Laboratoire d'Economie Forestière

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Climate Economics Chair
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Simulating the use of biomass in electricity with the *Green Electricity Simulate* (GES) model: An application to the French power generation

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Outline

1. Introduction

2. Presentation of the GES model

3. Application to France

4. Conclusion

Introduction : Context

– Interest for biomass in electricity

- Biomass = Renewable Energy Source (RES)

  ⟹ Unable increasing the share of RES in power generation

- No CO_2 emissions (carbon cycle)

  ⟹ Reduction of CO_2 emissions when substituted for fossils

– Options for biomass-based electricité

- **Dedicated biomass power plants** : Power plants that only use biomass
- **Co-firing in coal plants** : Burning biomass and coal in coal plants

  ⟹ Up to 80% of potential biomass demande form electricity sector in Europe (technical potential with existing fleet)

Introduction : Motivations

– Objective

- Simulation tool to analyse questions about biomass-based electricity

– Contribution to literature

- Co-firing not taken into account in existing electricity simualtion models (*e.g.* Rentizelas *et al.*,2012; Kannan and Turton, 2013)
- Contribution of the model : Analyse of co-firing and induced effects

– Questions that can be investigated with the model

- Biomass demand from electricity in different price and policy contexts? Contribution of co-firing?
- Influence of carbon price?
- What qualities of biomass are consumed?
- Impact of co-firing on decisions about prolongation/decommissioning of out-of-lifetime coal plants?
- Consequences if co-firing is accounted for as a RES?

Outline

Presentation of the GES model

– General presentation

- Minimisation of generation and investment costs in electricity = Partial equilibrium for 2010-2030 (annual periods + intra-annual periods)

- Different economic and technical constraints

  → Clearing (supply=demand)

  → Capacity constraint : Generation ≤ Available Capacities

  → Constraint about the share of RES in power generation

  → Constraints associated to co-firing : Losses on efficiency of coal plants ; Quantity of biomass depending on quality

  → Etc

- Three compartments in the model

  → **Dispatch** = Optimal dispatch of existing fleet (merit order) to meet power demand in different hours in the year

  → **Investment** = investment in new units to maintain and increase the size of the fleet so as to meet increasing power demand and adapt to decommissioning of out-of-lifetime units

  → **Identification of out-of-lifetime units** and decisions about **prolongation or decommissioning** of these units

  ⟹ Impact of co-firing on prolongation/decommissioning of coal plants

Presentation of the GES model

– Generation technologies

Summary of Main Technologies
Nuclear
Bituminous Coal (hard coal)
Lignite Coal
Oil and Bio-liquid (biofuel)
Gas and Biogas
Combined Cycle (CC) Gas turbine
Dedicated Biomass
Hydroelectricity
Solar PV
Wind
Geothermal

Main fuel categories	Fuels included in the categories
Oil	Oil
Natural Gas	Natural Gas
Coal	Bituminous coal (hard-coal)
	Lignite
Uranium	Uranium
quality Solid Biomass	Torrefied Pellets
	Wood Pellets
	Wood Chips
	Agricultural Residues
Waste	Mixed Grade Waste
Biogas	Biogas
Bio-Liquid	Bio-Liquid

Each technology can use one or several types of fuels

→ Dedicated biomass power plants = All the solid biomass fuels

→ Centrales Charbon = Charbon + Tous combustibles biomasse solide

- Data Base = *World Electric Power Plants* (WEPP) from Platts

→ Inventory for power generation capacities in Europe (and in the whole world)

→ **Installed capacities** and **Years of commissioning** for all the power plants

Presentation of the GES model

– **Co-firing** : Configuration of coal plants

- In each time, each coal plant can be used under two possible configurations

  → Classical configuration (only coal

  or

  → Co-firing configuration (coal + biomass)

- Efficiency (conversion) rate of coal plants depends on the configuration

  → Efficiency rate of classical > Efficiency rate of co-firing

- Losses on the efficiency rate of coal plants under co-firing

  → Presence of air and increased moisture content with biomass = Reduced efficiency rate for coal plants

Presentation of the GES model

– **Co-firing** : Effect of biomass quality

- Quantiy of biomass in coal plants depends on the biomass quality

  → More losses with low quality biomass

  → The quantity of biomass that can be incorporated in coal plants (*incorporation rate*) increases when the biomass quality increases

- Trade-off in the choice about the quality of biomass

Low quality
- Low price
- Few biomass in coal plants ⇨ Weak CO_2 emission reductions

High quality
- High price
- A lot of biomass in coal plants ⇨ Strong CO_2 emission reductions

- Illustration of effects : CO_2 emission factor of coal plant

	Charbon – Classique	Charbon – Co-firing déchets agricoles (5% de biomasse dans la centrale)	Charbon – Co-firing biomasse torréfiée (50% de biomasse dans la centrale)
tCO_2/MWh_{elec}	0,94	0,9	0,47

Highest quality

Outline

Results for France : Questions

- **Question 1** : Impact of co-firing on the electricity mix

- **Question 2** : Biomass demand in the power sector

Focus on :

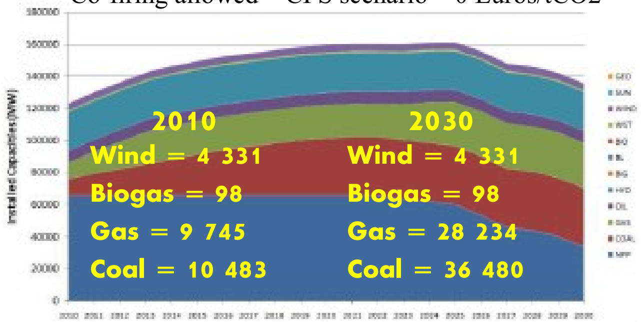
→ Sensibility with respect to carbon price

→ Consequences if co-firing is accounted for as a renewable

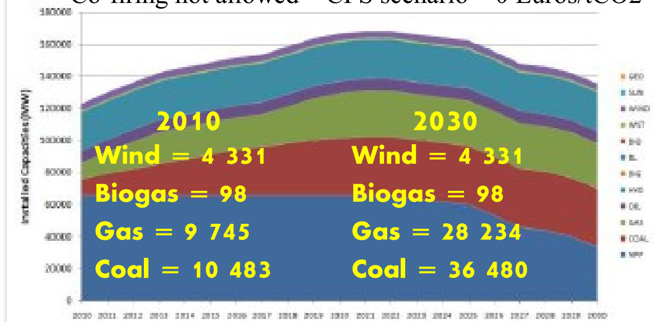
Results for France : Electricity mix

– Sensibility with respect to carbon price : Generation Capacities

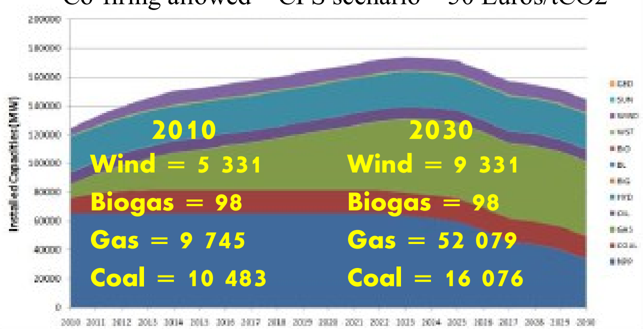
Co-firing allowed – CPS scenario – 0 Euros/tCO2



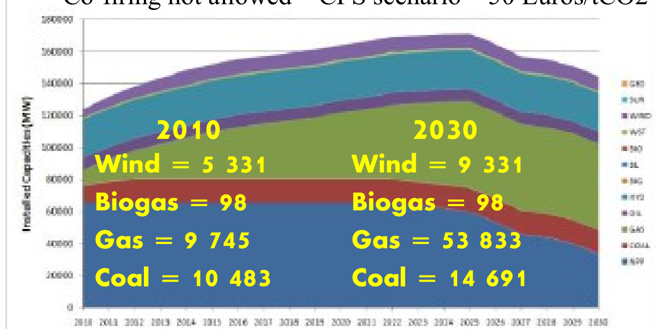
Co-firing not allowed – CPS scenario – 0 Euros/tCO2



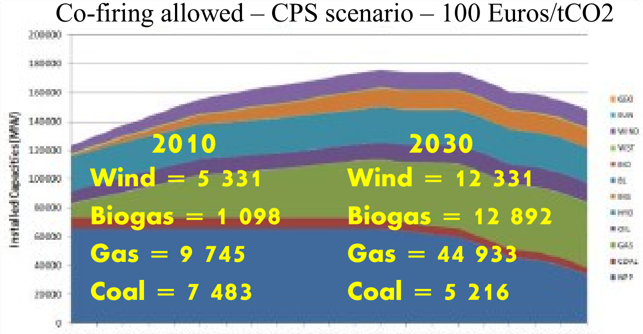
Co-firing allowed – CPS scenario – 50 Euros/tCO2



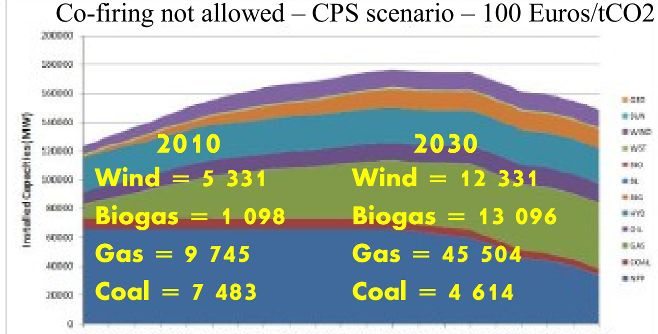
Co-firing not allowed – CPS scenario – 50 Euros/tCO2



Co-firing allowed – CPS scenario – 100 Euros/tCO2



Co-firing not allowed – CPS scenario – 100 Euros/tCO2

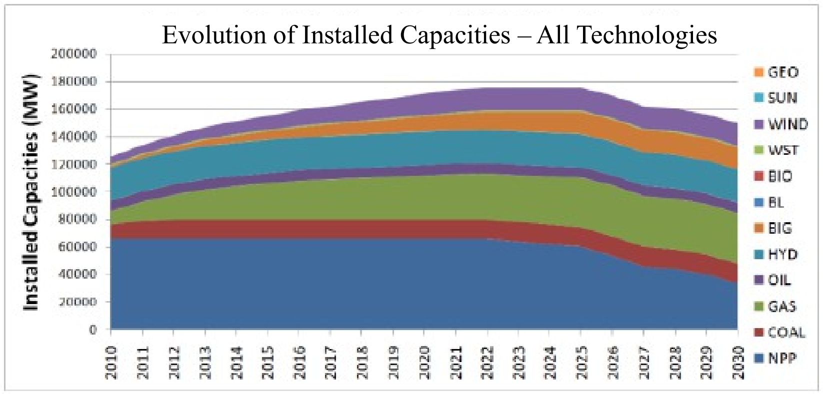


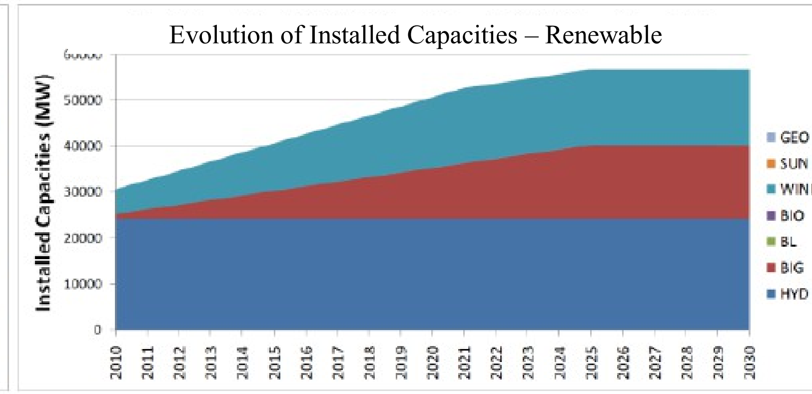
- **Increase in the carbon price**
  - → Reduction in Coal capacities
  - → Increase in Gas capacities
  - → Increase in Wind and Biogas capacities
- **Consequences of co-firing**
  - → Weaker reduction in Coal capacities
  - → Weaker increase in Gas capacities
  - → Weaker increase in Wind and Biogas capacities
  - ⇨ Increase in coal profitability with respect to low carbon competing technologies
- **Decommissioning of coal plants**
  - → Reduction in coal capacities when carbon carbon reaches 100 Euros = *Carbon Effect*
  - → Weaker reduction when co-firing is allowed in the model = *Co-firing Effect*

Results for France : Electricity mix

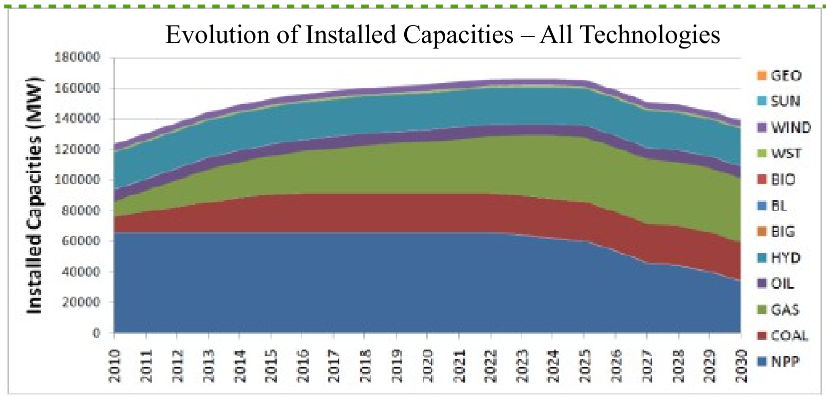
– Recognizing co-firing as a renewable (RES)

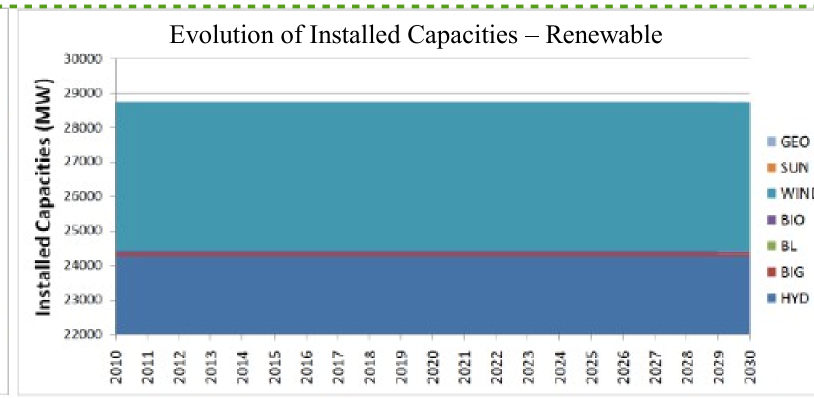
Co-firing not accounted for as a RES





Co-firing not accounted for as a RES





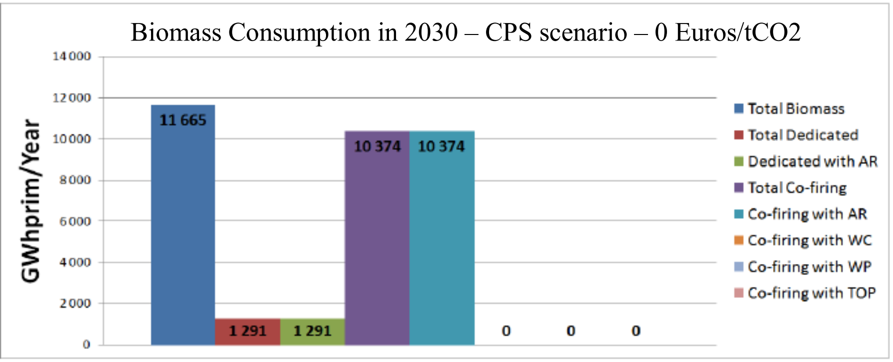
- If co-firing is accounted for as a RES, coal is substituted for *traditional* RESs

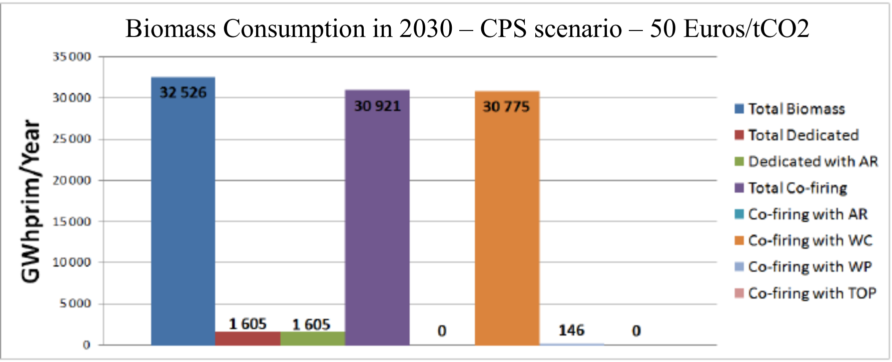
  → No investment in *traditional* RESs

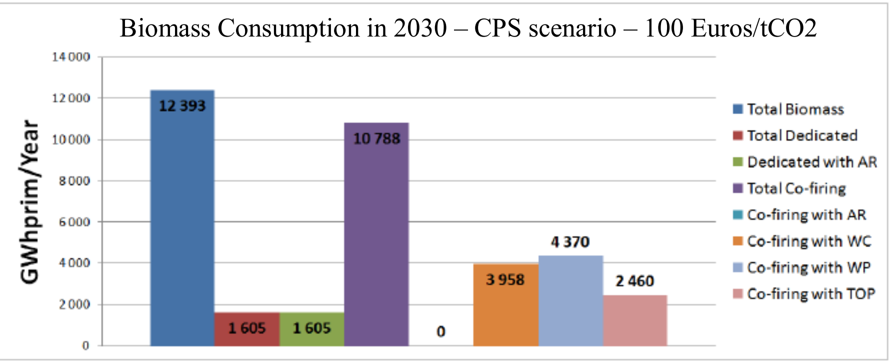
  ⟹ Social acceptability?

Results for France : Biomass demand

– Sensibility with respect to carbon price : Threshold effect







- From 0 to 50 Euros = Increase in total biomass demand

  → Weak increase in demand from dedicated biomass units

  → Strong increase in demand from co-firing

  Effect 1 = Coal plants move from classical to co-firing configuration (increase in biomass demand)

  Effect 2 = Fewer investment in coal = Fewer coal capacities to trigger biomass demand

  ⟹ *Effect 1* > *Effect 2* = Increase in total biomass demand

- From 50 to 100 Euros = Decrease in total biomass demand

  → No increase from dedicated biomass units

  → Strong decrease from co-firing = Co-firing is substantially less profitable compared with zero-carbon technologies

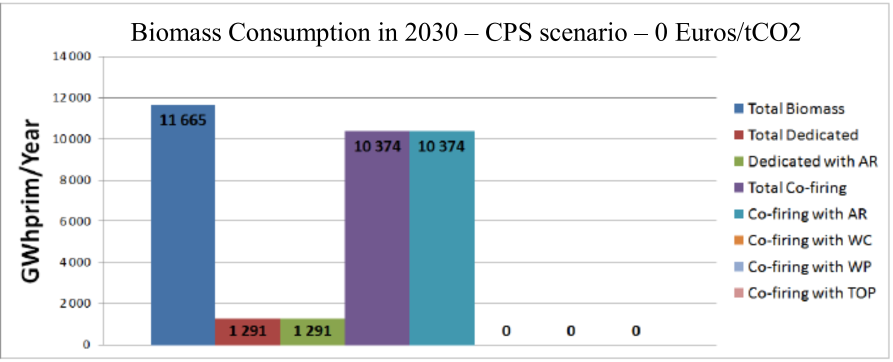
  Effect 1 = All the coal plants run the co-firing configuration

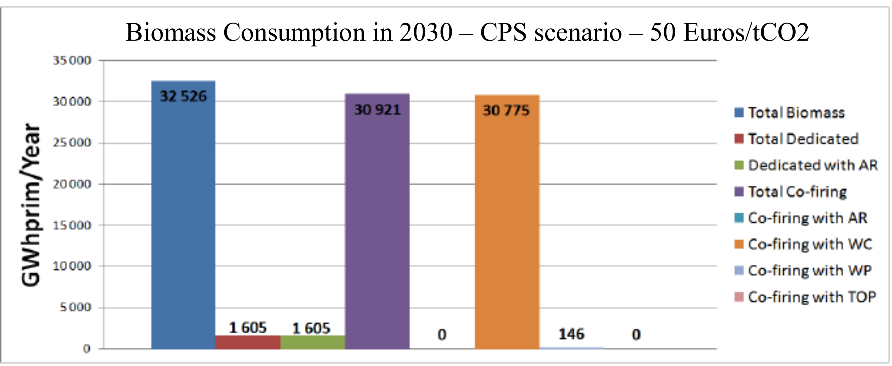
  Effect 2 = No more investment in coal plants + Decommissioning of coal pants = Strong decrease in coal capacities (and associated biomass demand)

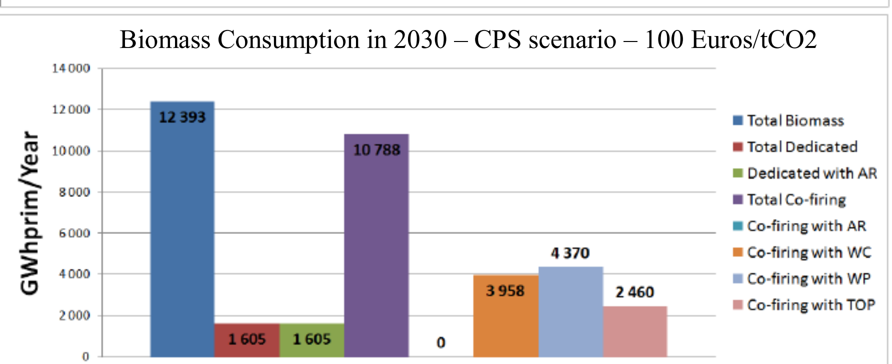
  ⟹ *Effect 1* < *Effect 2* = Decrease in total biomass demand

Results for France : Biomass demand

– **Sensibility with respect to carbon price** : Move towards quality







- From 0 to 50 Euros

  → Wood Chips (WC) substituted for Agricultural Residues (AR) = Increase in quality

- From 50 to 100 Euros

  → High quality biomass fuels = Wood Pellets (WP) and torrefied Pellets (TOP)

Move towards quality when the carbon price increases

⇨ When the quality increases there is more biomass in coal plants (higher incorporation rate) = Reduced carbon cost

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Conclusion : Main Results

- **Biomass demand**

  → Threshold effect with respect to carbon price

  → Move towards quality when the carbon price increases

- **Impact of co-firing on the electricity mix**

  → Co-firing can induce prolongation of coal plants that would be decommissioned otherwise

  → Recognizing co-firing as a RES = Substitution of coal for *traditional* RESs

  ⟹ No investment in *traditional* RESs = *S*ocial Acceptability?

Conclusion : Perspectives

– Works in Progress

⇨ Competition to access woody resources in France between electricty and other (traditional) sectors that consumes wood = Coupling with the FFSM (*French Forest Sector Model*) model

⇨ Consequences of co-firing in German electricity = Effect on prolongation/decommissioning decisions for old German coal stations?

– Projects with GES

⇨ GES France-Regions = Spatialization of the GES-France at the French-region level = Effect of co-firing on local resources in regions with large coal plants (*e.g.* the Gardanne co-firing project in France)?

⇨ GES Europe = Connecting all the country modules (current version) into a single European model = Competition between national power sectors to access the European biomass resource?

Thank you for your attention

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More information and documentation on the GES website :

Green Electricity Simulate Project

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