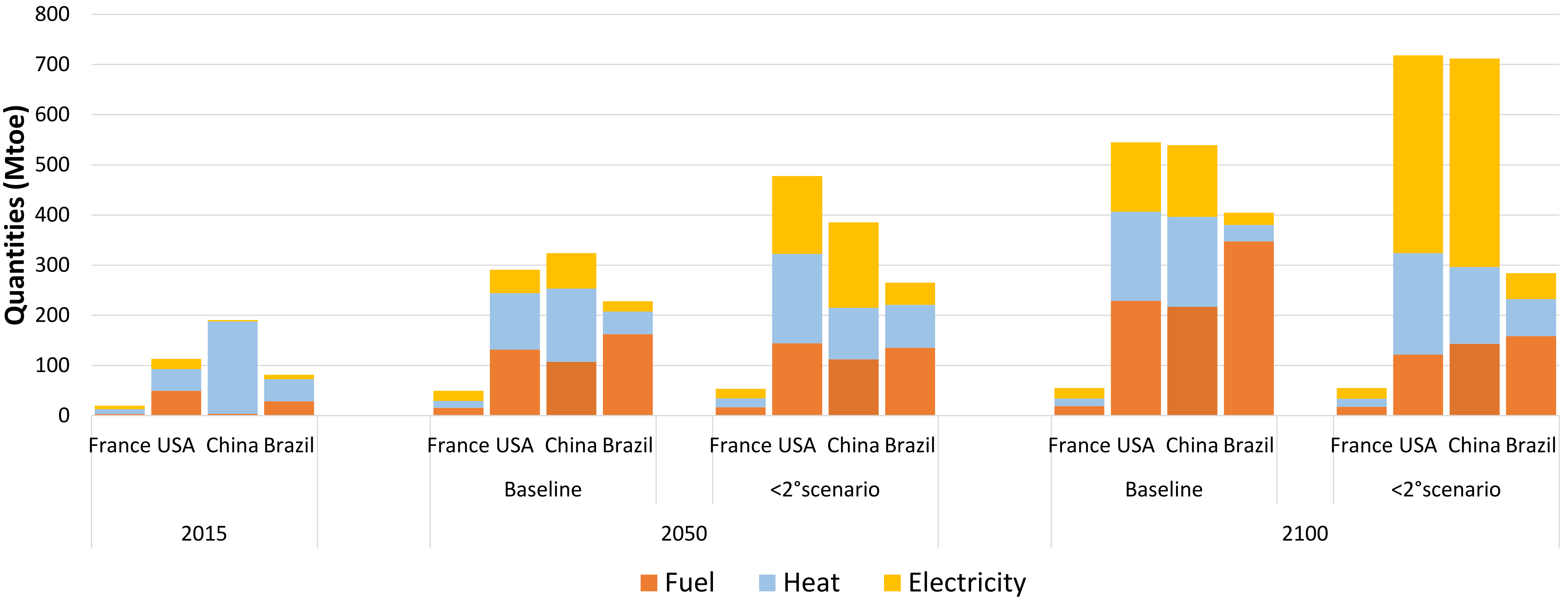
- Brazil (and Russia+Canada+RSAM) = massive exporter worldwide for 2nd gen biomass needs

IV – Modelling results: different biomass use pattern - world



- 2015: **heat** is currently the main valorisation field in the world for biomass.
- 2050-2100: growth in quantity and proportion for advanced valorization fields: **electricity** and **2nd gen biofuel**
  Electricity privileged in climate policies scenario, biofuels in baseline
  Same quantity of heat valorization.
- **Overall consumption increases** through the century and uses a **bigger proportion of potential** (from 23% in 2015 to 75% in 2100)

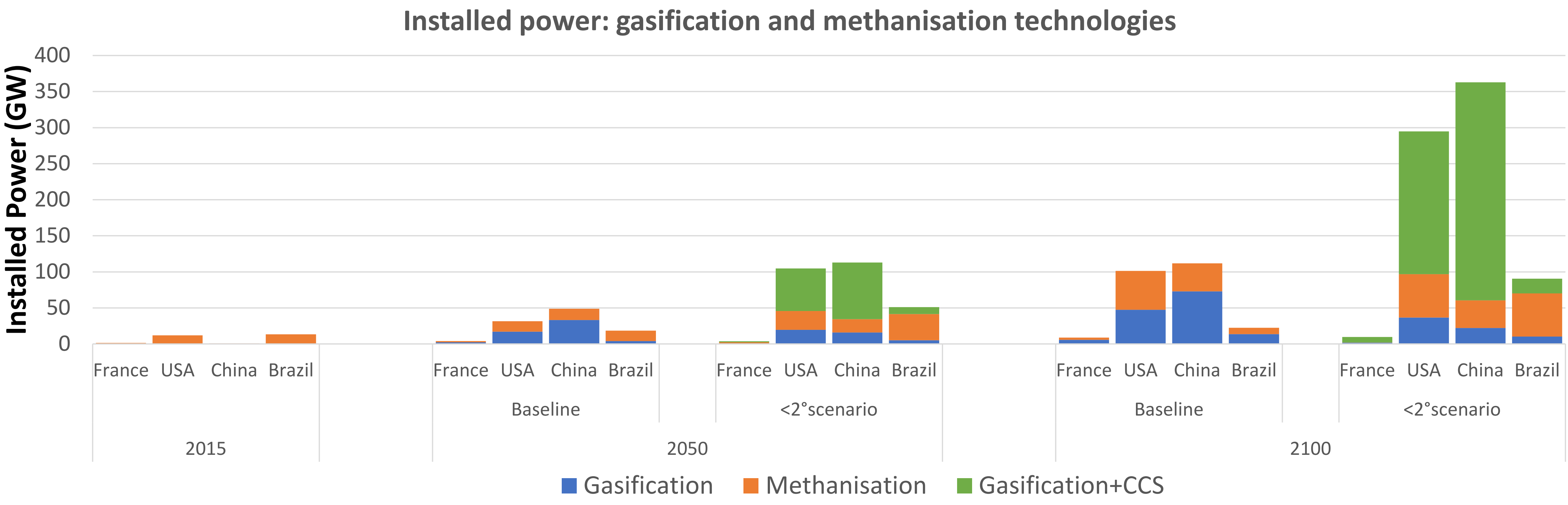
IV – Modelling results different biomass use pattern - countries



Various trends among countries according to scenarios

- The importance of “continent countries” in world energy trends
- More overall biomass consumption in climate policies scenario, with more electricity and heat and less biofue
- More valorization in electricity and heat in proportion in Northern countries and biofuel in others

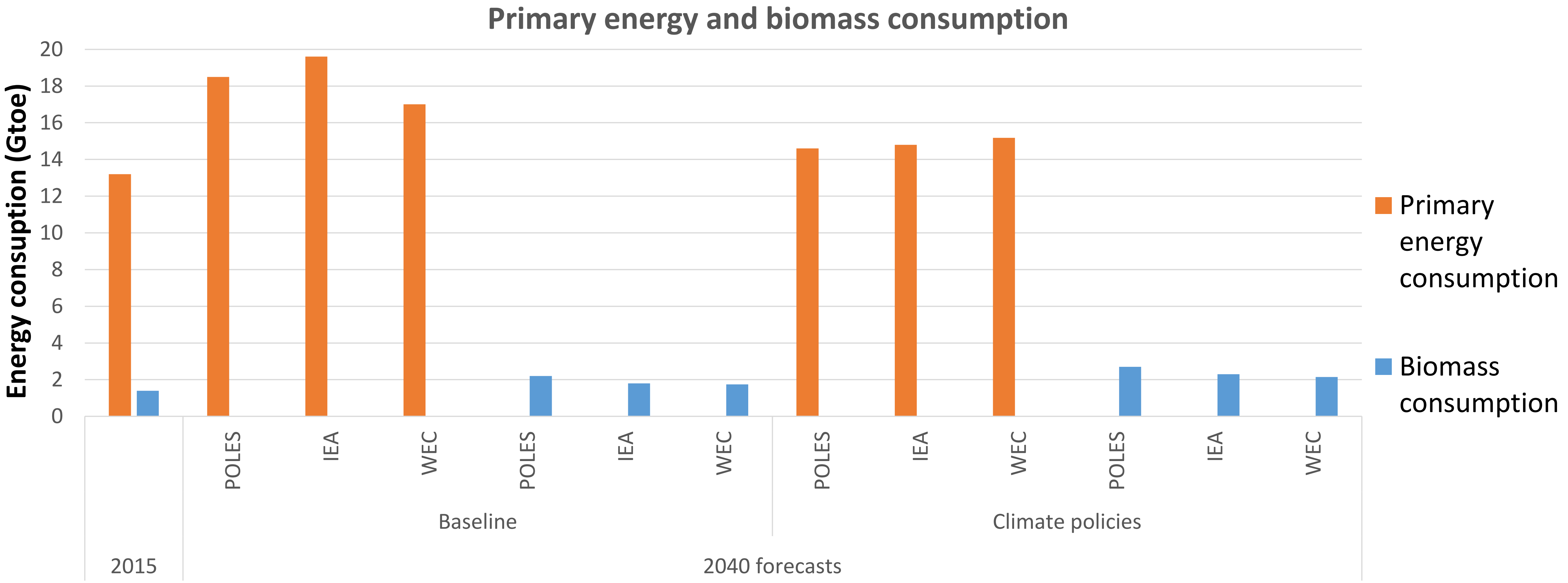
IV – Modelling results: different technologies penetration rate



- Only installed power for **methanisation** in 2015; **methanisation** develops **earlier** than **gasification**
- Approximately **same penetration rate in 2050 and 2100** for **both technologies**
- Importance of **CCS in climate policies scenarios** that explode the gasification installed power
- Functioning time = between 5000 and 8000h/y → base/semi base functioning pattern for both technologies

Plan

V – Results comparison: Baseline and climate policies scenarios from IEA and WEC

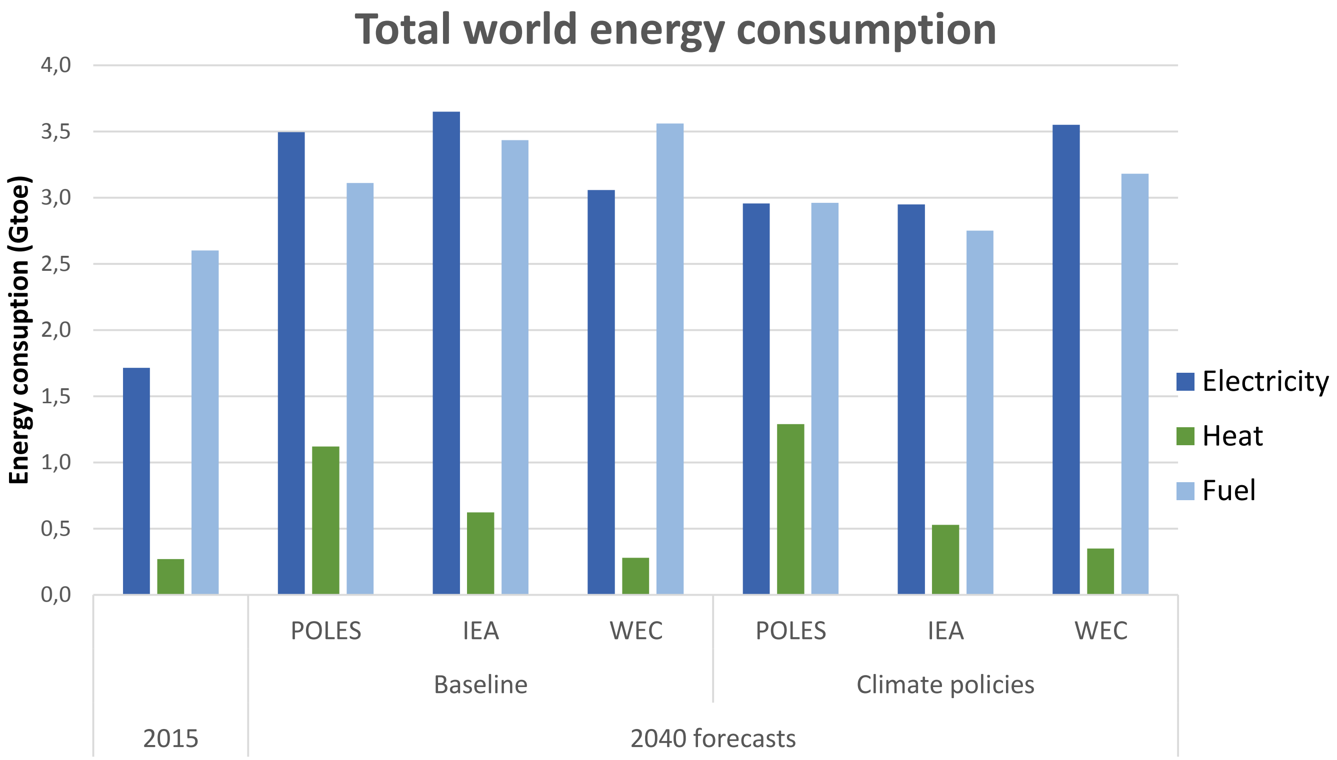


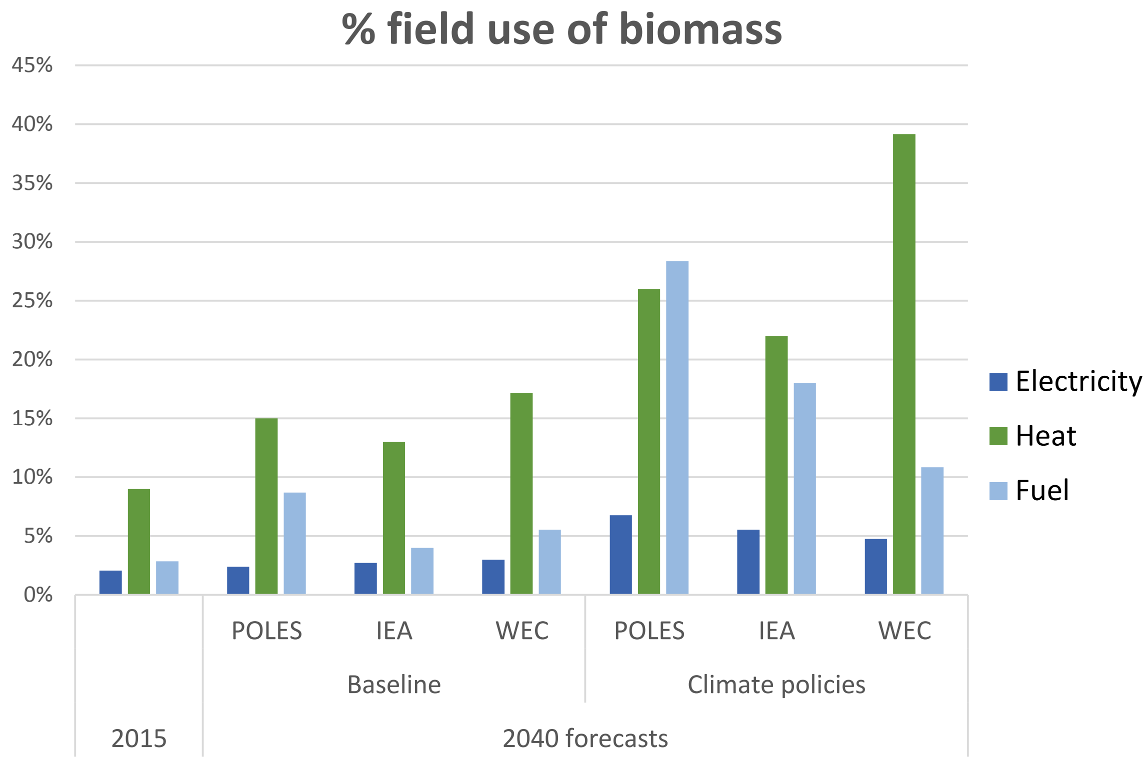
- Increase of total energy consumption, more limited in scenarios with climate policies
- Increase of biomass consumption, more pronounced in scenarios with climate policies with a growth of biomass proportion in the energy mix

Source: Conseil Mondial de l'Énergie et Conseil Français de l'Énergie," Les Scénarios Mondiaux de l'Énergie à l'horizon 2050 - Mise en musique des futurs de l'énergie », 2013

Source: IEA, "World energy outlook 2016", 2017

V – Results comparison: Baseline and climate policies scenarios from IEA and WEC





- **Decrease** of proportion of traditional **direct use** of biomass (combustion), from 55% of total bioenergy in 2015 to around 30% in 2040.

- Higher % of use of biomass in **climate policies scenarios**
- Higher % of use of biomass in **heat sector** than others fields where competition is more present

- Increase in proportion in **electric** mix (from 2,1% of energy produced in 2015 to around 6,8% in 2040) and others advanced vectors heat and fuel thanks to methanisation and gasification.

- POLES model gives a little bit more importance to bioenergies than others even if the order of magnitude is coherent.

Plan

VI – Conclusions and perspectives

Conclusion

- Bioenergies technologies will develop by 57 to 93% (according to the scenario) from 2015 to 2040 and the **bioenergy** could be **multipled by 5 from 2015 to 2100.**

- **2ND generation biomass** will be used widely in presence of **climate policy**, notably in **electric system**
- **Electricity and heat** are prominent in **northern countries**, **biofuels** in **developing countries**

- Penetration speed and rate depends on potential, technology maturities and cost effectiveness
  → Methanisation develops earlier than gasification …
  → … but methanisation and gasification will be used at the same rate in the second part of the century

Perspectives

1) Improve modelling
   - Adding **power to gas** to complete the full green gas chain
   - Adding **gas mobility** (Natural Gas Vehicle) in final use

2) The contribution in decarbonised energy system
   - Consider bioenergy and green gas technologies for **flexibility** and **energy security**
   - Consider **technology availability and trade market** that is crucial for the achievability and the costs of emission reduction targets and the future of the overall energy sector.

Laboratoire de Physique Subatomique et de Cosmologie

Projet PROSPEN 2
2017 - 2020

Laboratoire d'Économie Appliquée de Grenoble

Thank you for your attention

Gabin MANTULET, PhD student, LPSC – CNRS, Laboratoire de Physique Subatomique & Cosmologie (LPSC)
53 Avenue des Martyrs, 38000 Grenoble
Phone: +33 (0) 6 18 13 03 72, Email: gabin.mantulet@univ-grenoble-alpes.fr

Adrien BIDAUD, CNRS researcher, LPSC – CNRS, Laboratoire de Physique Subatomique & Cosmologie (LPSC)
Phone: +33 (0)4 76 28 40 45, Email: Adrien.Bidaud@lpsc.in2p3.fr

Silvana MIMA, CNRS researcher, GAEL – CNRS, UPMF - BP 47 - 38040 Grenoble
Phone : +33 (0)4 56 52 85 89, Email : silvana.mima@univ-grenoble-alpes.fr

Bibliography

ADEME, Anne-Laure Dubilly, ARTELYS, Laurent Fournié, Alice Chiche, “Mix électrique 100% EnR en 2050 : quelles opportunités pour décarboner les systèmes gaz et chaleur ? “, 51p, sept 2017

Conseil Mondial de l’Énergie et Conseil Français de l’Énergie,” Les Scénarios Mondiaux de l’Énergie à l’horizon 2050 - Mise en musique des futurs de l’énergie », 2013

CRIQUI P, MENENTEAU P, MIMA S, “Emissions Constraints and Induced Technical Change in the Energy Sector: simulations with the POLES model”, February 2009, available online/ http://www.feem.it/userfiles/attach/200911914381252009.02.18_patrick_criqui_presentation.pdf

BELLEVRAT E, MENANTEAU P, “Energy technologies and depletable resource database - Biomass supply curves”, MENGTECH, CNRS GAEL, 2012

CHEN Q and LIU T, “biogas system in rural China: upgrading from decentralized to centralized?”, Department of Economic and technological Change, Center for development research (ZEF), University of Bonn, Germany, available online 11 May 2017 and consulted 8 September 2017

Commissariat général au développement durable, « Les énergies renouvelables en France en 2016 - Suivi de la directive 2009/28/CE relative à la promotion de l'utilisation des énergies renouvelables », sept 2017, 4 p. (Datalab essentiel n° 118), available online: http://www.statistiques.developpement-durable.gouv.fr/publications/p/2668/1023/energies-renouvelables-france-2016-suivi-directive-200928ce.html

GRTgaz – GRDF – TIGF – SPEGNN, « Perspectives gaz naturel et renouvelable », 2016, available online: http://www.grdf.fr/documents/10184/1291504/Perspectives-gaz-naturel-et-renouvelable.pdf/9ef0b81d-5873-469d-b2ac-2ba8d42370db

Enerdata, Global Energy Statistical Yearbook 2017, available online : https://yearbook.enerdata.net/total-energy/world-consumption-statistics.html

IEA, “How to guide for bioenergy, roadmap development and implementation”, 2017, available online: https://www.iea.org/publications/freepublications/publication/technology-roadmap-how2guide-for-bioenergy.html

IEA, “Energy Technology Perspectives 2017: Catalysing Energy Technology Transformations”, chapter 7: Delivering sustainable bioenergy, June 2017, 315-360 p., available online: https://www.iea.org/bookshop/758-Energy_Technology_Perspectives_2017

IEA, “World energy outlook 2016”, 2017

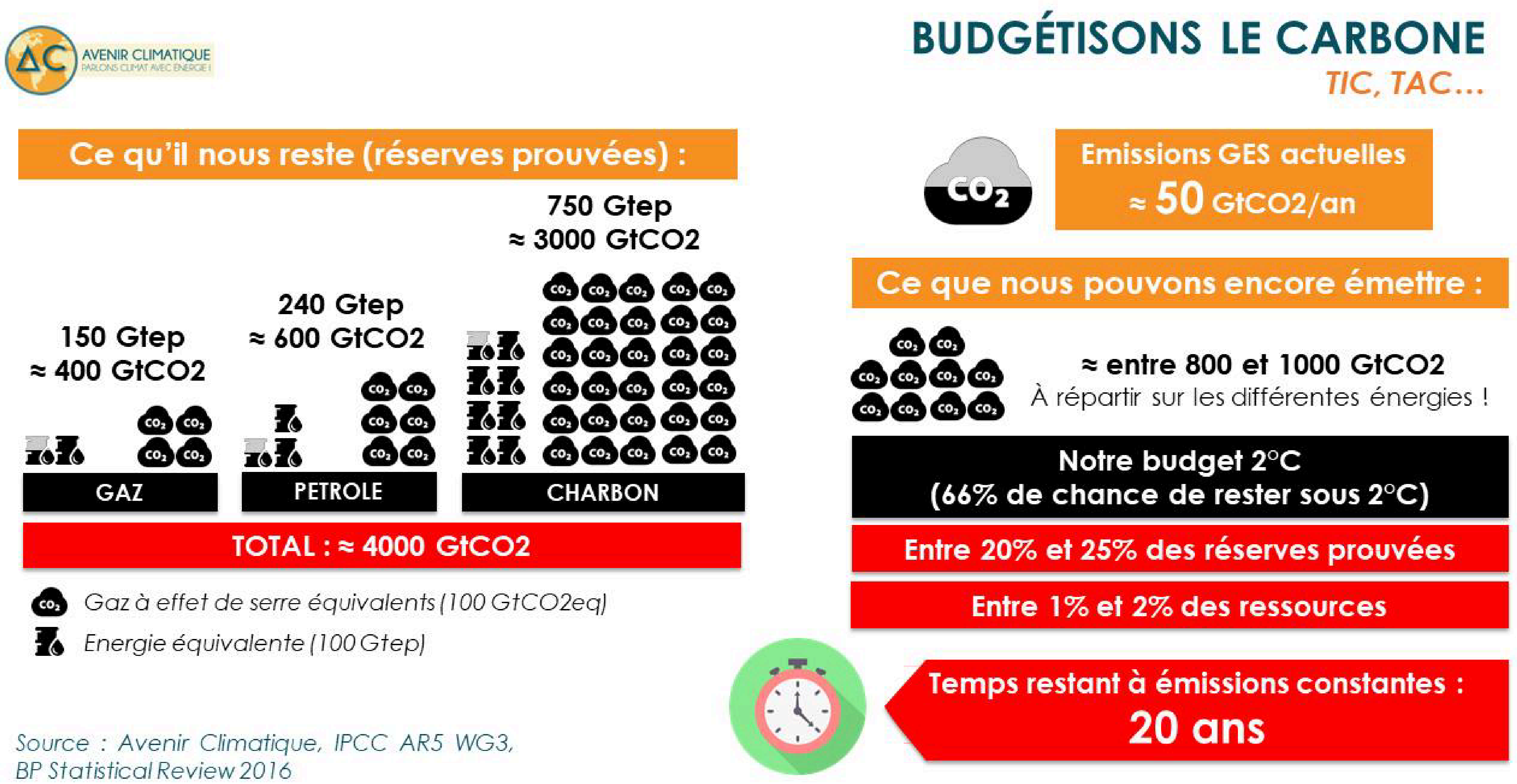
LAMBERT M, “Biogas: a significant contribution to decarbonizing gas markets?”, The Oxford institute for energy studies, June 2017, available online July 2017 and consulted 26 August 2017

LONG H an al.,”Biomass resources and their bioenergy potential estimation: A review”, College of Resources Science and Technology, Beijing Normal University, available online 25 June 2013 and consulted 15 June 2017.

OZTURKA M and al., “Biomass and bioenergy: An overview of the development potential in Turkey and Malaysia”, Center for environmental studies, EGE University, Izmir, Turkey, available online 27 May 2017 and consulted 8 June 2017.

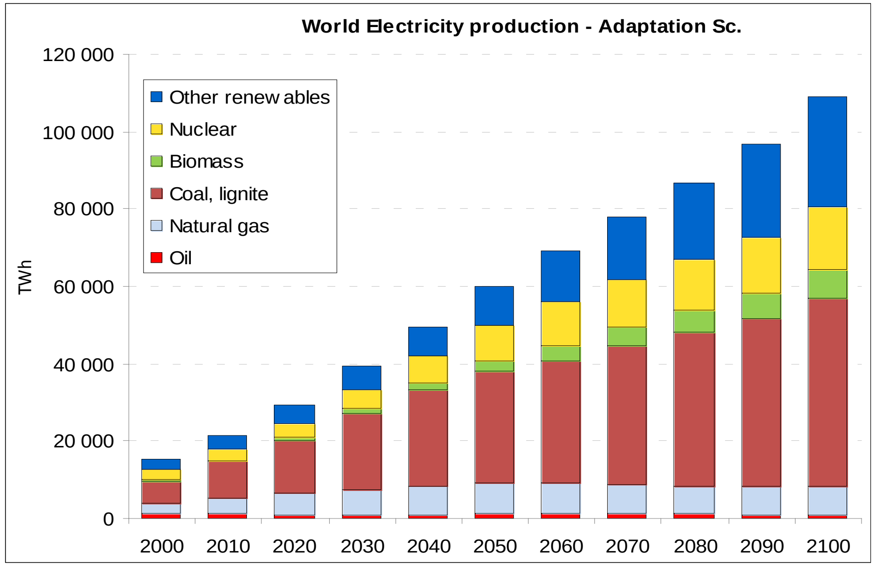
SANSANIWAL S.K. and al, “recent advances in the development of biomass gasification technology: a comprehensive review”, Sardar Swaran Singh National institute of Renewable Energy, Kapurthala 144601, Punjab, India, available online 17 January 2017 and consulted 6 July 2017

I – Energy context: decarbonisation of energetic system

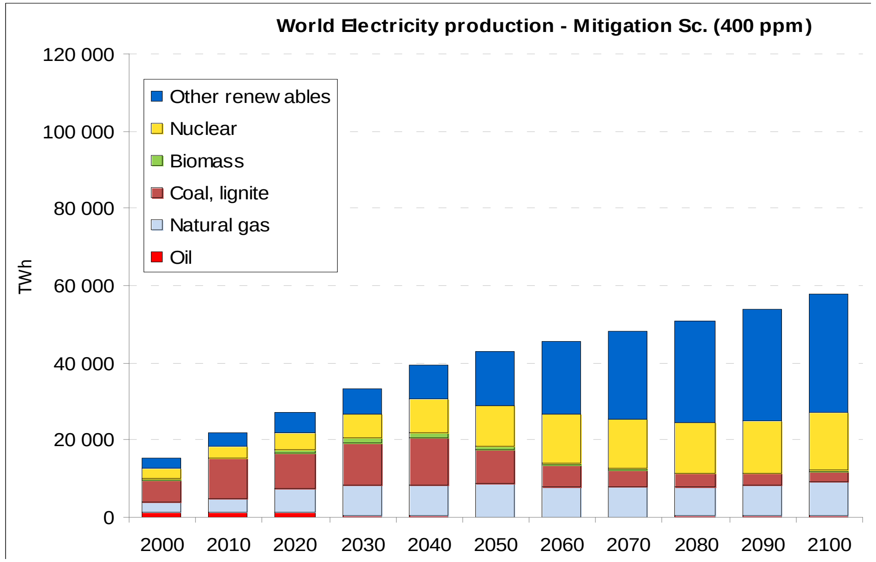


I – Energy context: decarbonisation of the electricity system

Total energy mix

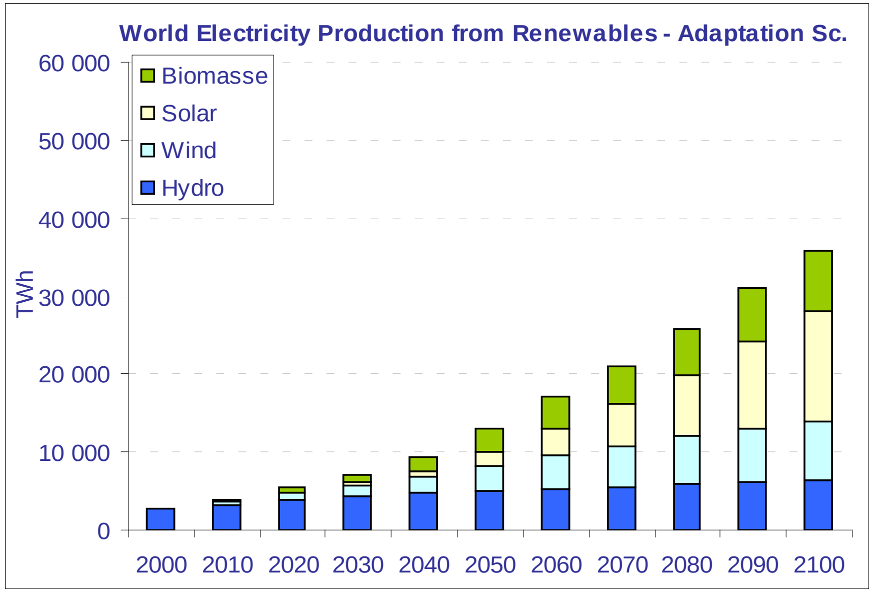


Scénario POLES BaU

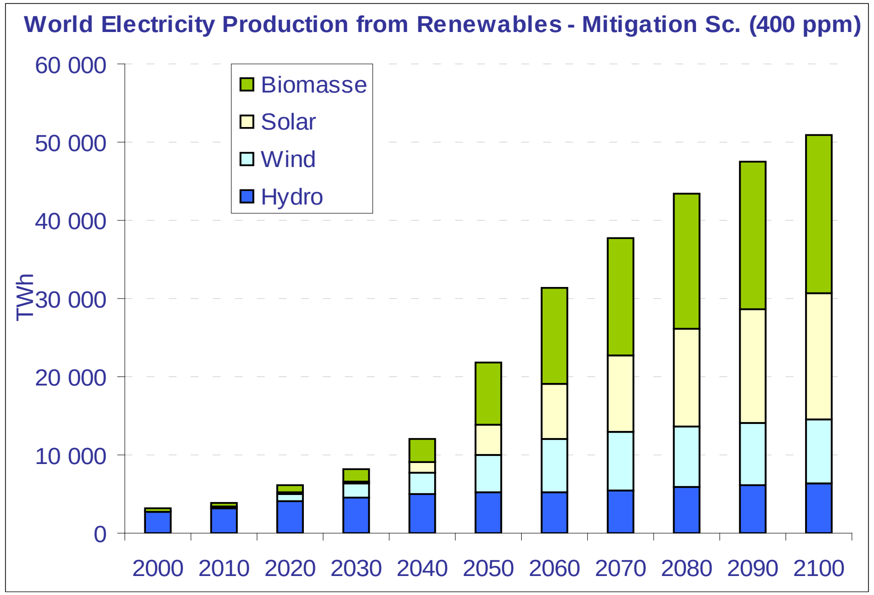


Scénario POLES <2°C

Renewables



Scénario POLES BaU

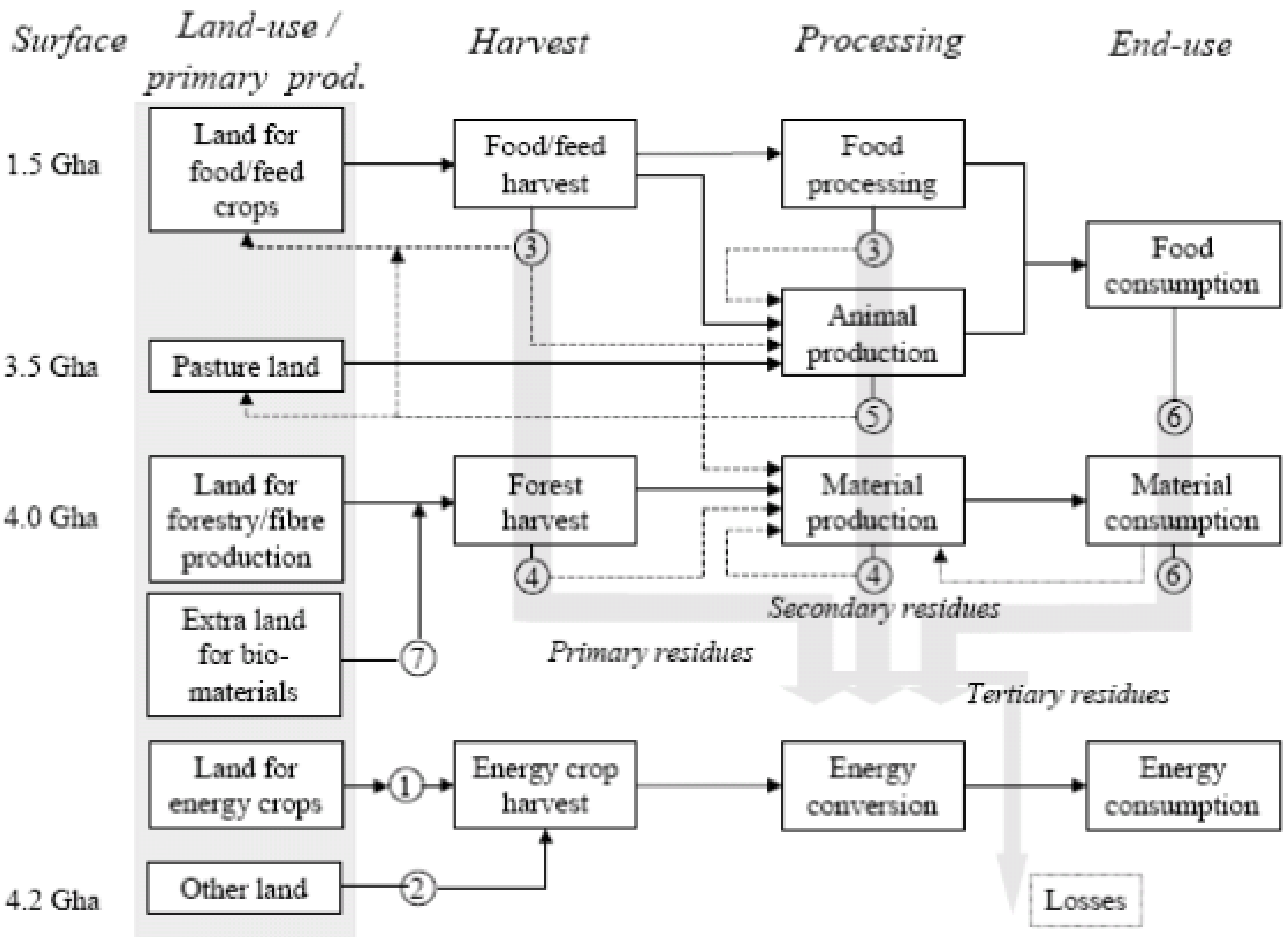


Scénario POLES <2°C

II – Bioenergies

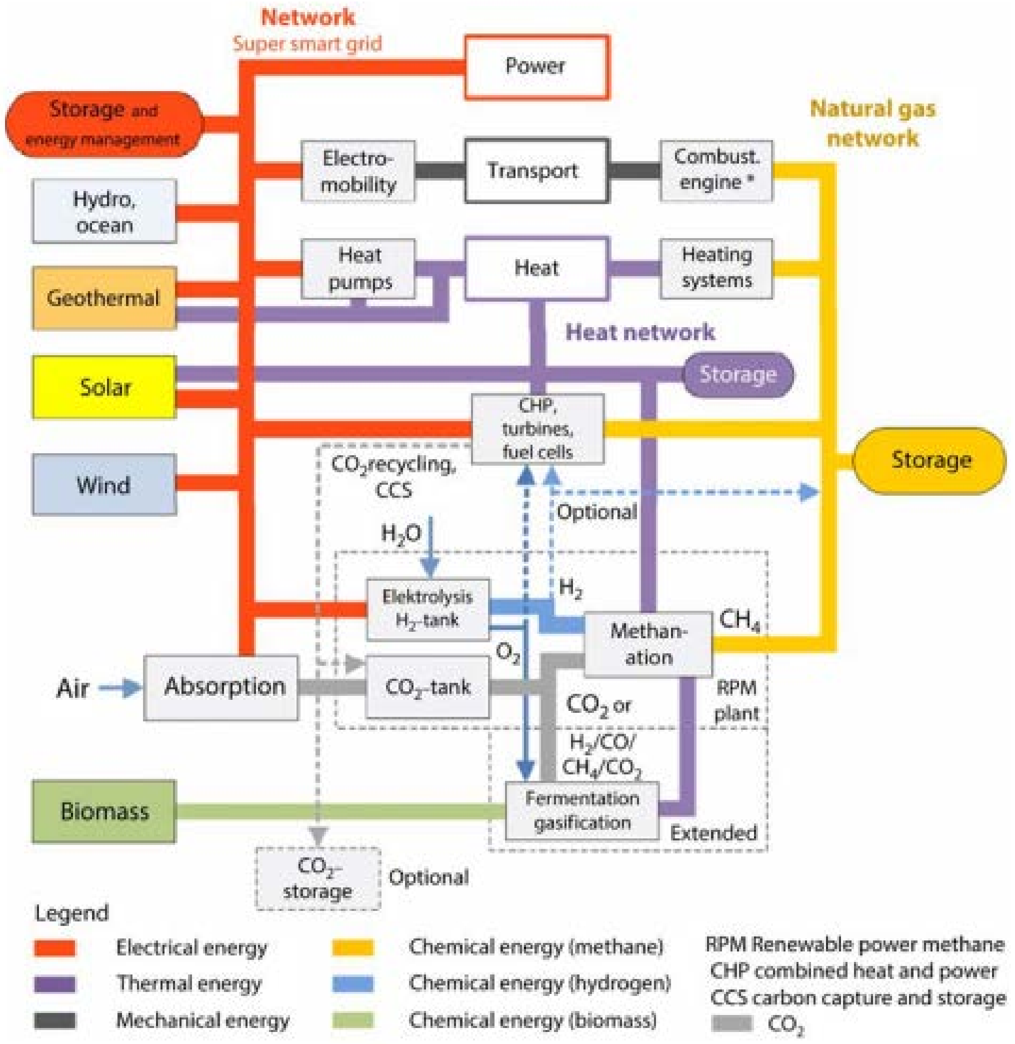
End use competition for biomass resource

Figure 32: Overview of the biomass flows and the global land surface (Source: Hoogwijk, 2003)



II – Bioenergies

Biogas production from biomass: multiples synergies and competitions with the other sources of energy

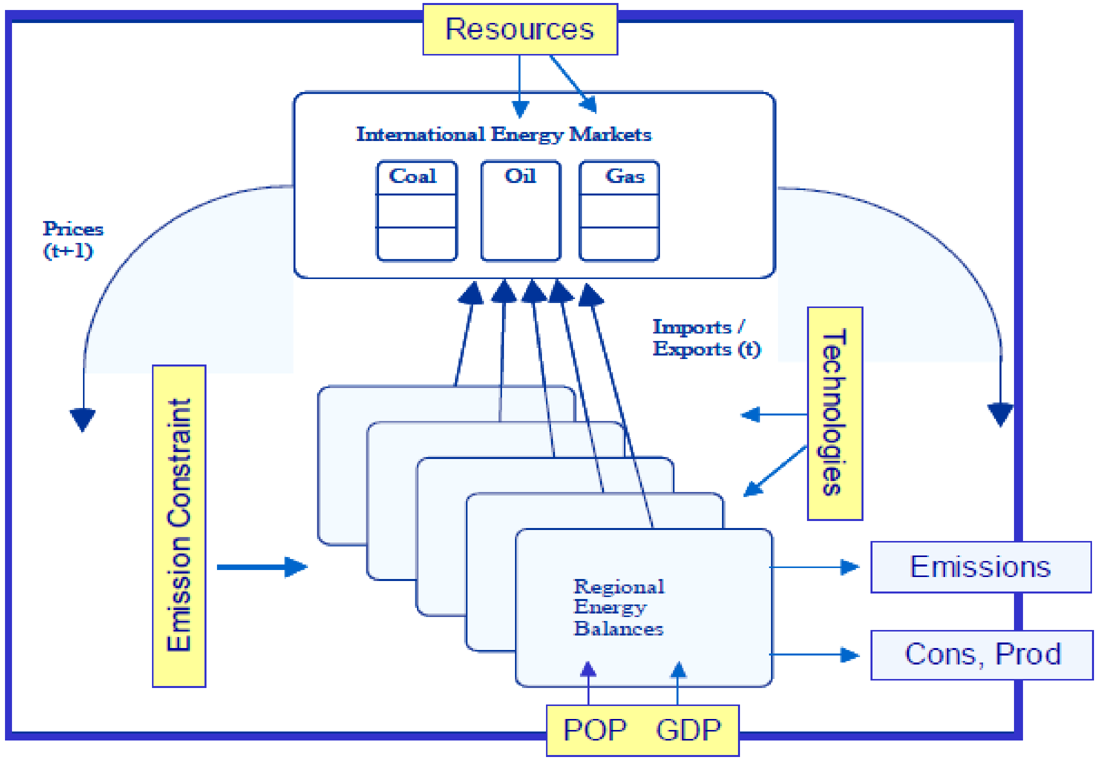


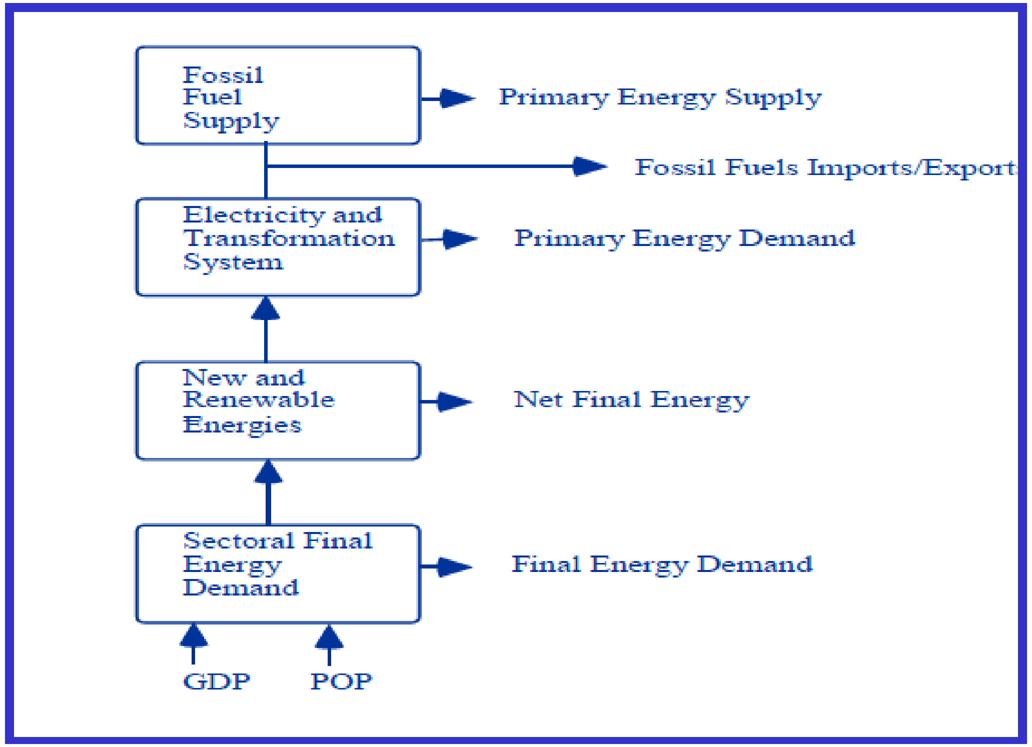
Europe's Energy Transition, Insights for Policy Making

Conceivable design of an integrated energy network system. From Sterner, Bioenergy and renewable power methane in integrated 100% renewable energy systems, Dissertation, University of Kassel, 2009 [38]; L. Brodecki, J. Tomaschek, U. Fahl, Synergies in the integration of energy networks for electricity, gas, heating and cooling. INSIGHT_E Rapid Response Energy Brief, 2014 [39].

III – Methodology

POLES, a long term energy prospective Bottom-Up modelling tool …





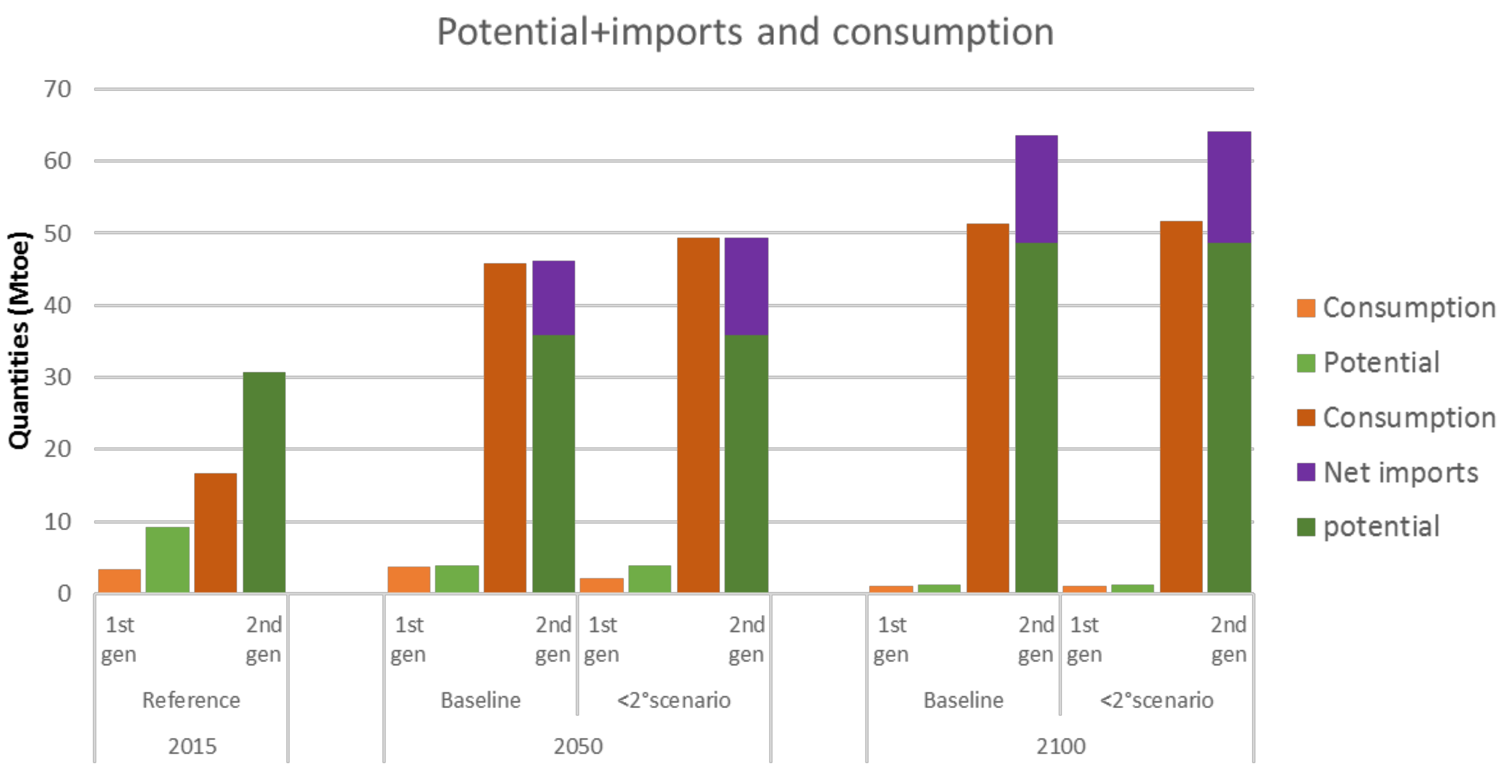
The POLES model is a global sectoral model for the world energy system. It has been developed in the framework of a hierarchical structure of interconnected sub-models at the international, regional, national level. The dynamics of the model is based on a recursive (year by year) simulation process of energy demand and supply, with lagged adjustments to prices and a feedback loop through international energy prices.

Allocation of resources by merit order (cost)

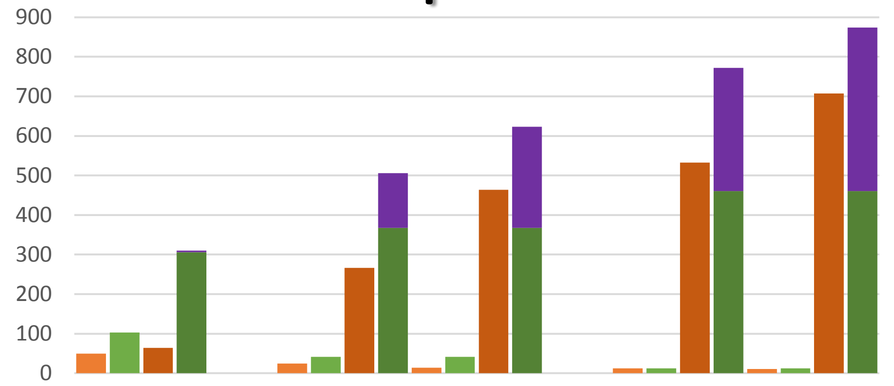
Source: Enerdata, POLES model, a world energy model

IV – Modelling results : growth of biomass potential and consumption

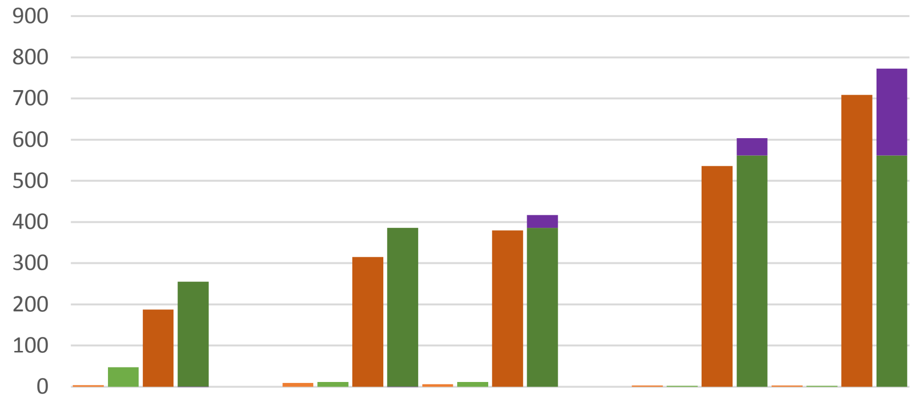
France



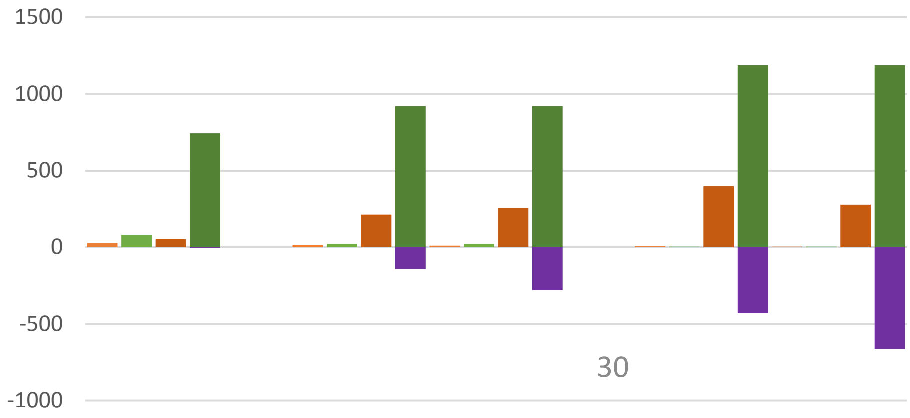
USA



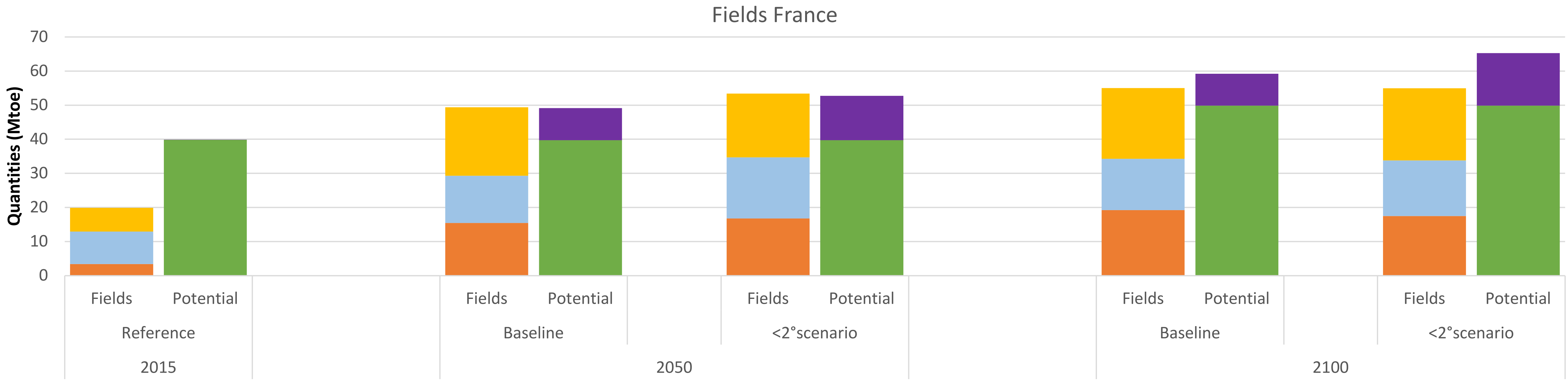
China

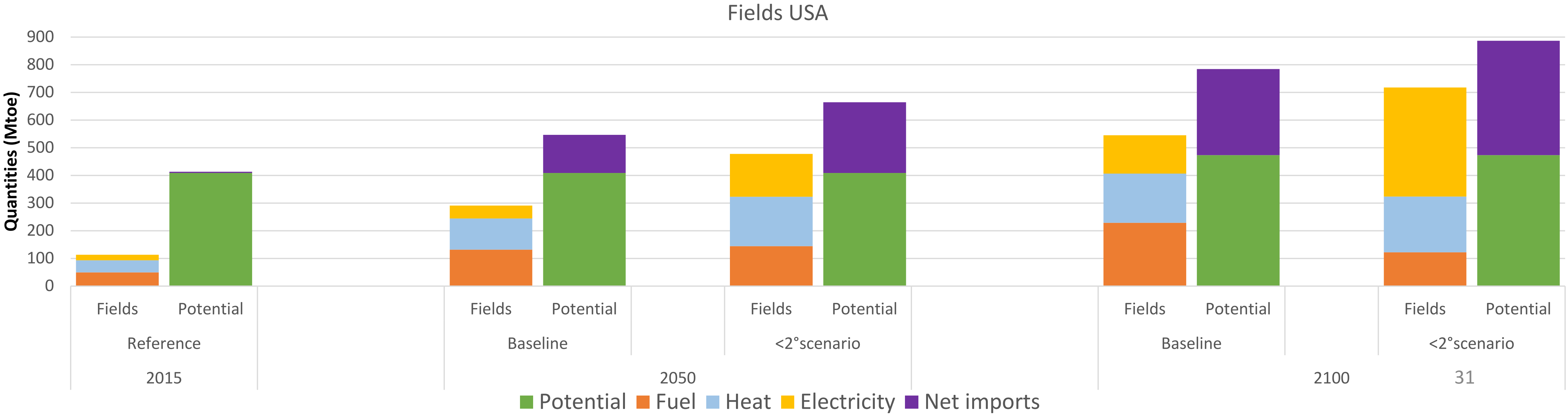


Brazil

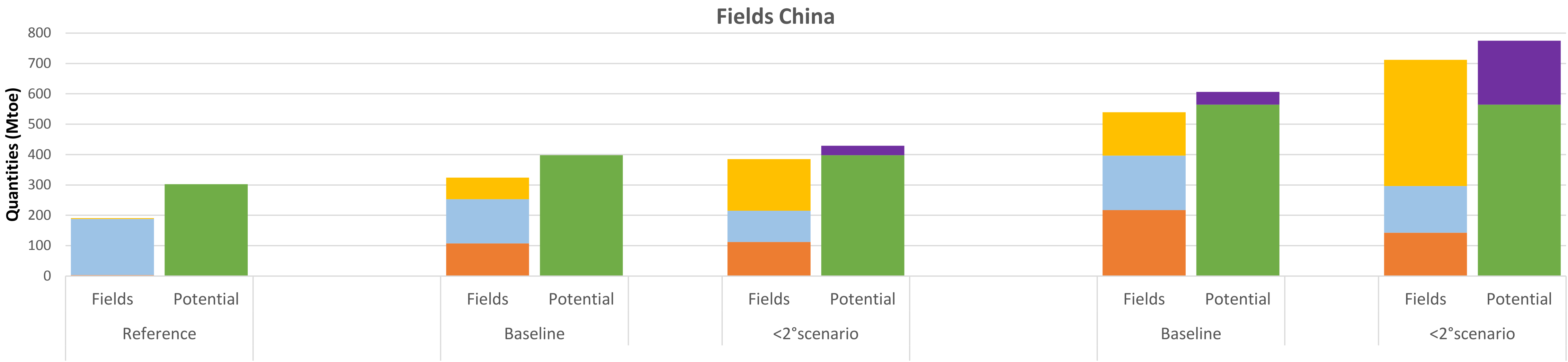


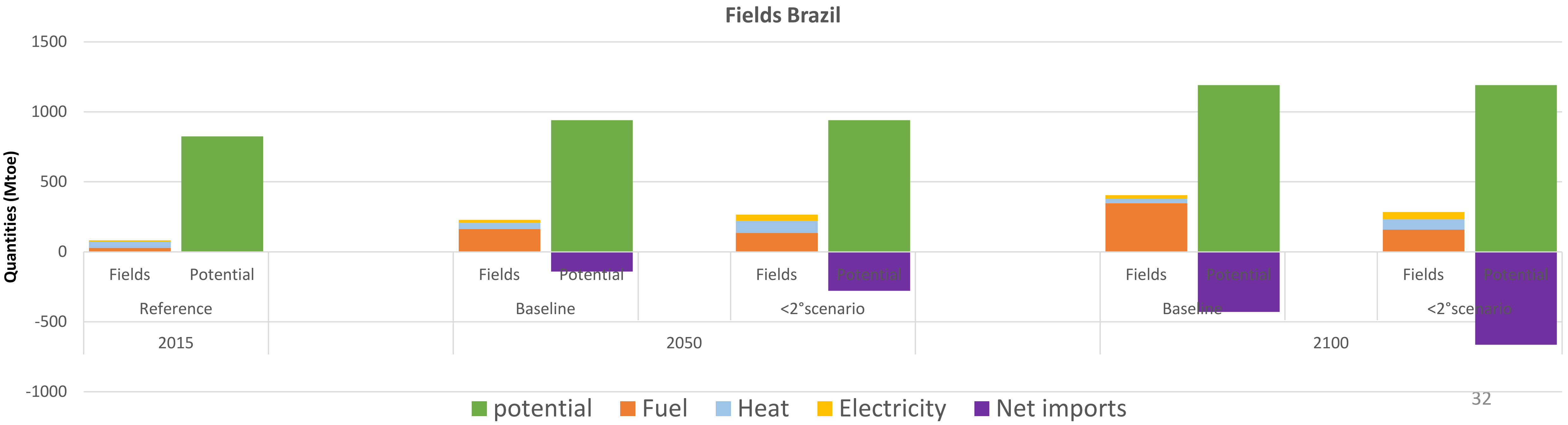
IV – Modelling results : different trends among fields



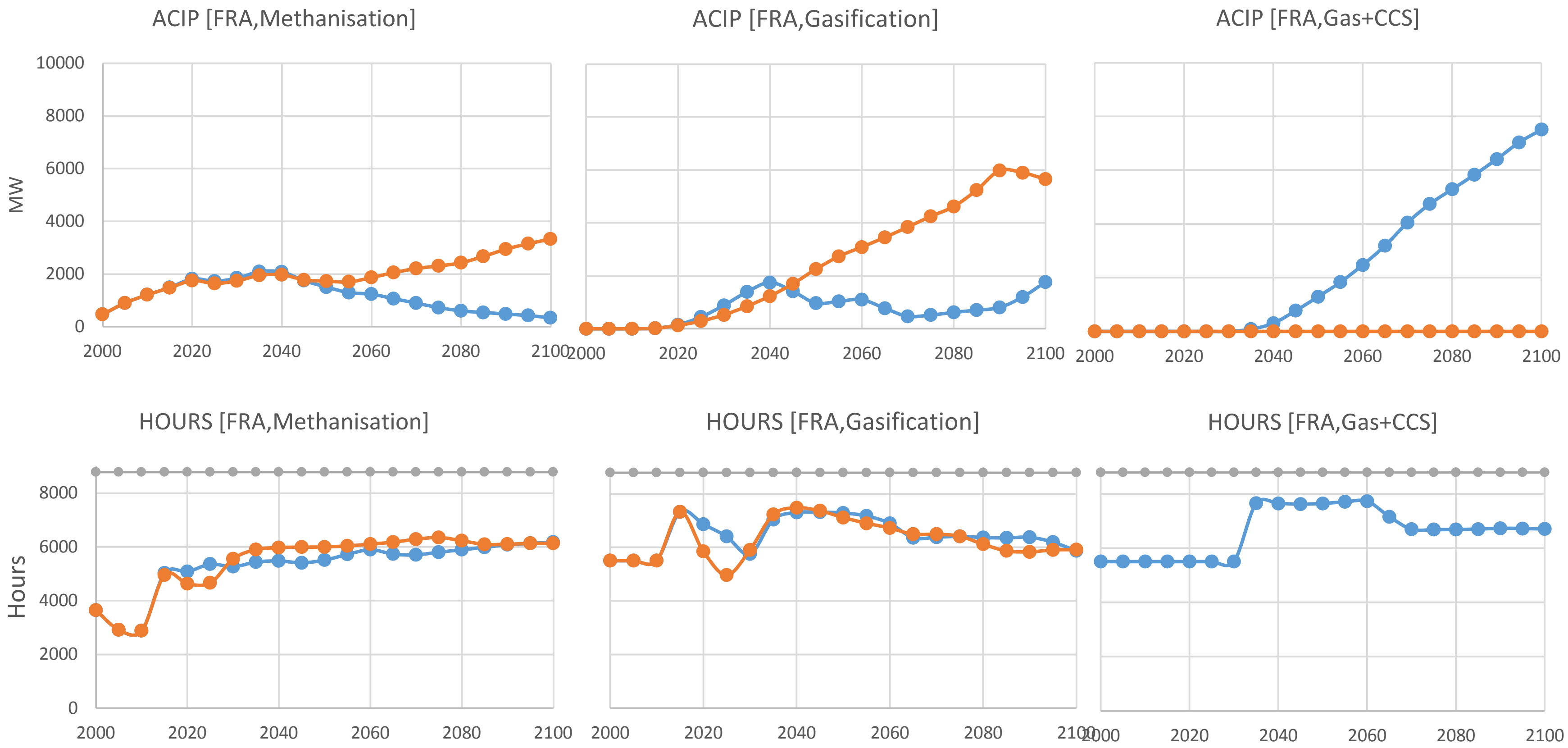


IV – Modelling results : different trends among fields





IV – Modelling results : installed power

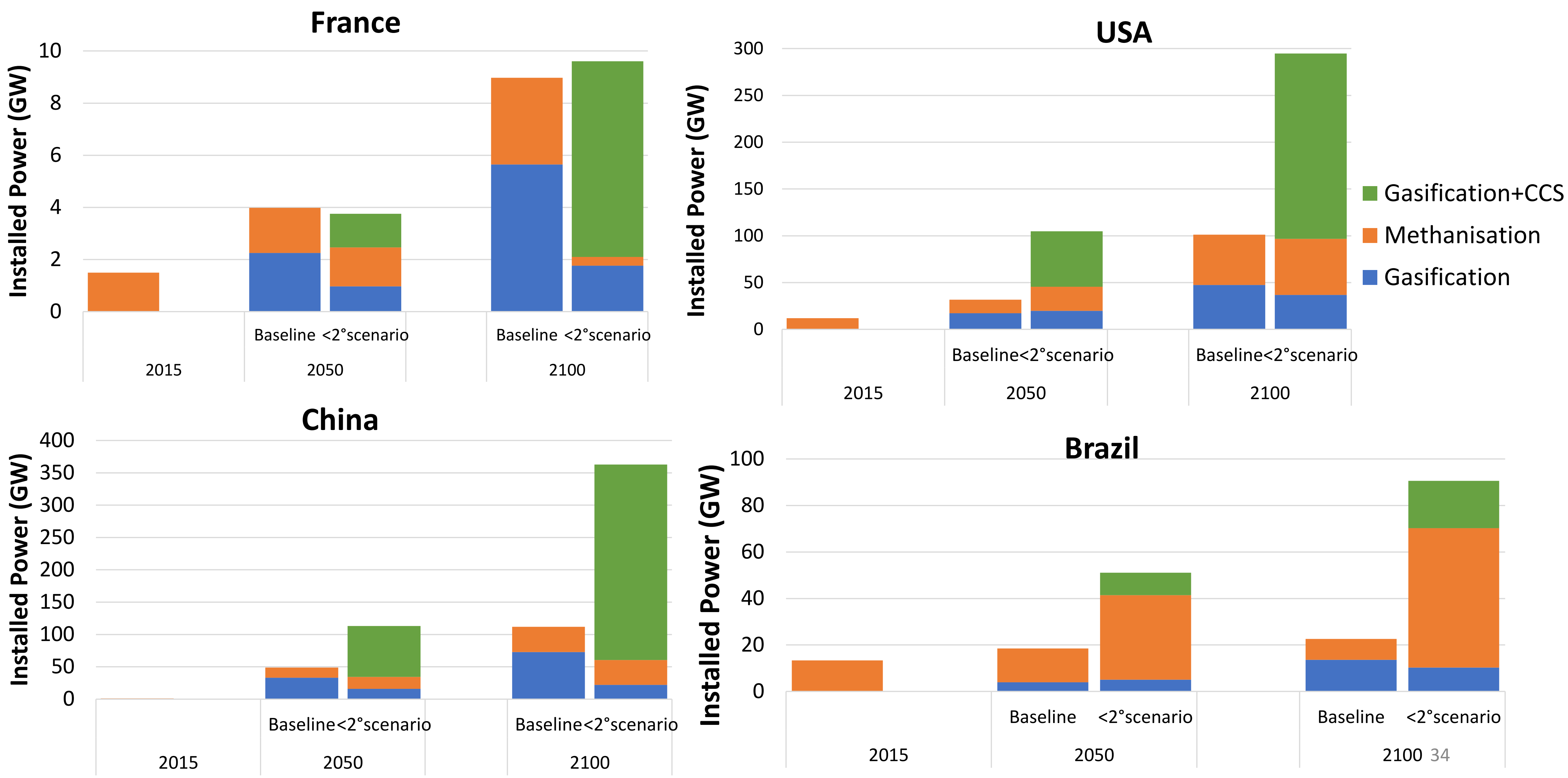


Production infrastructures using gasification gas is increasing with time in both scenarios from 0GW in 2000 to 6GW in 2100 in baseline and 9GW in climate policies scenarios
Methanisation infrastructures are developing quickly: they reach a peak of 9GW installed power in 2040 and stabilize to a plateau.

Load factor is high: from 57% to 85% for gasification technologies, a little bit below for methanisation and direct heat valorisation.
Hence, these technologies are used in **base/semi base,** and represent a **major actor for energy system regulation**.

We highlight the forecast trend that g**reen gas** will become a **main actor** for **electricity production** for the future with **increasing installed capacity** and **high load factor,** but not at maximum that make this **technology flexible.**
Big development starts with methanisation until 2040 and then gasification until 2100. These technologies are massively developed one after another but will contribute at the end at the same level of biomass valorisation

IV – Modelling results: different technologies penetration rate among countries

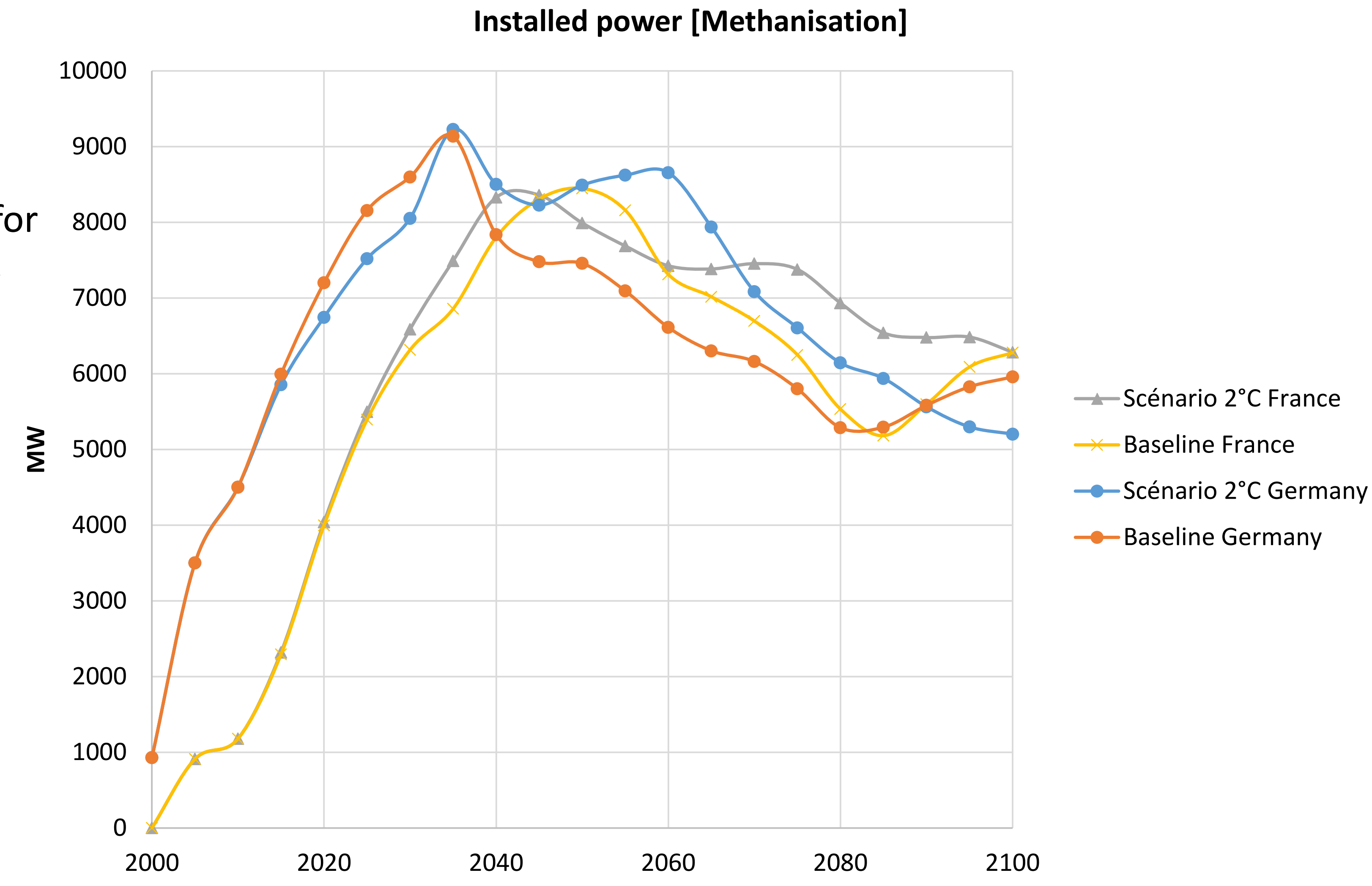


IV – Modelling results: different penetration rate among technologies

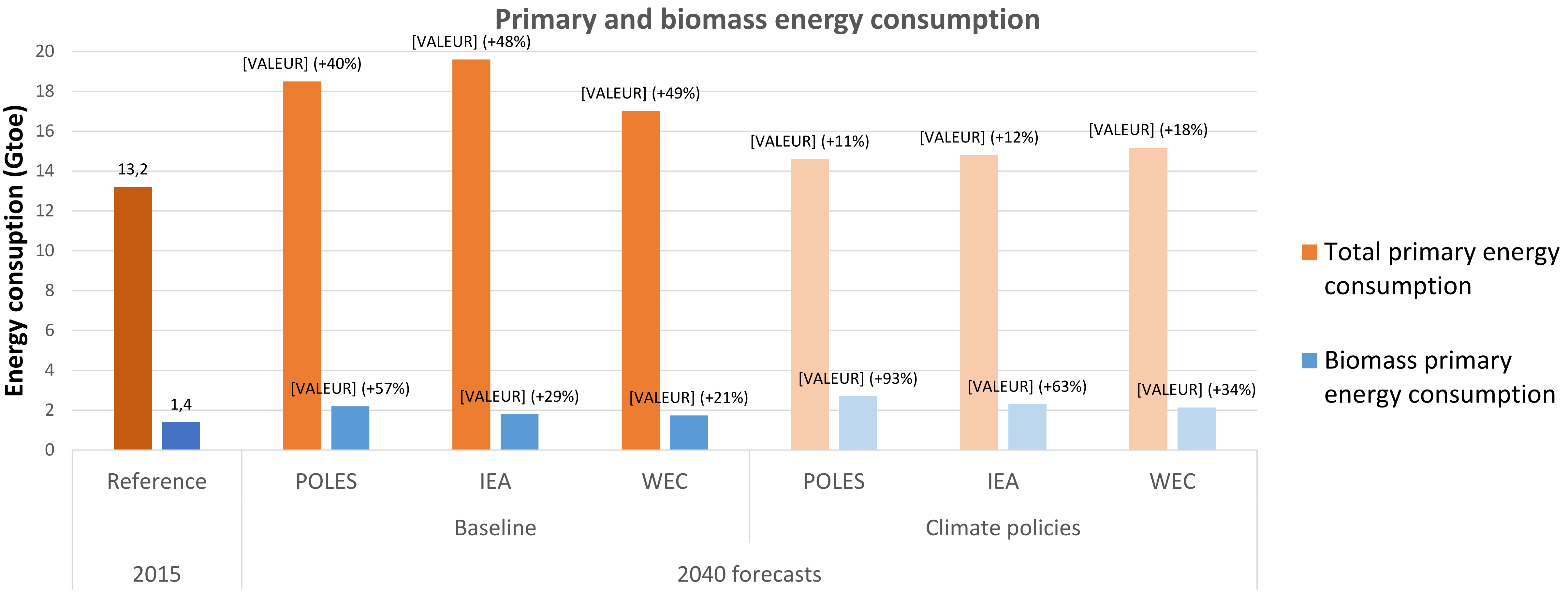
France/Germany

- Germany above France for methanisation development
- However, thanks to the country resource, France will catch up Germany around 2050 for installed power where energy production is comparable

- Huge methanisation penetration in both countries is attempted for the first half of the century.
- Potential of technology saturated and decreasing capacity at the end of century



V – Results comparison: Baseline and climate policies scenarios from IEA and WEC



- Increasing of total energy consumption, more limited in scenarios with climate policies
- Increasing of biomass consumption, more pronounced in scenarios with climate policies with a growth of biomass proportion in the energy mix,

Source: Conseil Mondial de l’Énergie et Conseil Français de l’Énergie,” Les Scénarios Mondiaux de l’Énergie à l’horizon 2050 - Mise en musique des futurs de l’énergie », 2013
Source: IEA, “World energy outlook 2016”, 2017