ParisTech's Chair Modeling for sustainable development

Water and Energy Allocations: Long term issues

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4th Forum on the Climate-Energy Security Nexus: Water and Energy

Future power mix : a major issue for the next decades

- Huge investments are forecasted in the power sector
- Electricity environmental impact are consequent: power generation stands for more than 45% of Carbon Dioxide emissions.

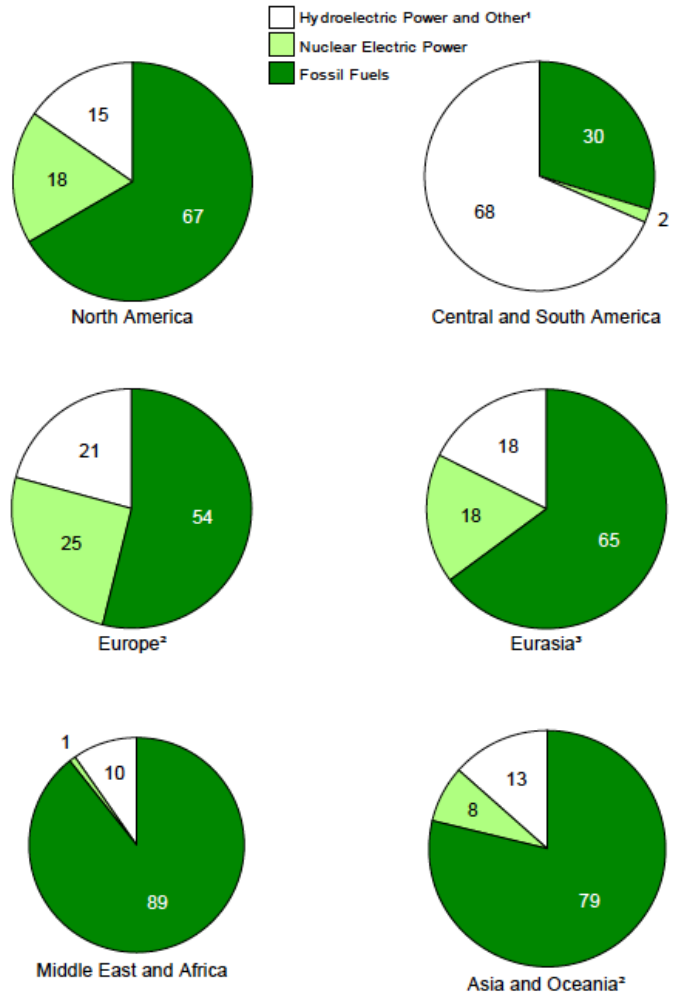

Figure : Power generation by region Source: AER 2009.

Trend towards low carbon future power system

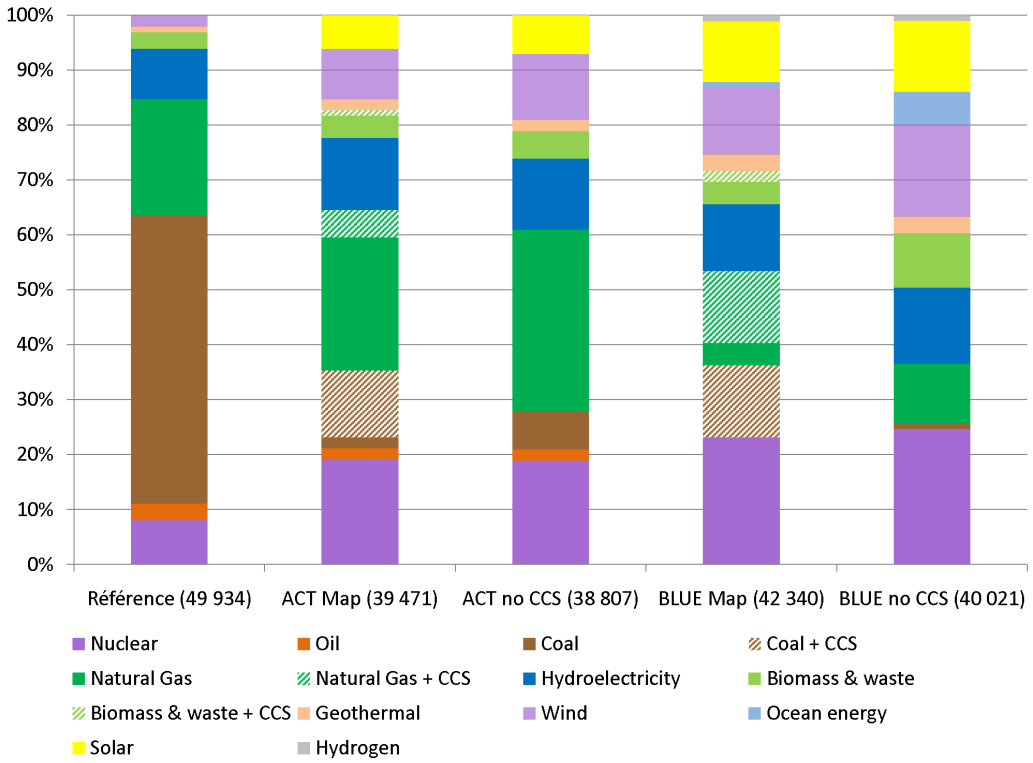

Figure : Power Generation Mix Scenarios ETP 2008

☞ Water Issues ?

Policies dealt separetely but... interdependecy

Growing issues for water and energy

- Energy sector: depletion of fossil resources, environmental impacts
- Water supply: availability and sustainability of water resources

Policies dealt separetely but... interdependecy

Growing issues for water and energy

- Energy sector: depletion of fossil resources, environmental impacts
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Water for energy

- Cooling systems
- Hydropower
- Extraction and mining
- Fuel production
- Emission controls

Energy for water

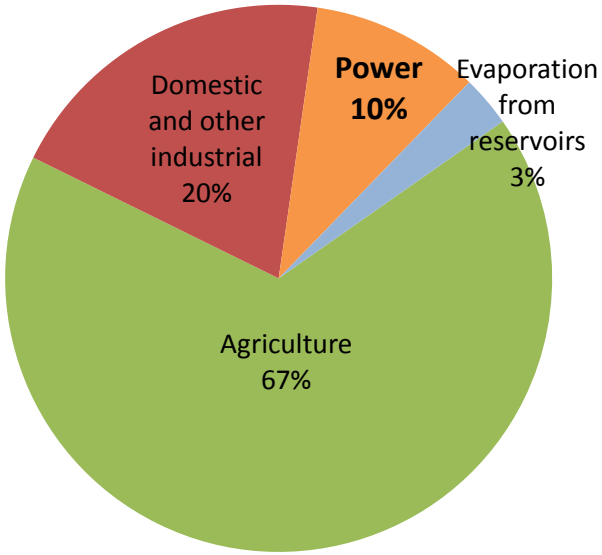
- Pumping
- Transport
- Treatment
- Desalination

Increase of water uses

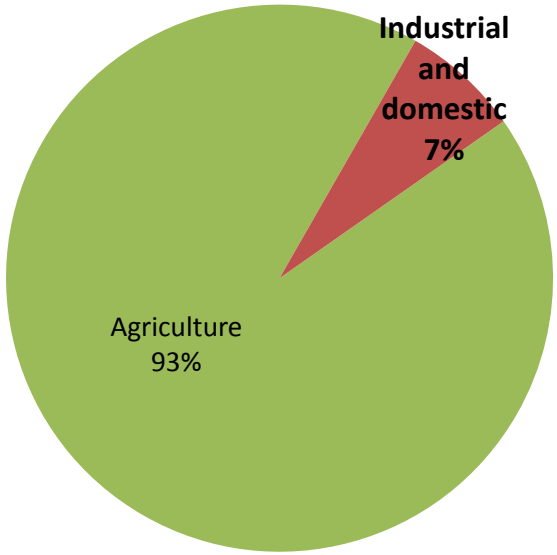
Basic knowledge

- Withdrawal: water removed from any sources, either permanently or temporarily
- Consumption: part of withdrawal which is no longer available for use

World withdrawals



World consumptions



WDR Report 2010

TIMES as a Prospective tool

"What we have the right to ask a conceptual model is that is seize on the strategic relationships that control the phenomenon it describes and that it thereby permit us to manipulate, i.e., **think about the situation**"

Source: R. Dorfman, P. A. Samuelson,R. M. Solow

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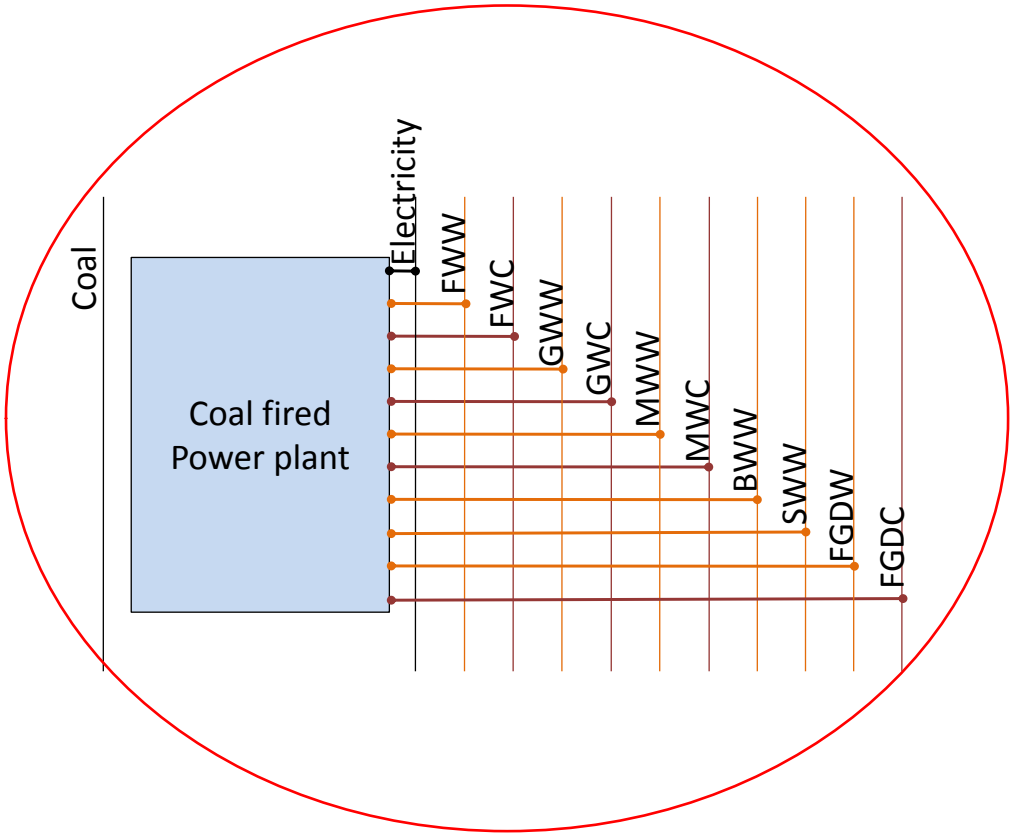
TIAM-FR model: long term planning tool

- TIMES Integrated Assessment Model developed by ETSAP (Energy Technology System Analysis Program)
- Technology-rich representation of the energy systems: bottom-up model
- Global model: 15 regions
- Long-term development of the energy system (2005-2100)
- Technical optimum: minimizing the discounted global cost

Water RES



1. Consumption :*WC
2. Withdrawal : *WW

- F: Fresh water
- B: Brackish water
- M: Municipal water
- G: Ground water
- S: Saline water
- FGD: Water for FGD process

Water factor for each technology :

- *Upstream*: type of coal mine, ratio onshore/offshore etc.
- *Electricity*: cooling systems, efficiency, FGD etc.

Review and analysis of factor of influence

Different scenarios have been considered to analyze the influence of :

1. Cooling systems used
2. FGD process in coal thermal power plant
3. Environmental policies and extraction costs
4. Taking into account upstream chain energy activities
5. Water as a constraint

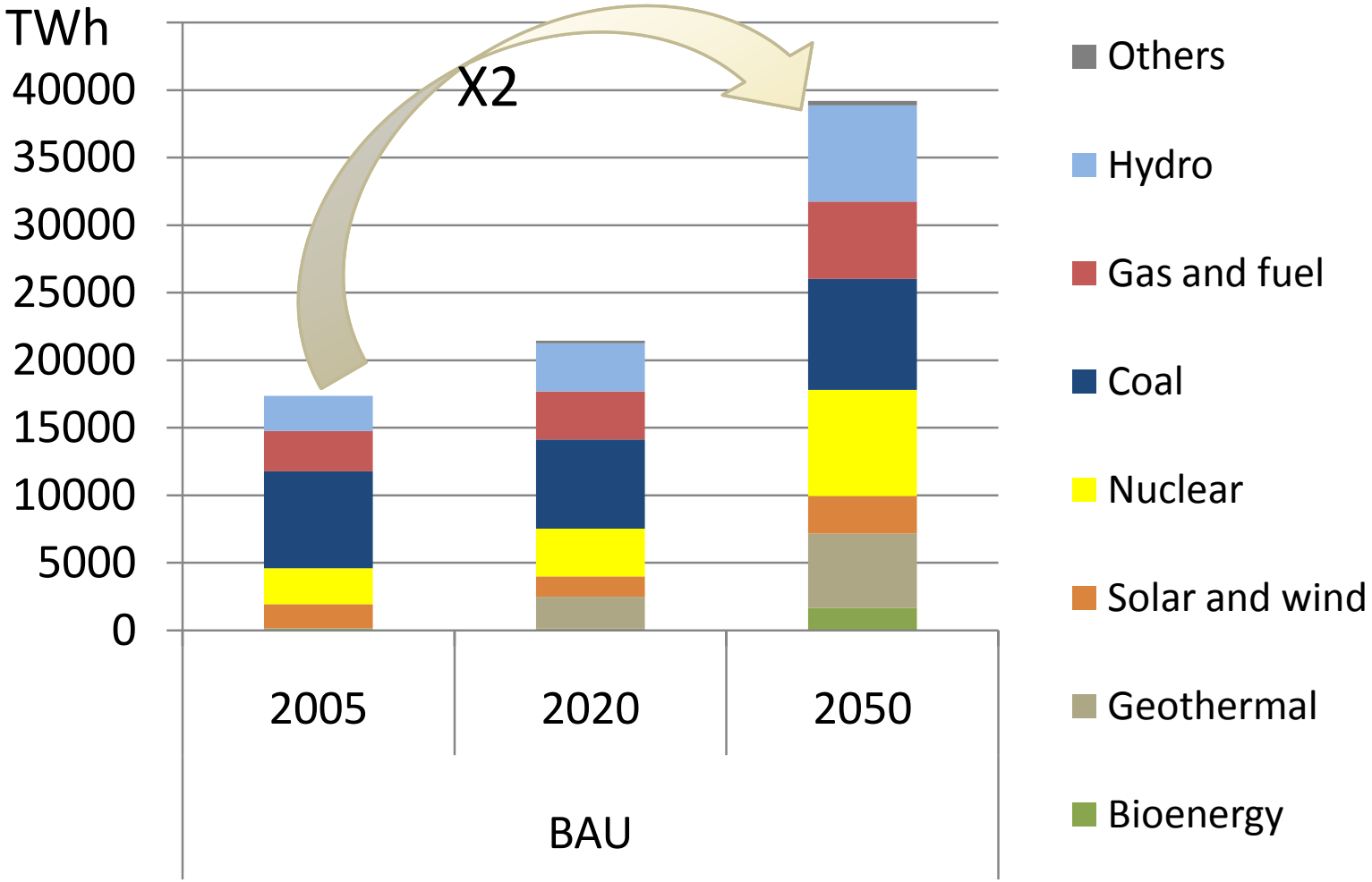
1. Cooling systems

Scenarios for new installations, no change of existing power plants water factors.

- **BAU (Business as usual scenario)**: Water factors for new installations = water factors for existing installations
- **CL (closed loop)**: New installations use only closed loop systems (better efficiency enables to decrease the temperature difference)
- **CL+NR (efficience)**: New installations use only closed loop systems and better efficiency allows decreasing the flow needed in the cooling system

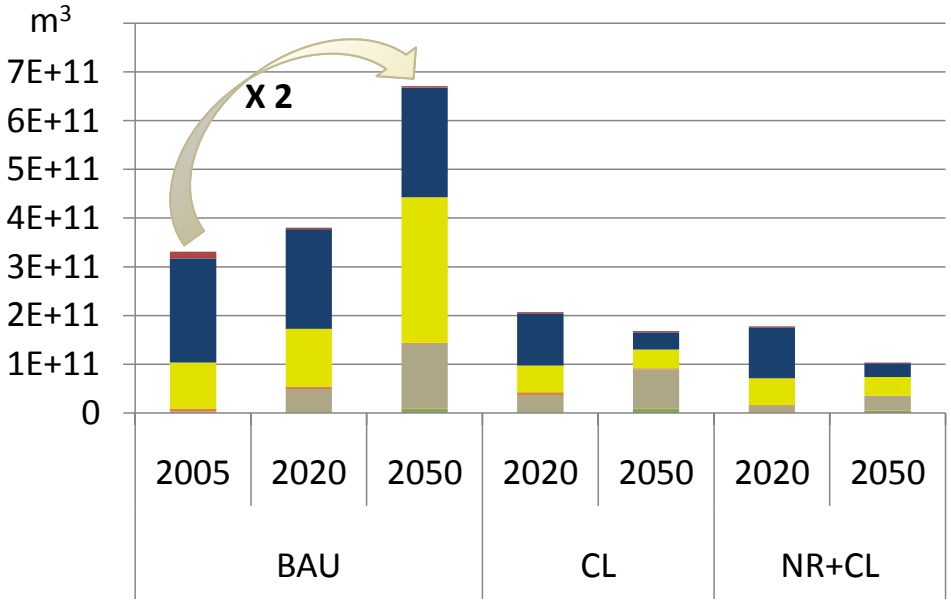
1. Cooling systems

Worldwide electricity generation by source

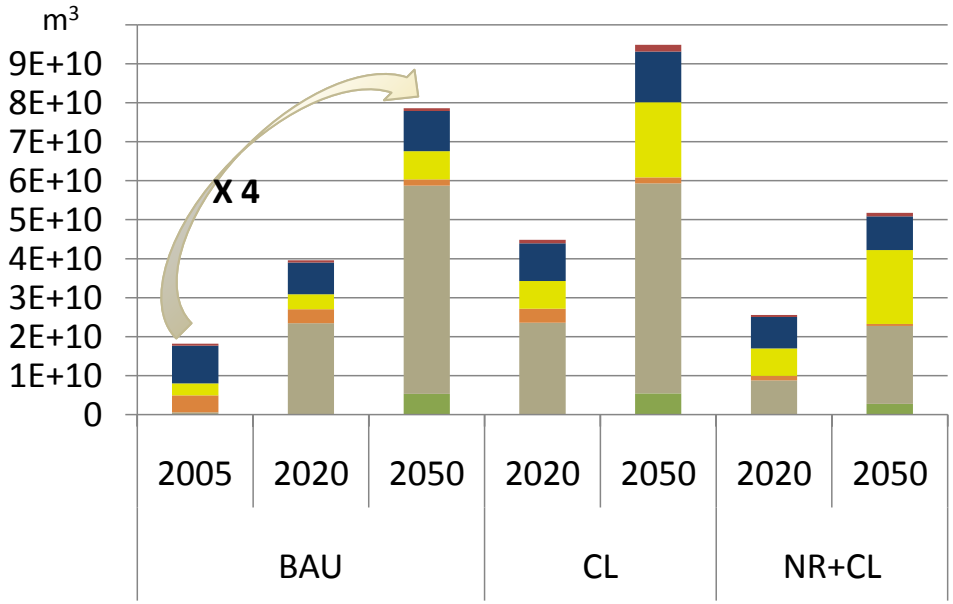


1. Cooling systems

Fresh water withdrawals



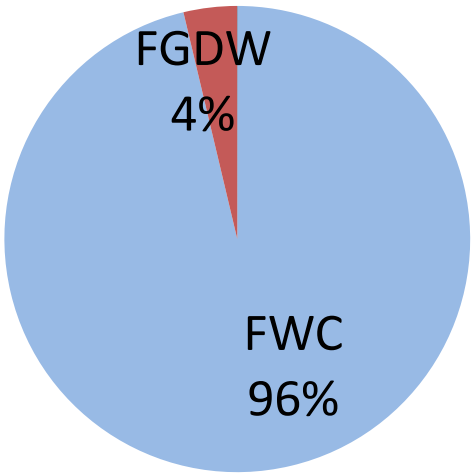
Fresh water consumptions



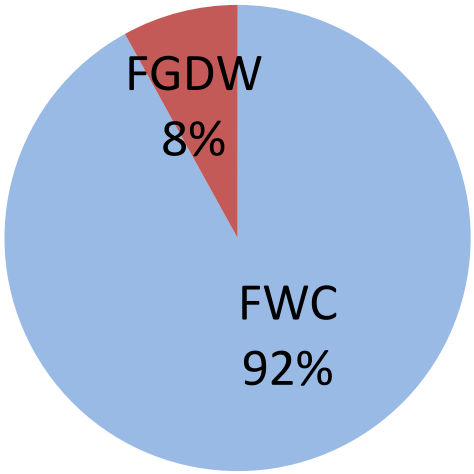
Bioenergy Geothermal Solar Nuclear Coal Gas and fuel

2. Increase of water consumption for FGD process in coal thermal power plant

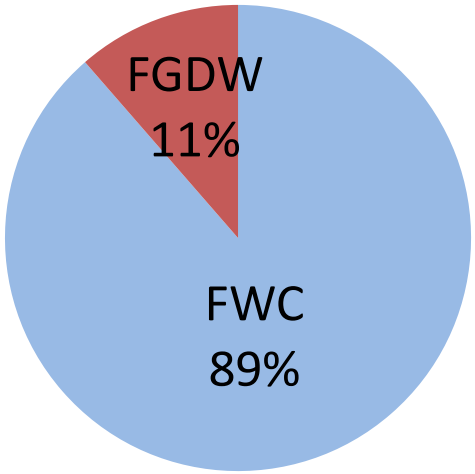
BAU 2005



BAU 2020

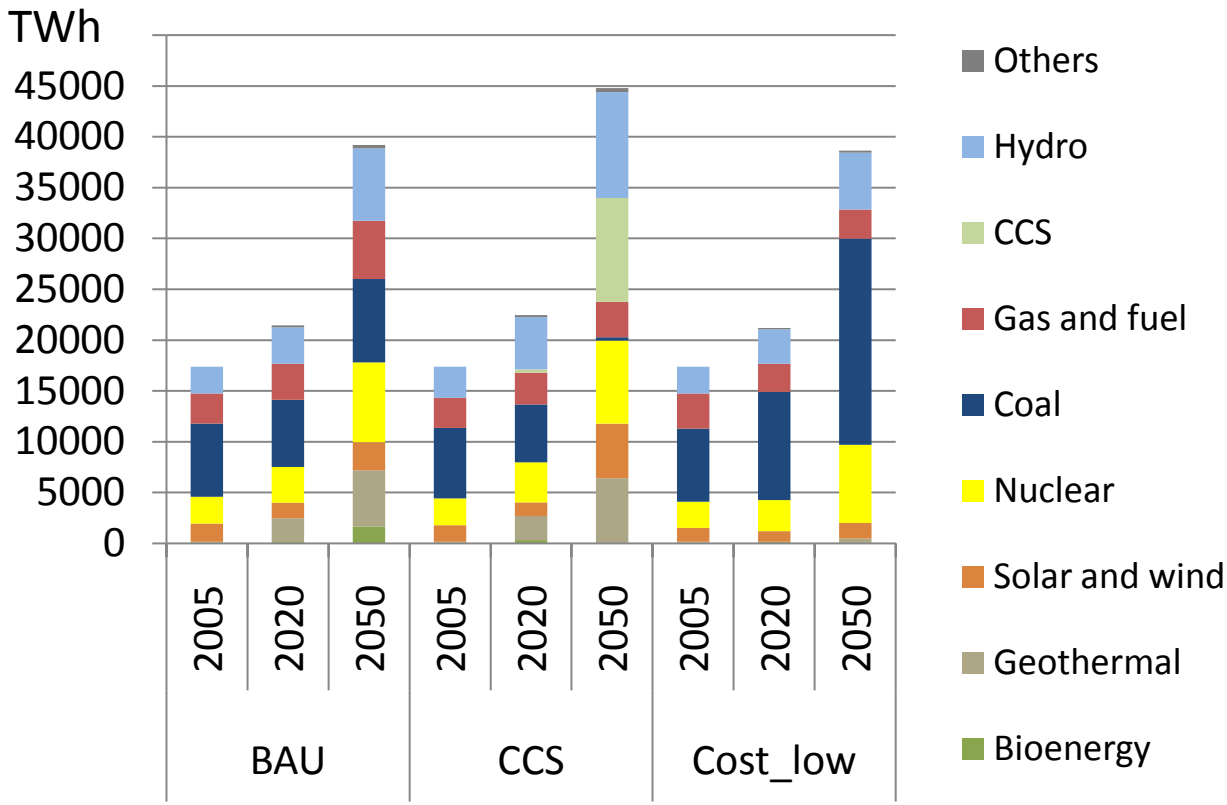


BAU 2050



3. Environmental policies and decrease of extraction costs

- *CCS*: constraint the energy system to a maximum increase of temperature of 2°C in 2100
- *Cost_low*: decrease of extraction cost of fossil energy



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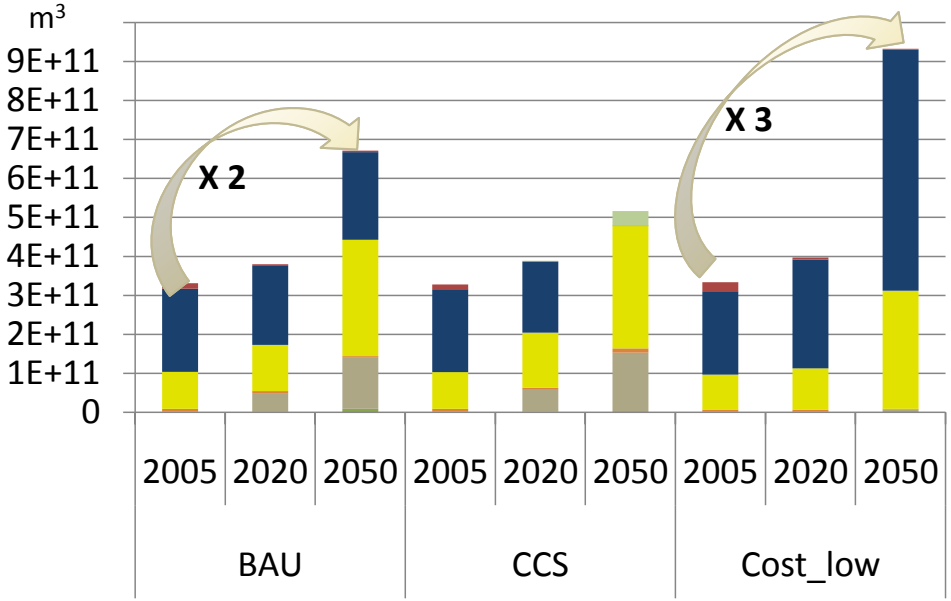
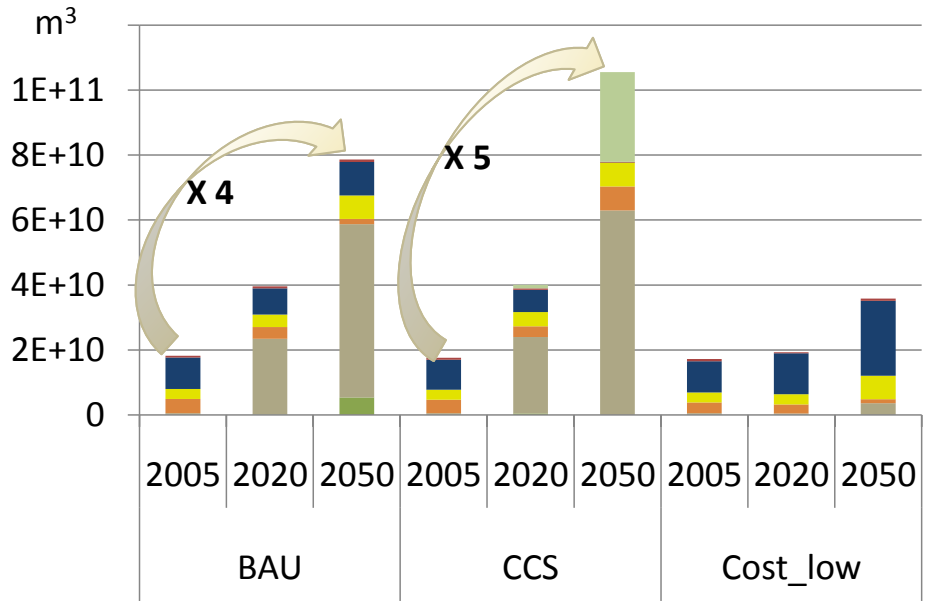
Fresh water withdrawals

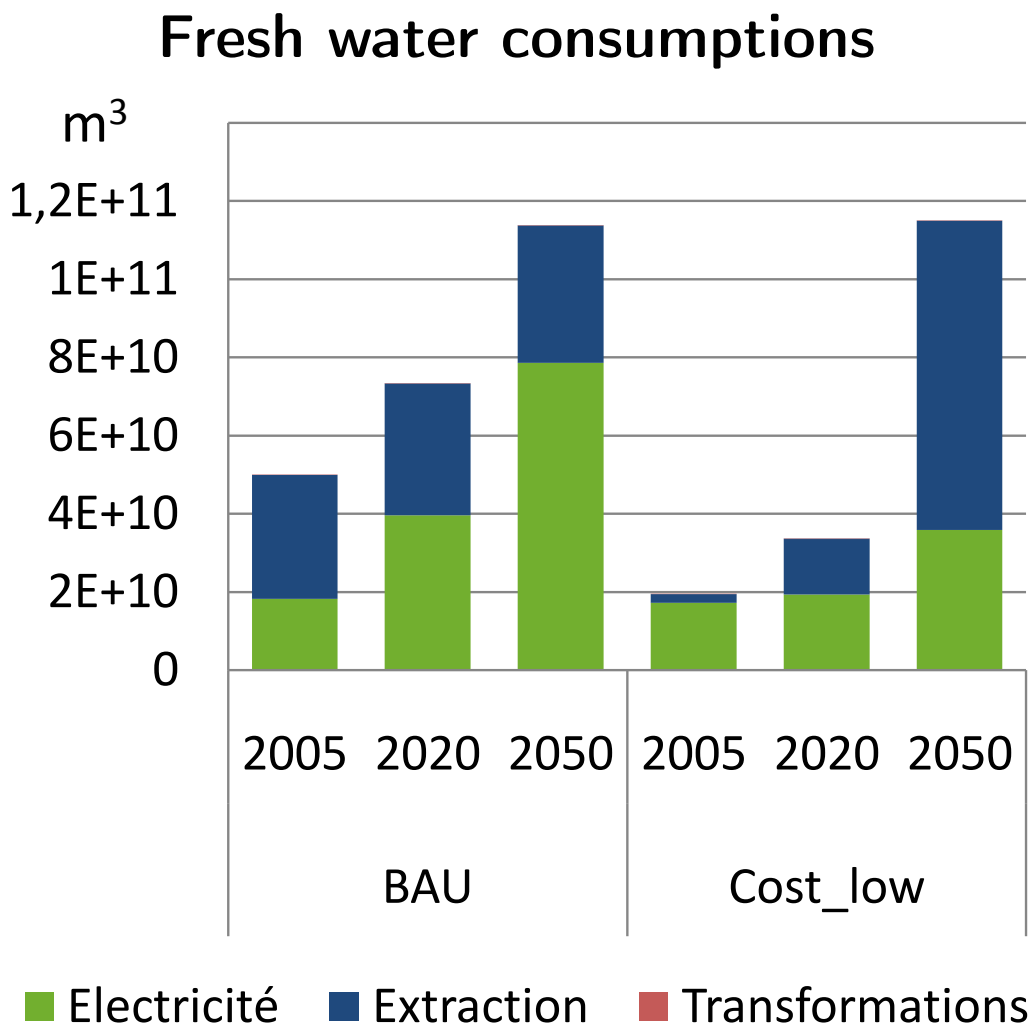


Fresh water consumptions



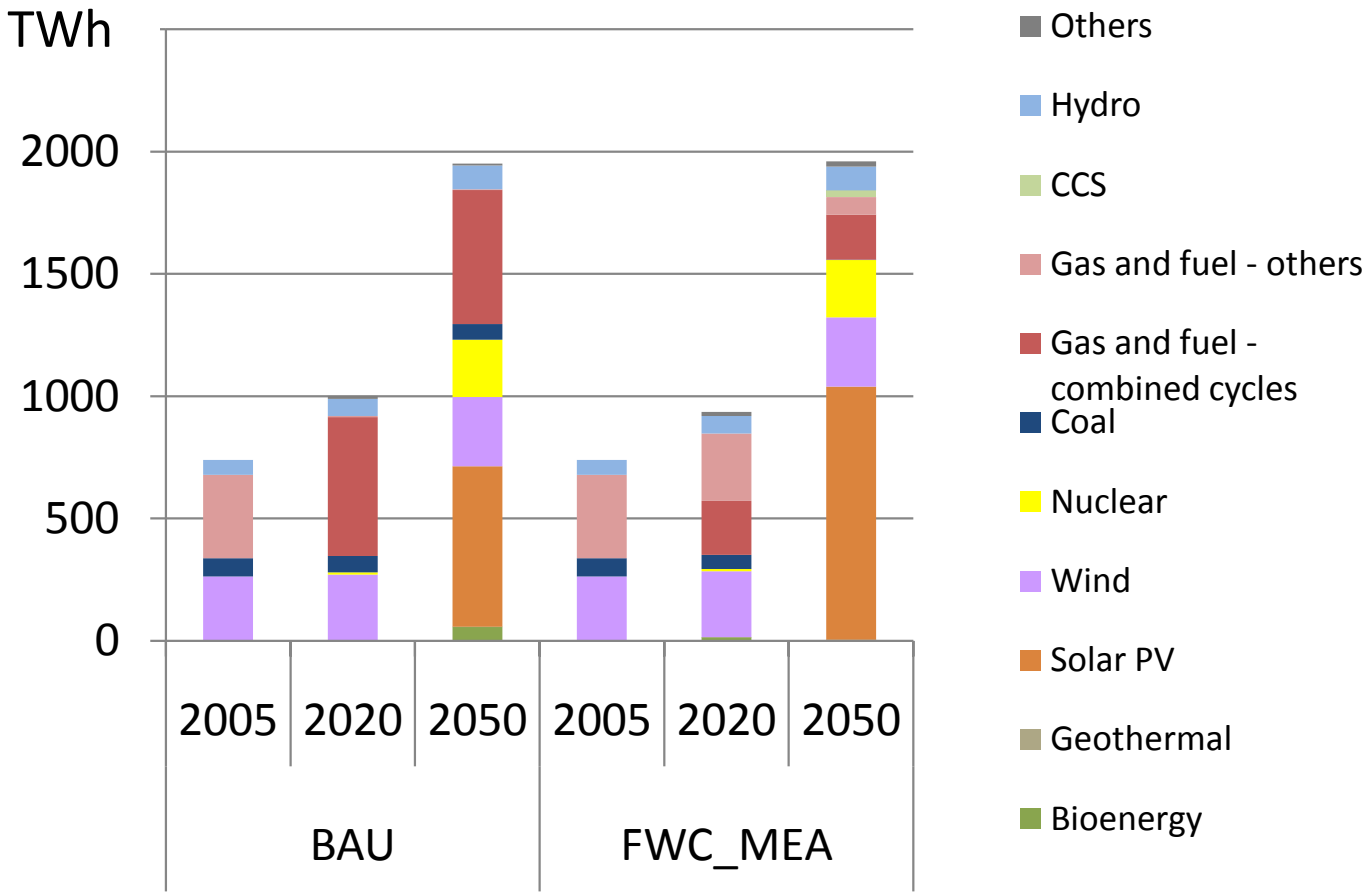
Bioenergy Geothermal Solar Nuclear Coal Gas and fuel CCS

4. Upstream chain energy in water consumption



5. Water as a constraint

- *FWC_MEA*: fresh water consumptions in Middle East until 2100 $\leqslant$ consumptions in 2005



Technical plausibility of power generation assessed scenarios

In order to cope with environmental issues, some technological options are highly recommended.

Strategic factors impact technical feasibility and relevance of future power mix

1. **Water** as an output commodity and as a constraint
   - Some technologies water footprints may be important
   - Extraction process

Prospective issues have been raised using planning tools : the power mixes must fulfill a balance :

a global optimum associating water and energy

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Web Sites : http://www.modelisation-prospective.org/
www.cma.mines-paristech.fr

- Water modeling in an energy optimization framework - The water-scarce middle east context, A. Dubreuil, S. Bouckaert, S. Selosse, E. Assoumou, N. Maïzi in Applied Energy (2012)
- A prospective analysis of waste heat management at power plants and water conservation issues using a global TIMES model Energy, S. Bouckaert, E. Assoumou, N. Maïzi in Energy (2014)

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Consommations d'eau dans le cycle pétrole

Procédé	[m^3/TJ]
Extraction et production onshore de pétrole conventionnel	3-8
Injection d'eau (Récupération secondaire)	600
Injection de gaz immiscible (Récupération secondaire)	340
Injection de vapeur (EOR)	100-180
Injection de CO_2 miscible (EOR)	340
Combustion *in situ* (EOR)	50
Injection de polymères (EOR)	8900
Injection de solutions caustiques (EOR)	100
Schistes bitumineux	55-135
Sables bitumineux (mines)	70-180
Sables bitumineux (*in situ*)	30-60
Raffinerie (classique)	25-65
Raffinerie (reformage et hydrogénation)	60-120

Consommations d'eau dans le secteur gazier

Procédé	[m^3/TJ]
Extraction du gaz conventionnel	Négligeable
Extraction du *Shale Gas*	3-13
Process du gaz	6
Transport par pipeline	3

Consommations d'eau dans la filière charbon

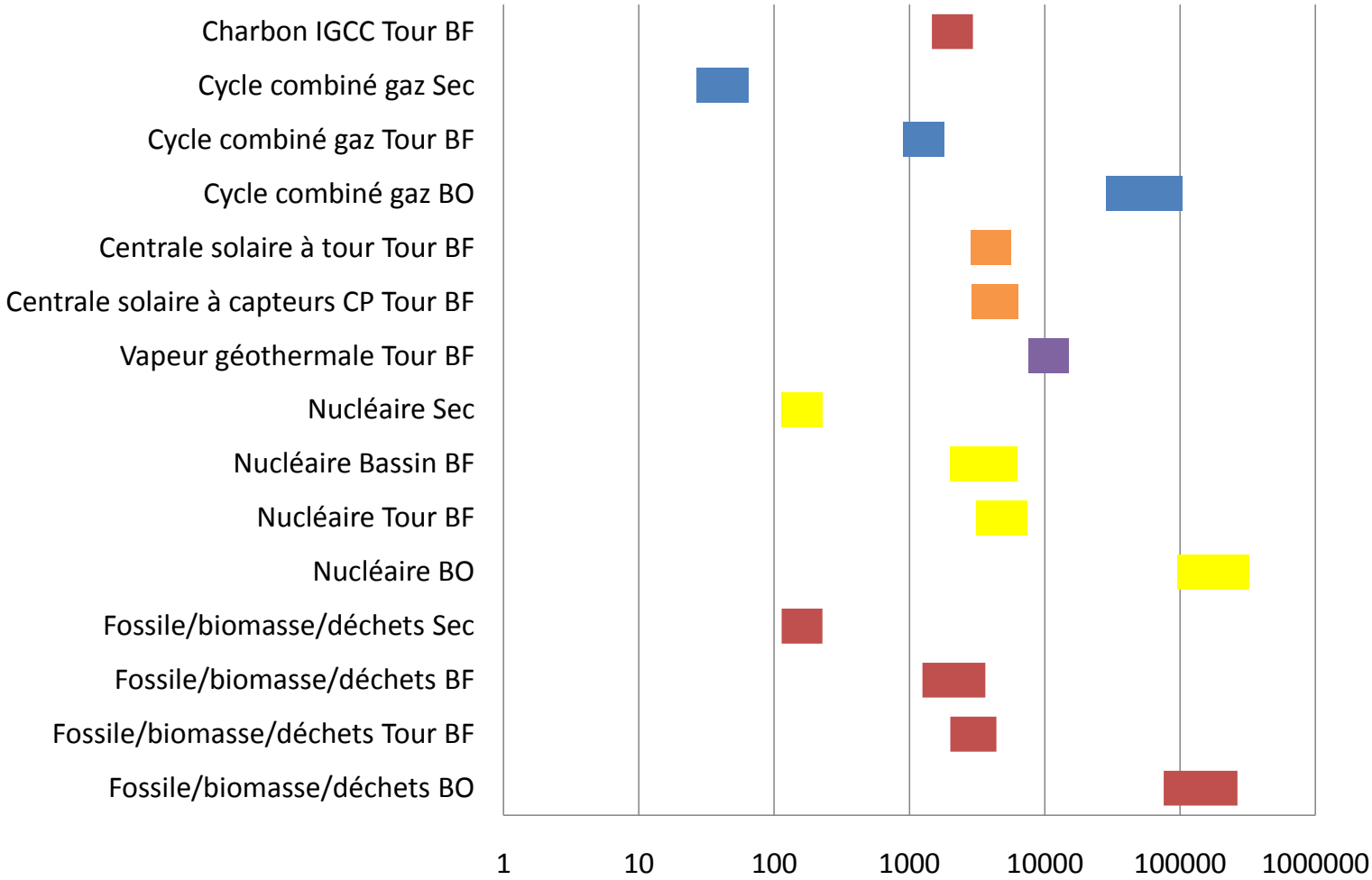
Procédé	[m^3/TJ]
Carrière à ciel ouvert sans revégétation	2
Carrière à ciel ouvert avec revégétation	5
Mine souterraine	3-20[1]
Lavage du charbon	4
Transport par boues	40-85
Gazéification	40-95
Liquéfaction (Fischer-Tropsch)	150-215

[1] L'intervalle dépend du type de refroidissement utilisé, le plus élevé correspondant à un circuit ouvert

Consommations d'eau dans la filière uranium

Procédé	[m^3/TJ]
Carrière à ciel ouvert	20
Mine souterraine	0.2
Lessivage du minerai	8-10
Conversion de l'uranium en hexafluoride	4
Enrichissement de l'uranium : diffusion gazeuse	11-13
Enrichissement de l'uranium : centrifugation	2
Fabrication du combustible	1
Recyclage du combustible nucléaire	50

Prélèvements d'eau dans la production d'électricité



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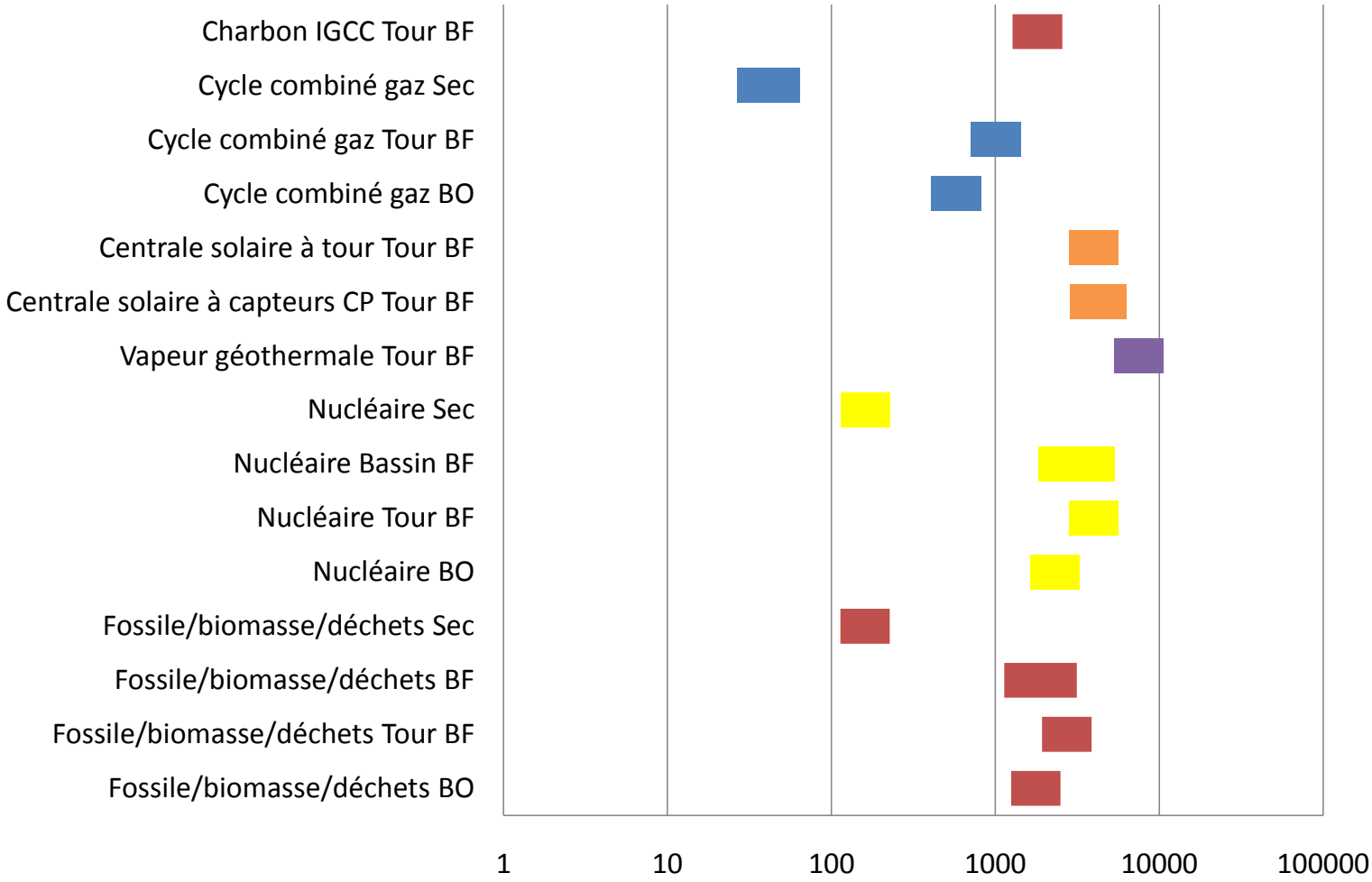

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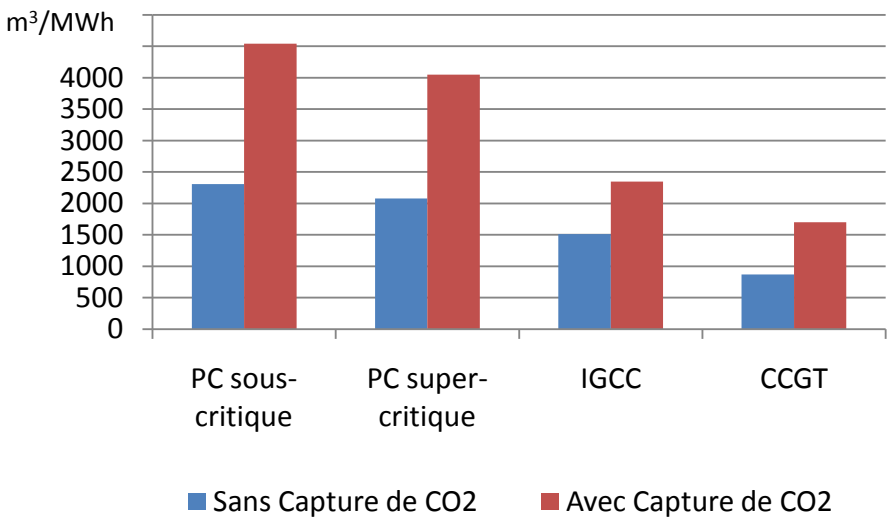
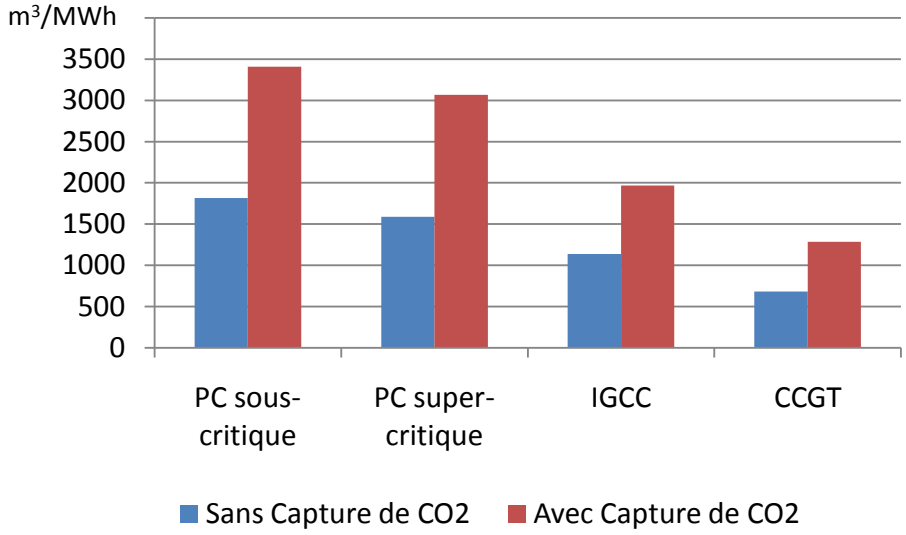


Consommations



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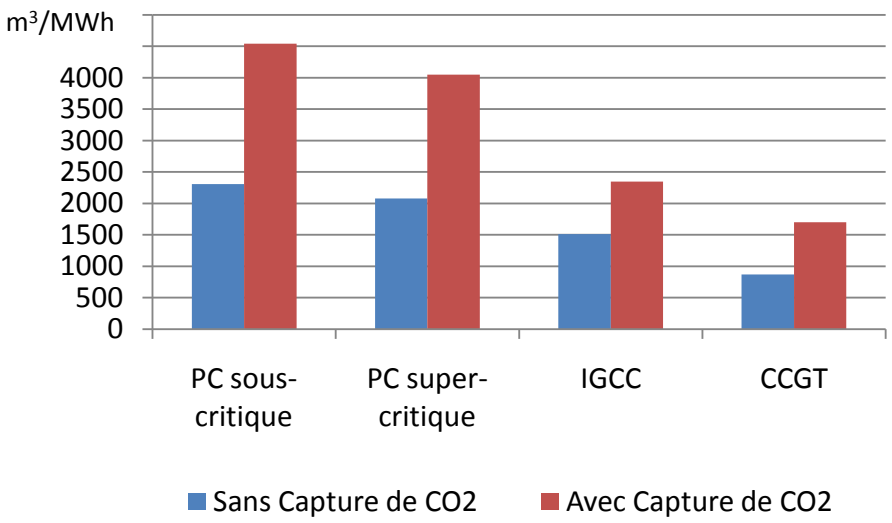

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