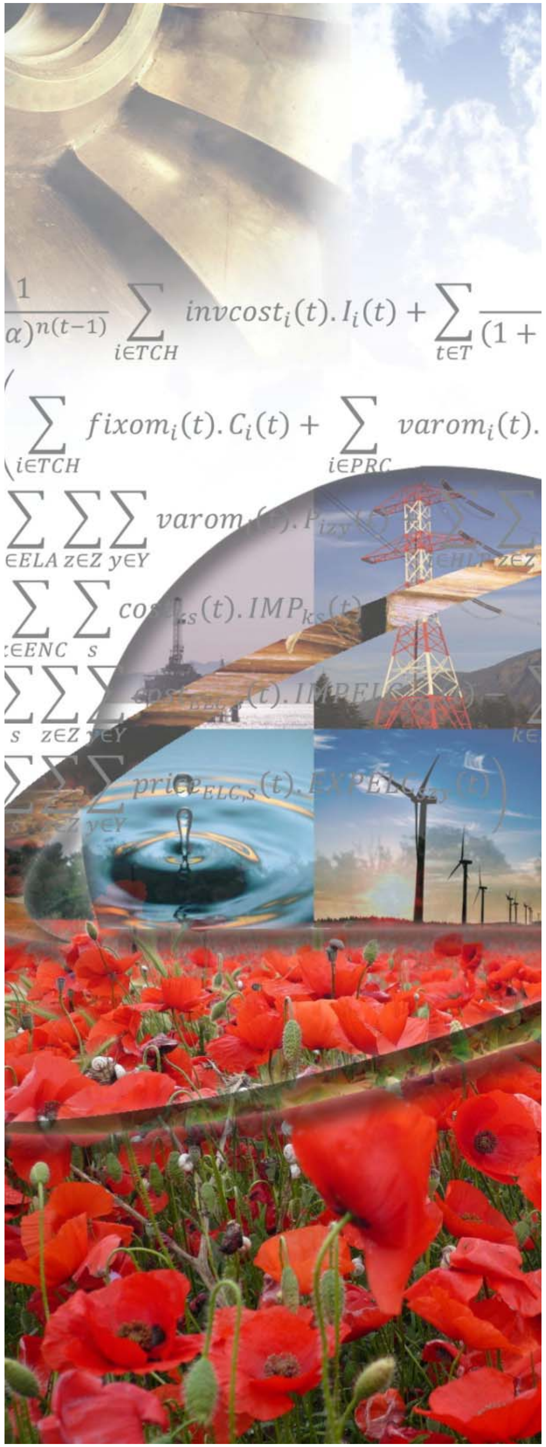

Centre for Applied Mathematics

Power system and carbon capture under climate policy: a water impact analysis with TIAM-FR

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November 27th, 2012

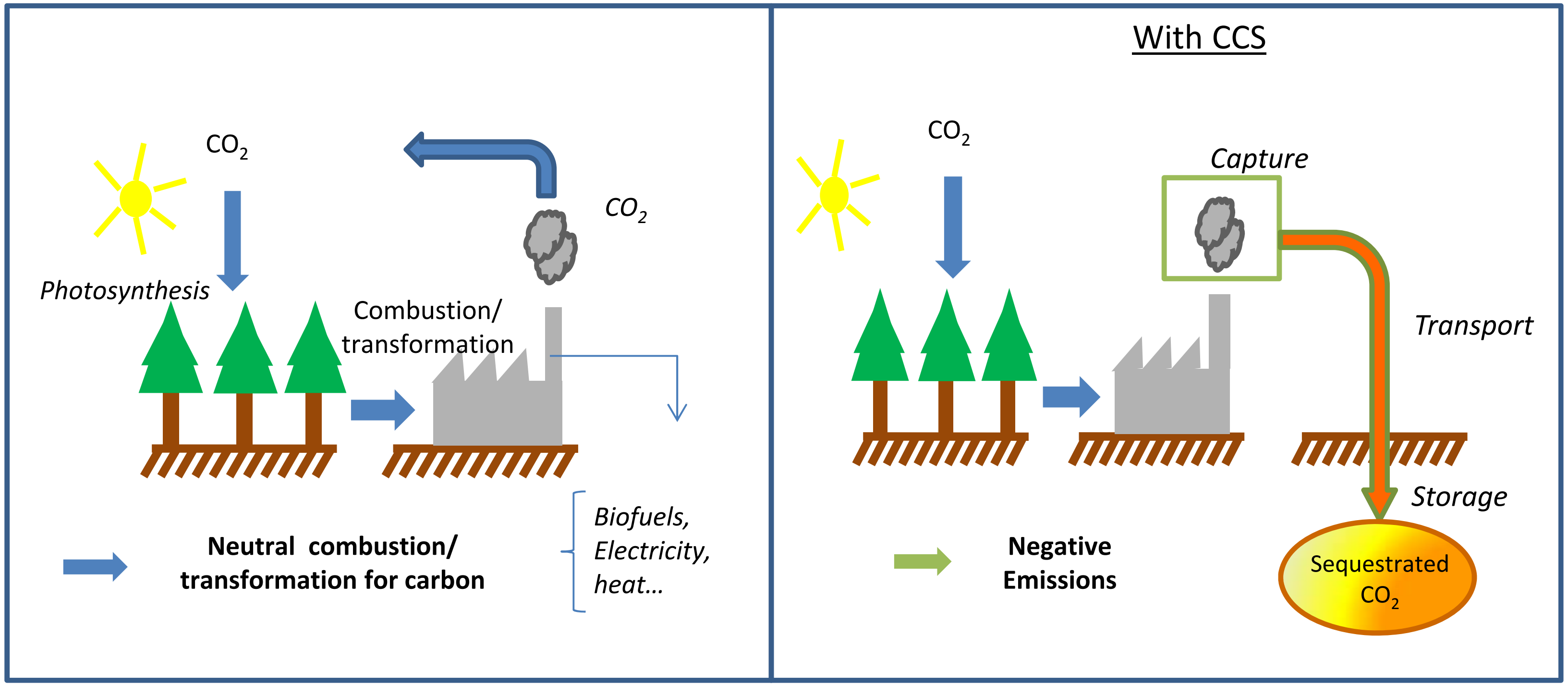
COP 18 – Doha – European Pavilion

Overview

- Context of Energy/Climate issues
- The attainability of stringent CO_2 mitigation targets depends notably on
  - A wide range of different reduction options
  - The technology « readiness » of advanced technologies

- Among these options : Carbon capture and storage
  - Fossil fuels: dominant source of energy over the next decades (CO_2 emissions will drastically increase: unsustainable level)
  - Bioenergies + CCS (BECCS) : opportunity for a net carbon removal from the atmosphere (negative emissions)

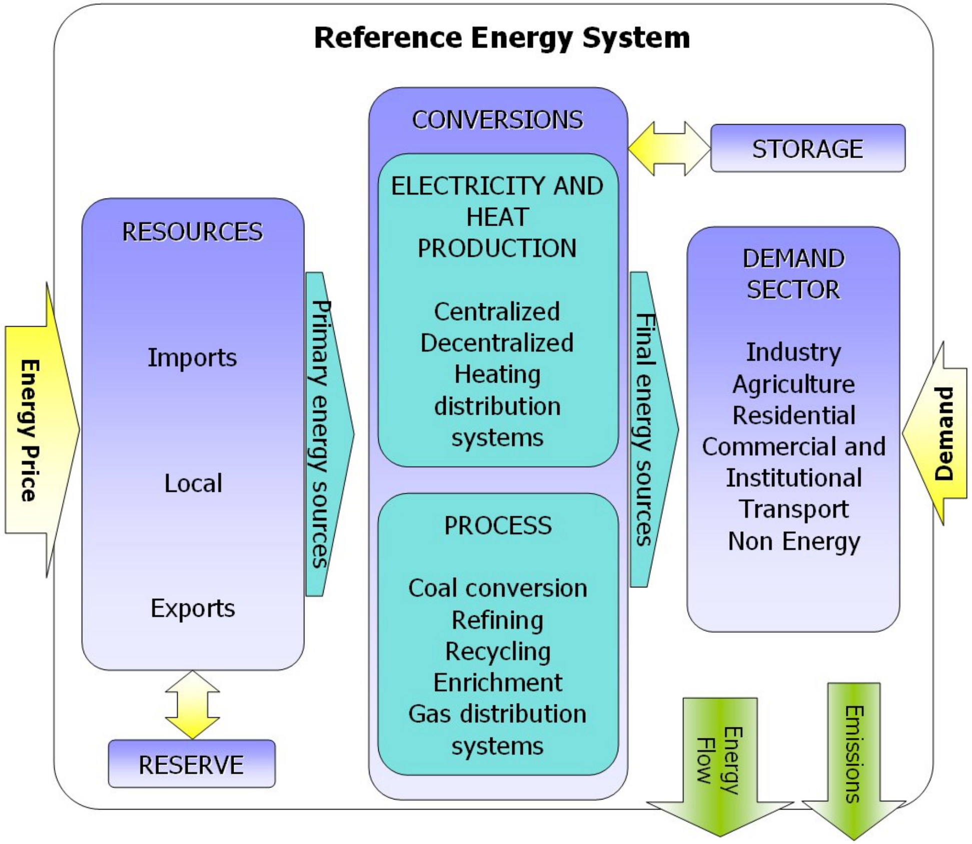
Bioenergy + CCS



Tools: TIAM-FR

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

Simplified RES



Inputs, exogenous
- Extraction costs
- Reserves of fossil
- Potential of biomass

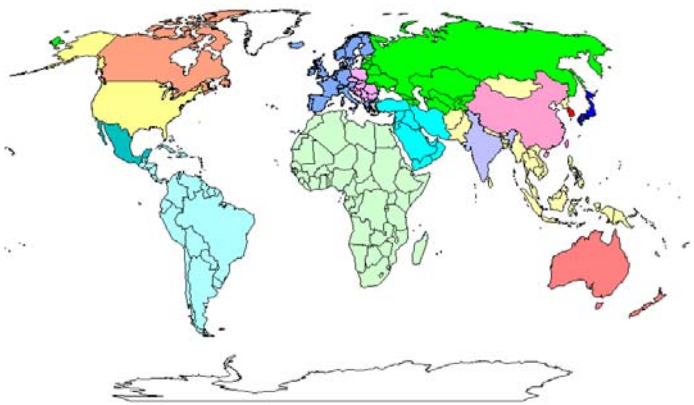
Thousands of technologies for each region

Agriculture
Energy needs
Commercial
Cooling
Refrigeration
Cooking
Space heat
Hot water
Lighting
Office equipment
Other
Industry
Chemicals
Iron and Steel
Pulp and Paper
Non-ferrous metals
Non Metals
Other
Residential
Cooling
Clothes drying
Clothes washing
Dishwashing
Space heat
Hot water
Cooking
Lighting
Refrigeration
Other
Transport
Aviation: domestic
Aviation: international
Road: bus
Road: commercial trucks
Road: three wheels
Road: heavy trucks
Road: light vehicle
Road: medium trucks
Road: auto
Road: two wheels
Rail: freight
Rail: passengers
Navigation: domestic internal
Navigation: international

Demand for energy services

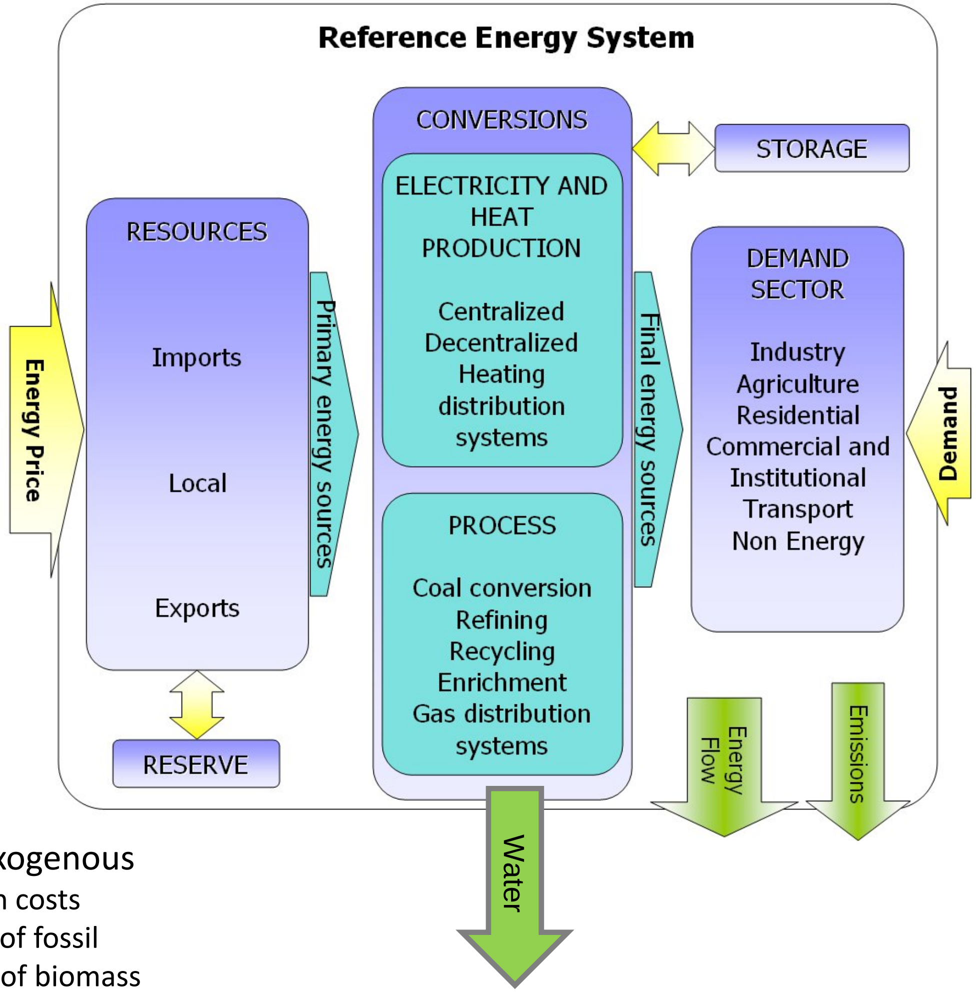
Tools: TIAM-FR (2)

- World integrated model in 15 regions



- Time horizon: 2005-2050
- GHG emissions and climate module
  - CO_2, CH_4 and N_2O
  - Atmospheric concentration, temperature change and radiative forcing
- Carbon capture and sequestration technologies
  - Fossil and Bioenergy
- Water consumption of processes

Simplified RES



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Demand for energy services

Assumptions

- Climate policies
  - Radiative forcing : 2.6 W/m² (450 ppm CO_2-eq)
  - Radiative forcing : 3.7 W/m² (550 ppm CO_2-eq)

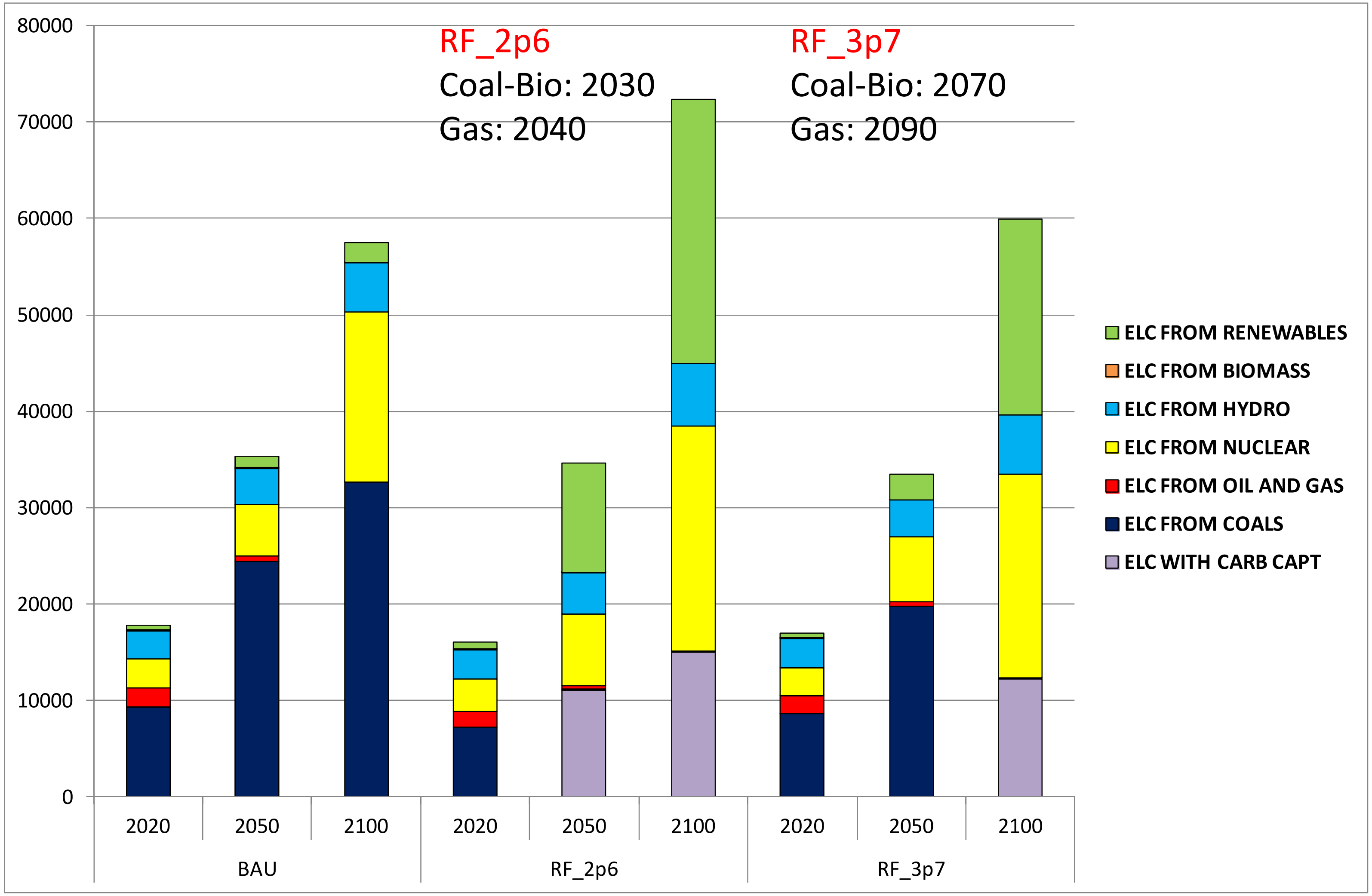
- Technology availability
  - Scenario without BECCS with co-firing (coal/biomass)
  - Scenario without BECCS without co-firing
  - Scenario without CCS

- Resources availability
  - Biomass potential: 234 EJ/yr in 2050
  - Carbon sink potential: 9 392 Gt CO_2
  - Water consumption

Results

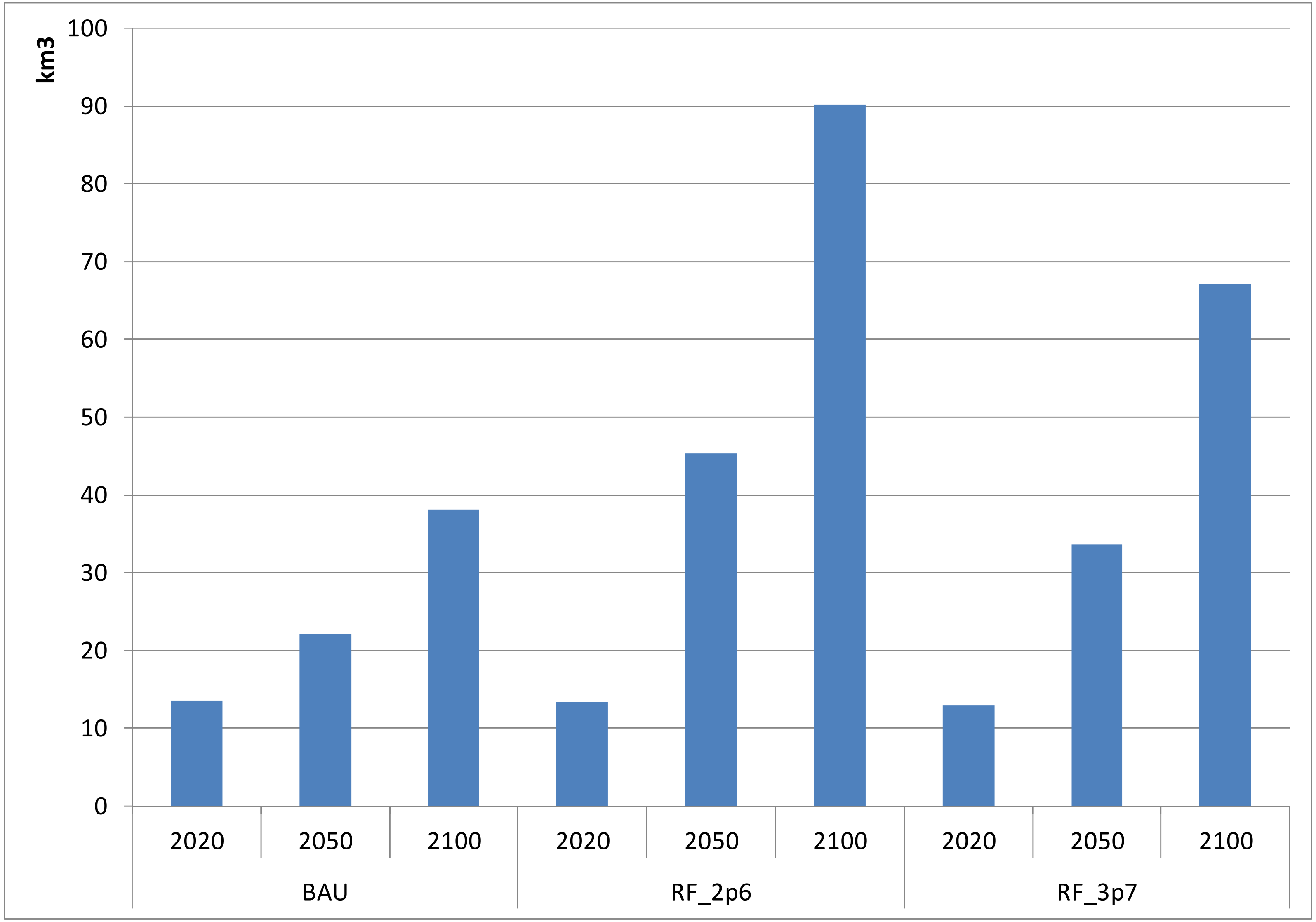
World power generation (TWh)

Under climate constraint



Fresh water consumption (km^3)

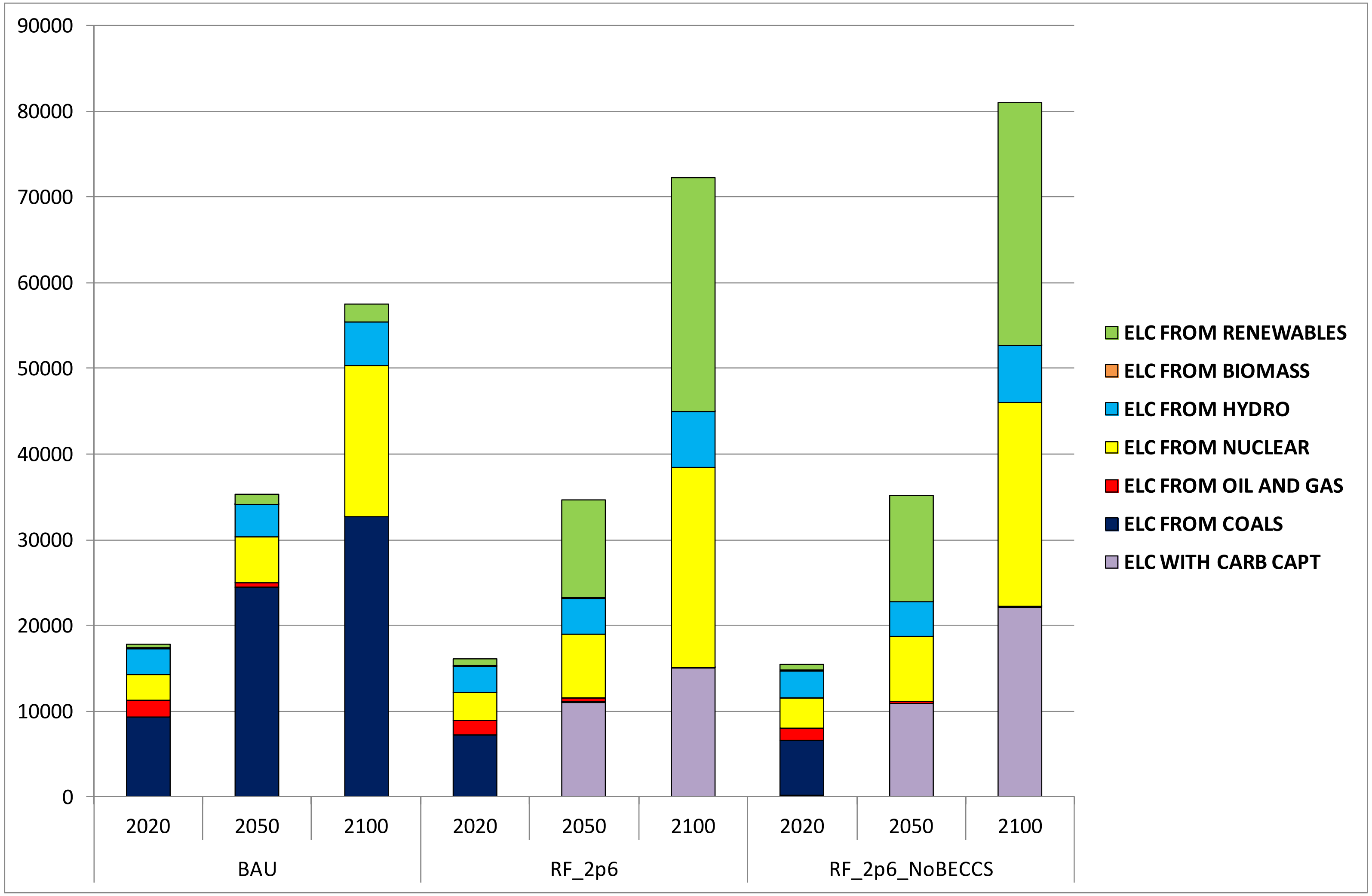
World – Power plants



Technological sensitivity

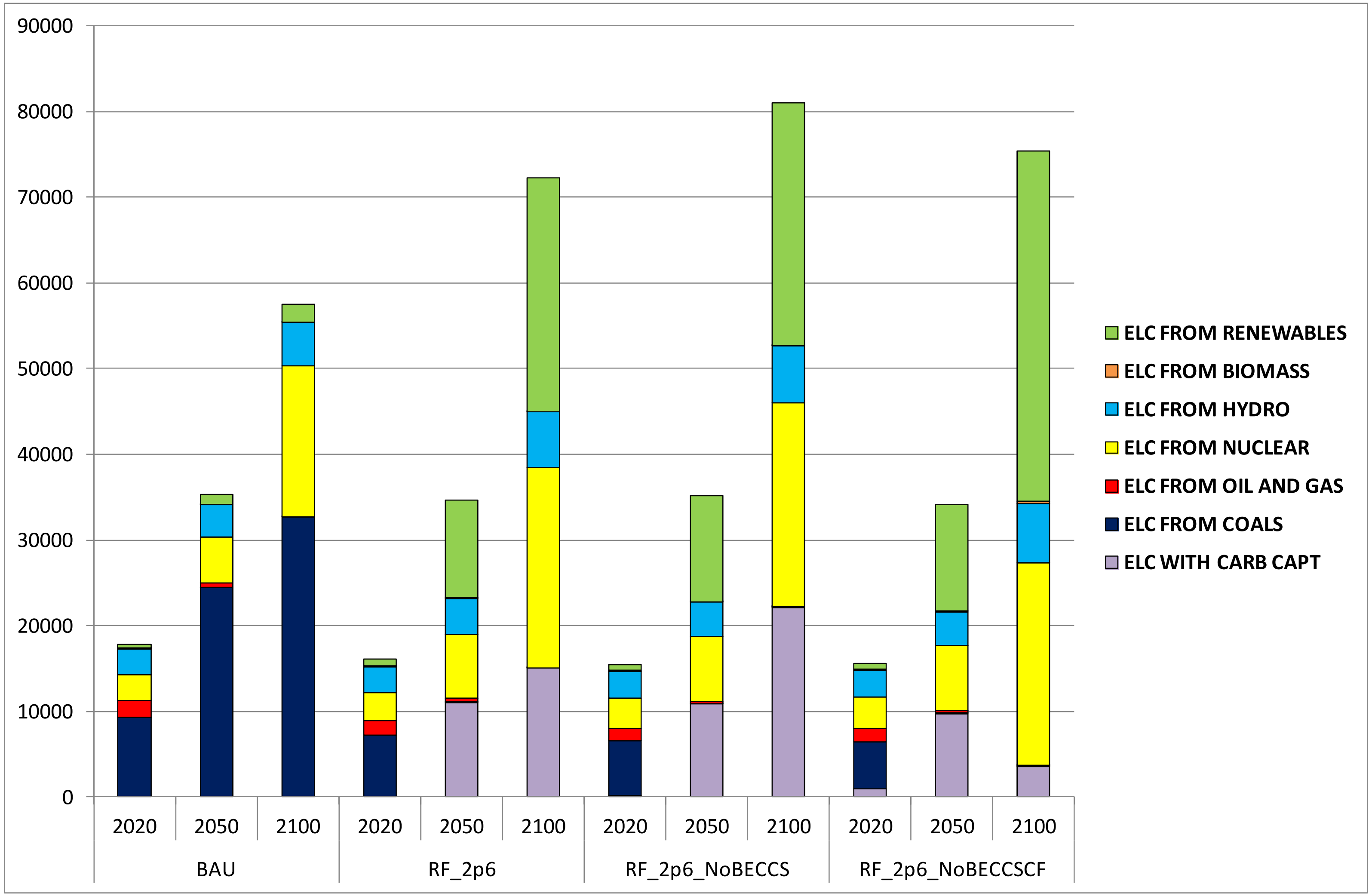
World power generation (TWh)

No BECCS



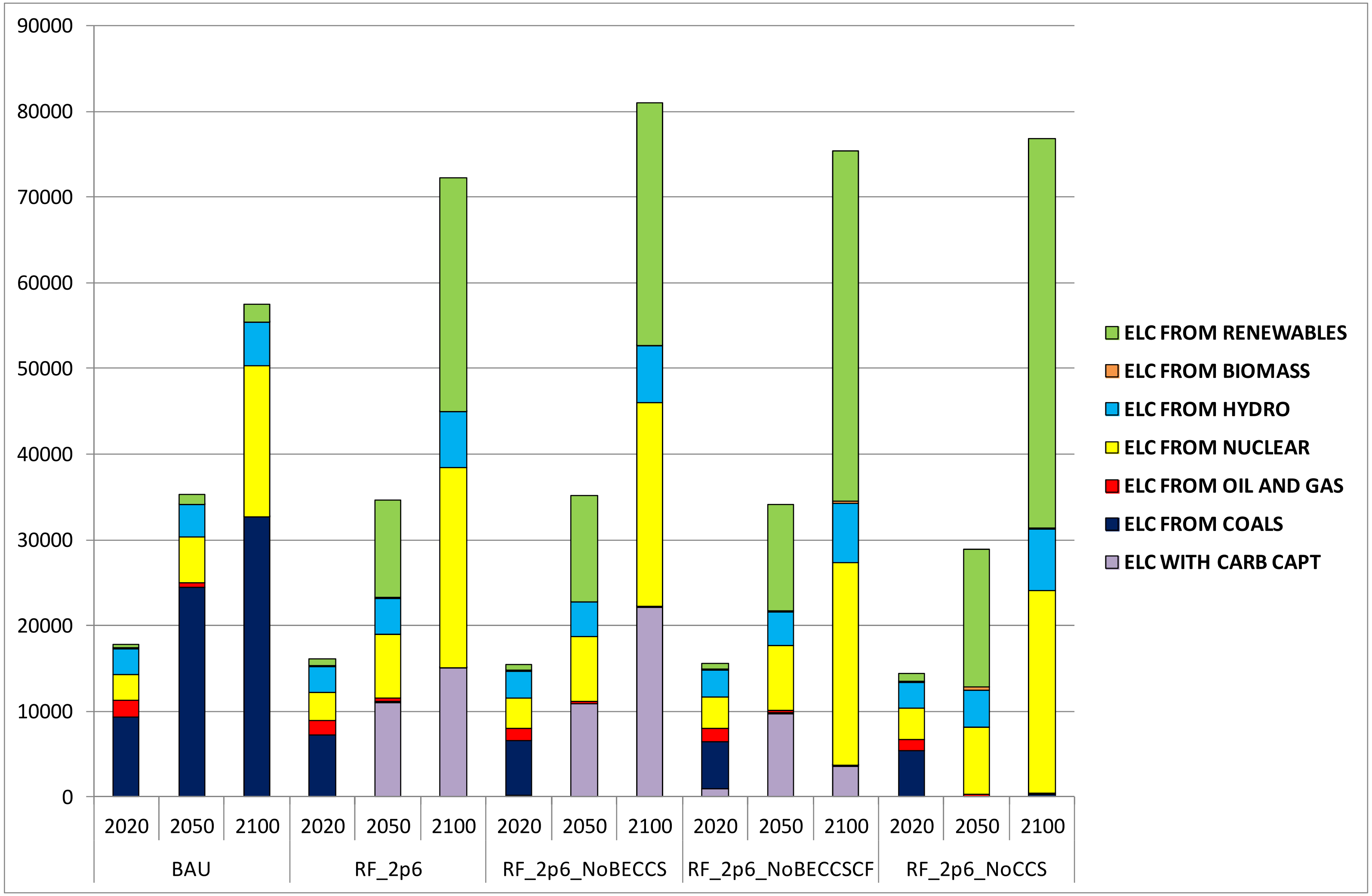
World power generation (TWh)

No BECCS – No co-firing



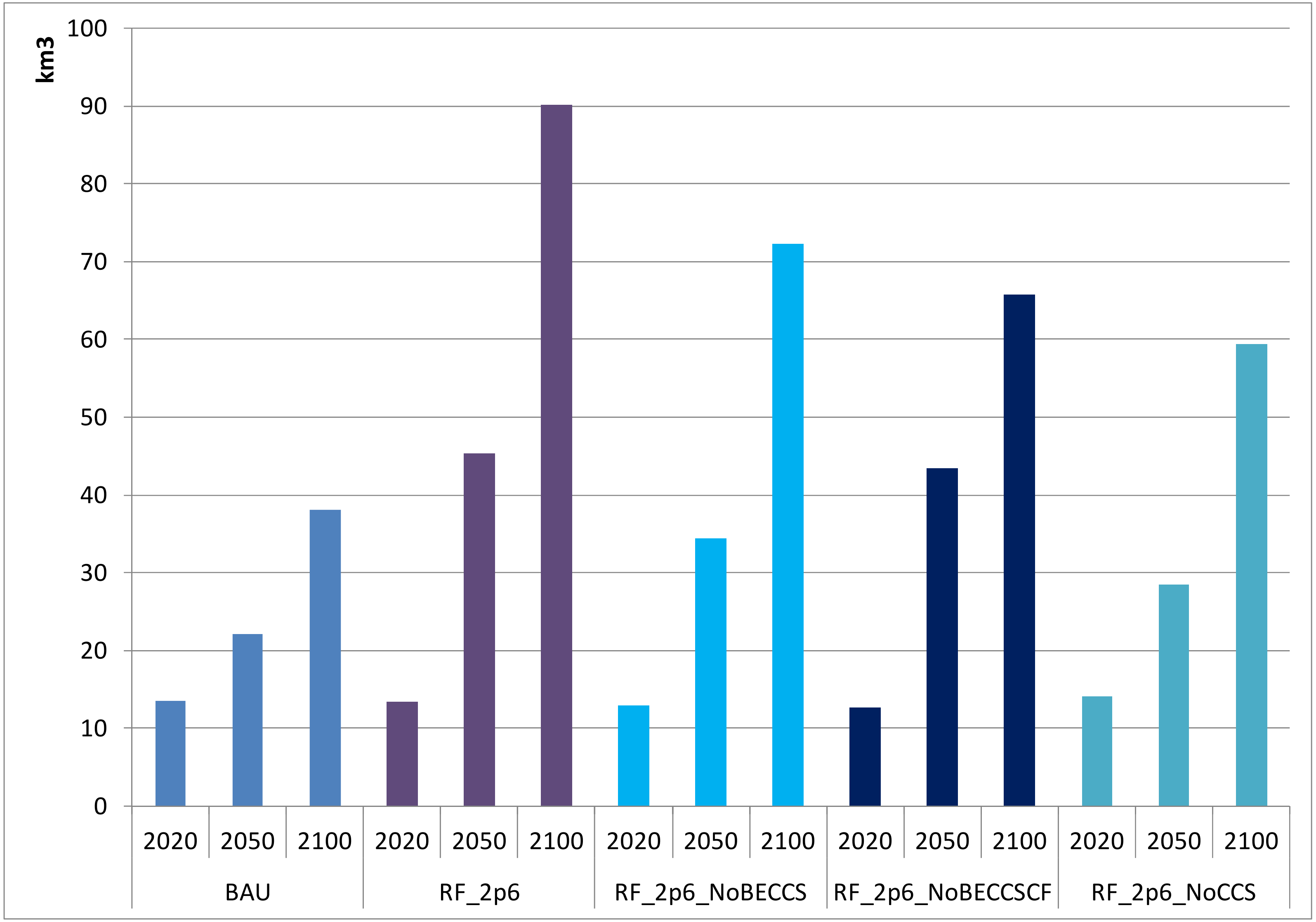
World power generation (TWh)

No BECCS – No co-firing – No CCS



Fresh water consumption (km^3)

World – Power plants -



Conclusion

CCS/BECCS technologies: an increasing option
But their contribution to the CO_2 mitigation policy depends on the interplay of several factors:

- The large scale availability of technologies
- Cost/advantages according to alternatives
- Political choices
  - Incentives to CCS/BECCS
  - Climate change stake versus social objectives (social acceptance about storage sites)
- Water consideration with higher consumption
  - Regional perspectives (CO_2 mitigation targets and water scarcity)

Annex

Reference energy system