SUBSIDIZING BIOMASS COMBUSTION IN A CO-FIRING FOSSIL FUEL PLANT –

The Effects on State Level Electricity Production and CO_2 -emissions

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BACKGROUND (1)

- Pressure to increase RES-E production has increased globally
  - Yet, the RES-E technologies are still developing

- There is large scale production of electricity and CHP by fossil fuels

  → Remarkable potential to increase biomass use and decrease coal use (50-90 TWh in EU27) by co-combustion in existing power plants

BACKGROUND (2)

- Criticism for biomass combustion subsidies in co-firing
  - ‘increased profitability of existing fossil power plants’

- Biomass combustion in co-firing power plants has been treated differently in renewable electricity promoting policy schemes

→ In this study, we calculate the impacts of that choice (implementation strategy)
  - on the fuel uses, investment decisions, CO_2 emissions and renewable electricity promoting policy instruments' values

THE MODEL

- **Three types of production:**
  1) Co-firing power plants - all the solid fossil fuel power plants are able to co-fire (biomass, coal and peat)
  2) Single fuel power plants (natural gas, oil)
  3) Wind power plants (onshore, offshore)

- **Hydro and nuclear power are exogenous**

- **Two time periods**
  - 1st period: current state
  - 2nd period: objective period

- **Four sub-periods**
  - peak, high, average and low demand

- **Investments increase the second period capacity**

POLICIES (1)

- **Three policy instruments:**
  - Feed-in tariff (FIT)
  - Renewables subsidy (s)
  - CO_2 emissions price
- **Four policies:**
  - all the policies include CO_2 emissions price

Strategy:	**Instrument**: Feed-in tariff	**Instrument**: Renewables subsidy
Biomass co-firing **is not** subsidized	NoCF, FIT	NoCF, s
Biomass co-firing **is** subsidized	YesCF, FIT	YesCF, s

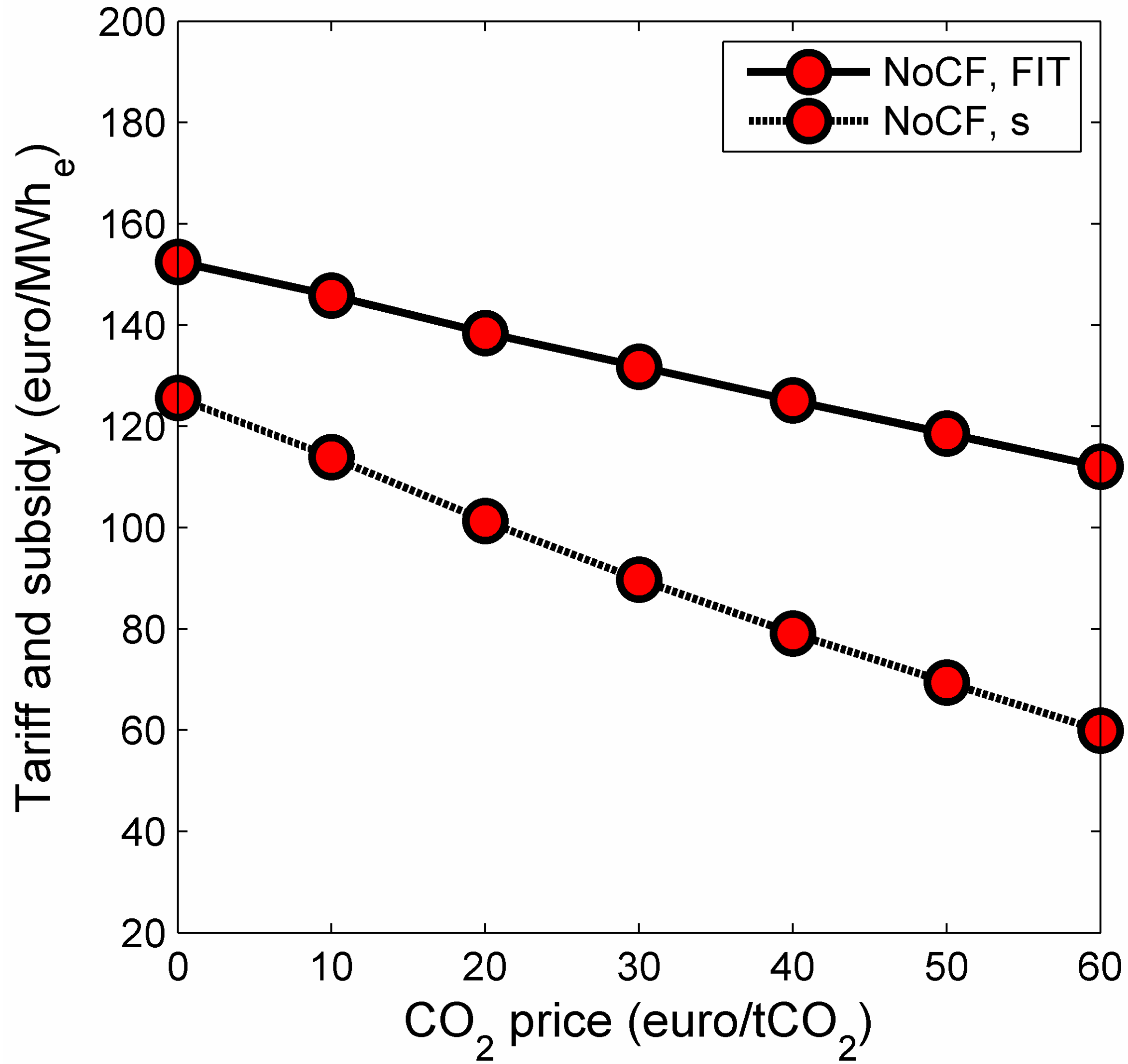
POLICIES (2)

- RES-E requirement of 30 %
  - Equal for feed-in tariff and renewables subsidy
  - The model calculates the *FIT* and *s* values that are needed to obtain the RES-E requirement

- The results are presented for 0-60 €/tCO_2 emissions price

- The numerical application is calculated for Finnish energy markets
  - The biomass is energywood

RESULTS (1) - RES-E INSTRUMENTS



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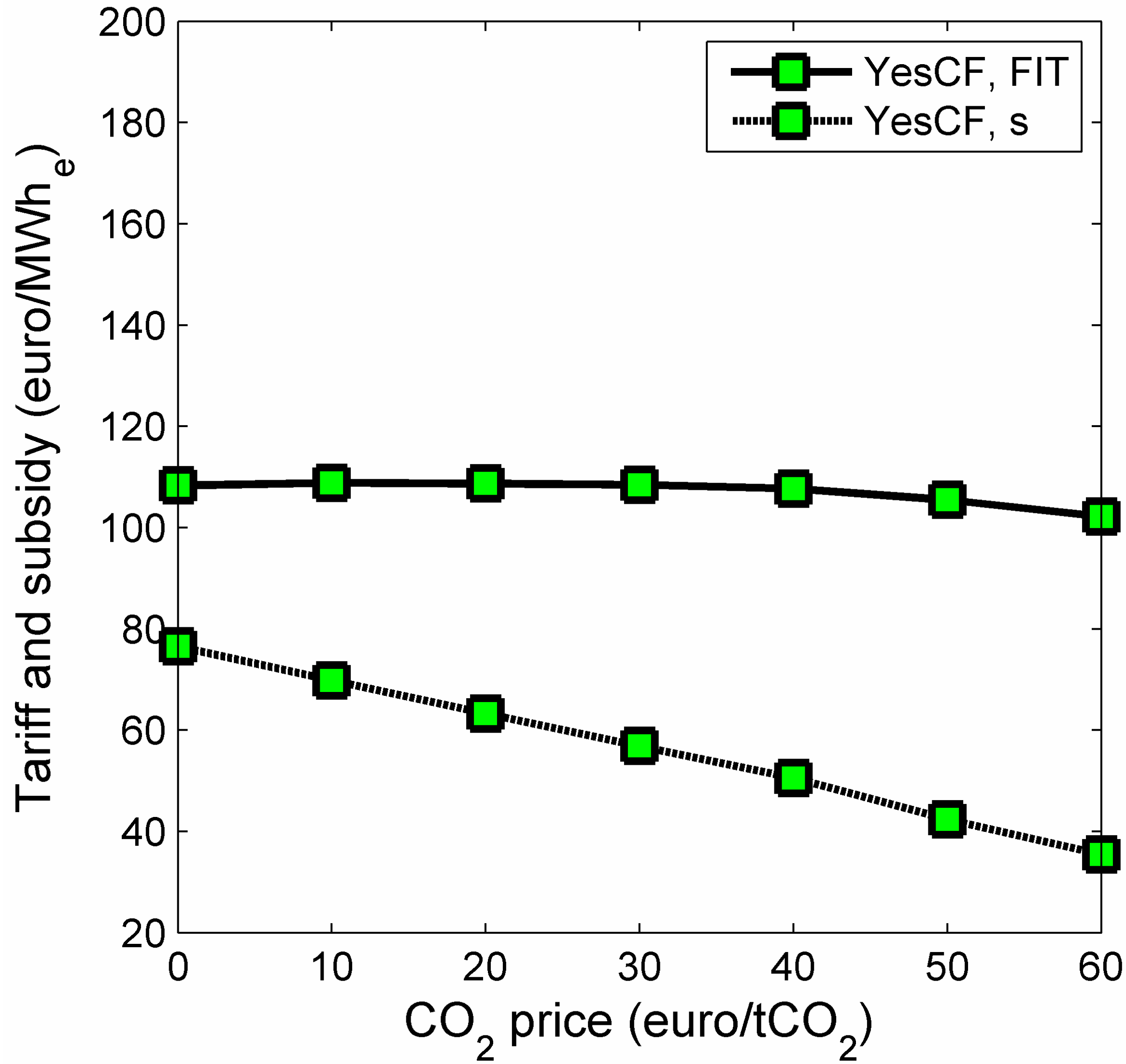
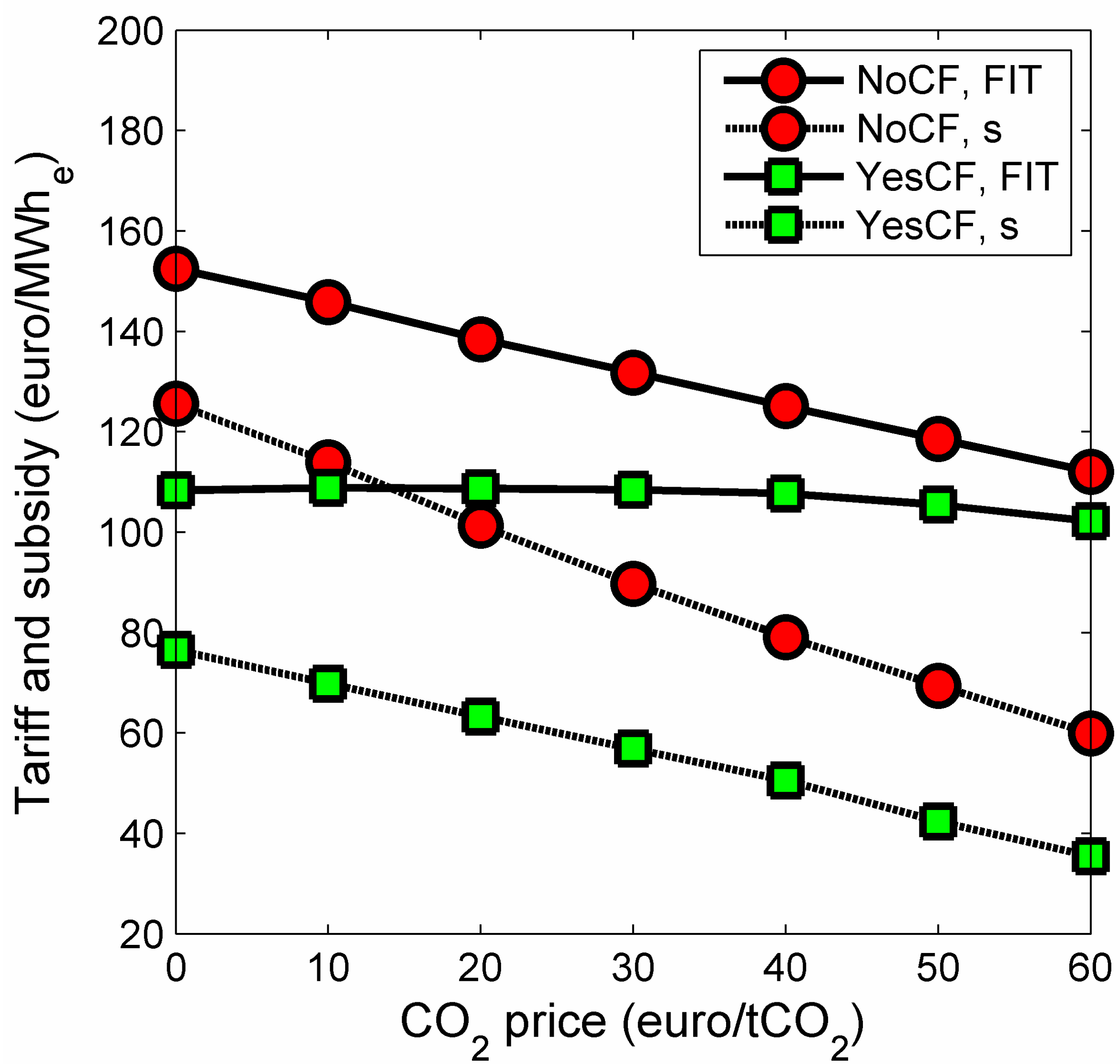
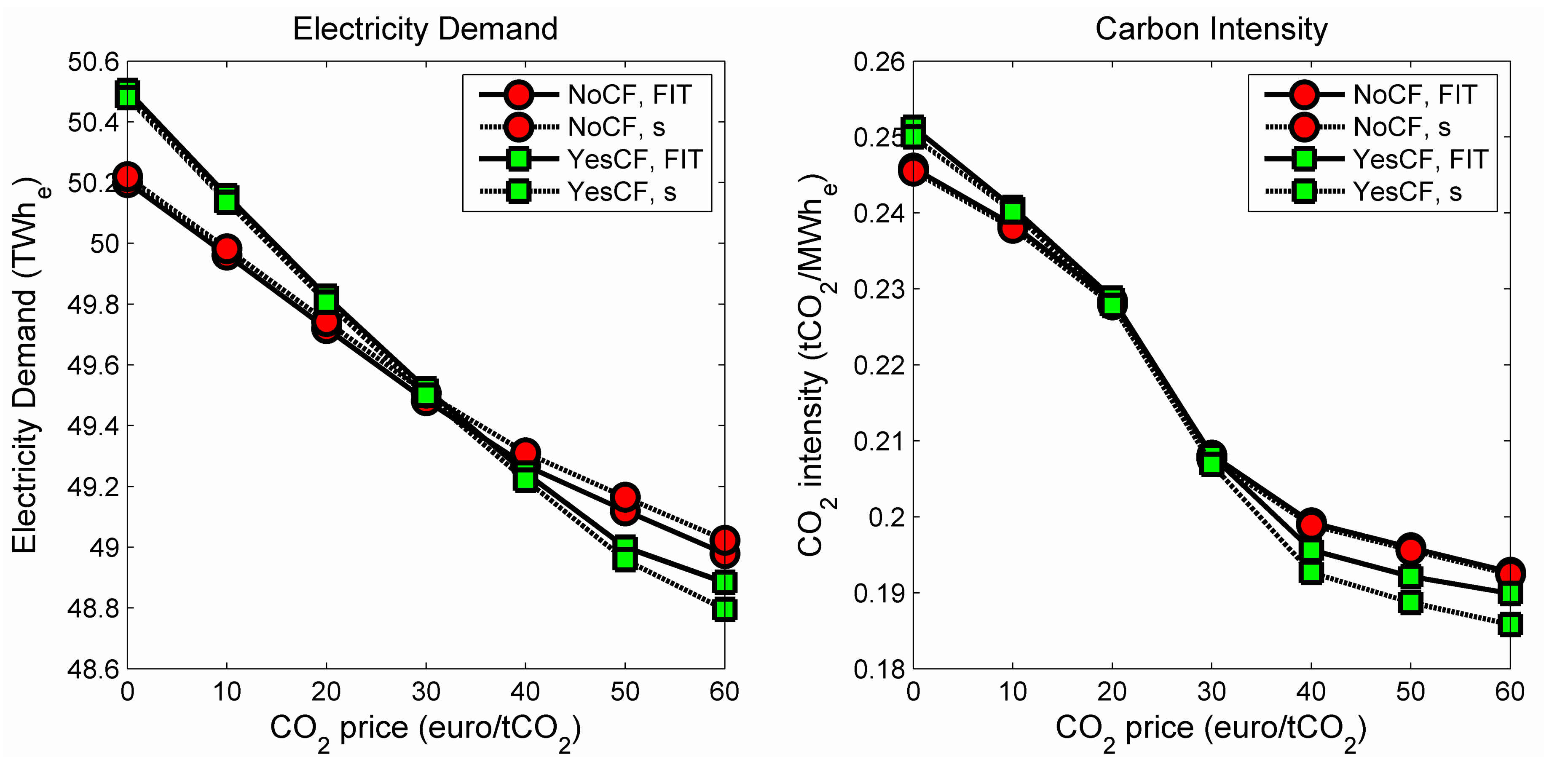


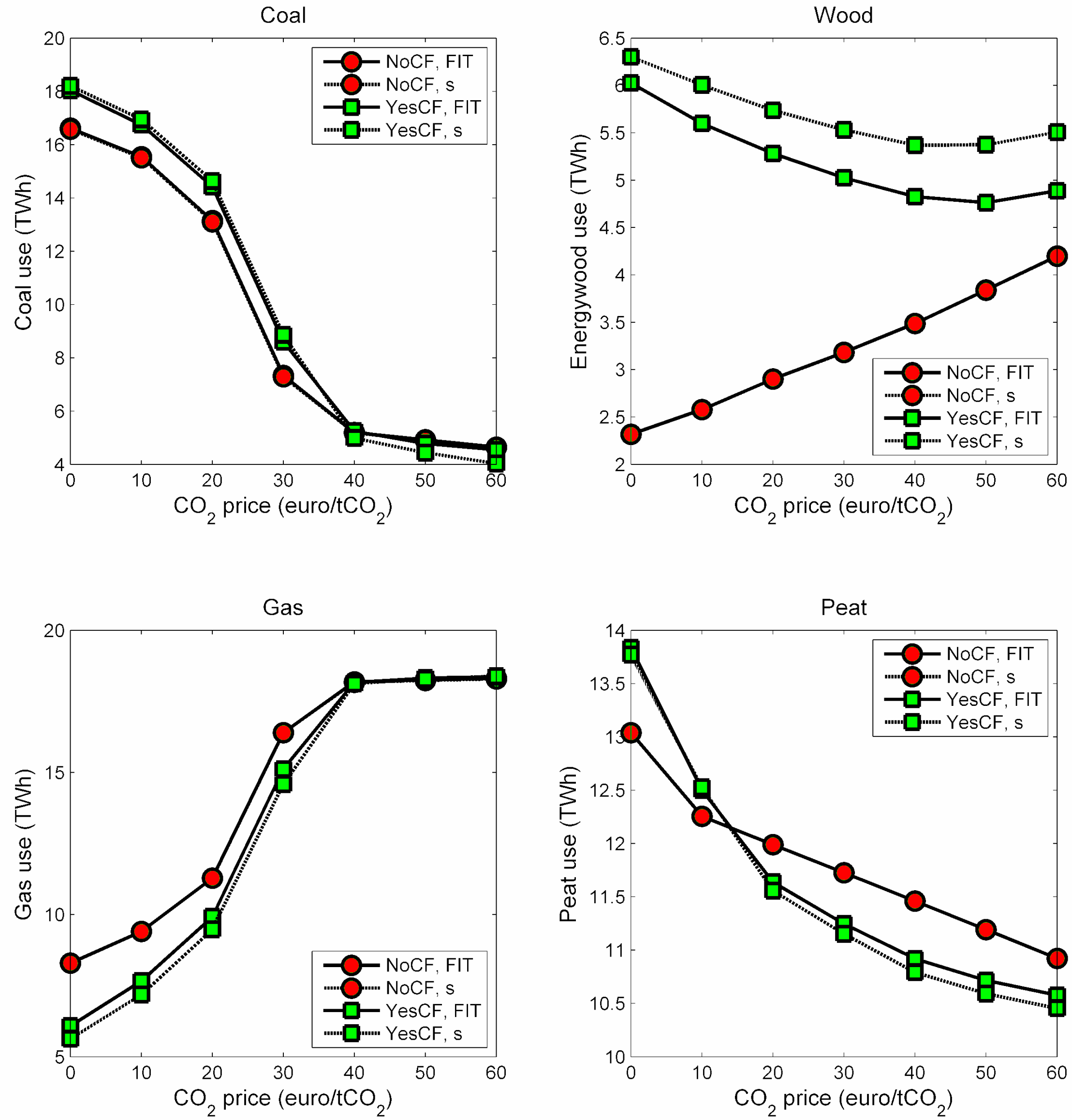
RESULTS (1) RES-E - INSTRUMENTS



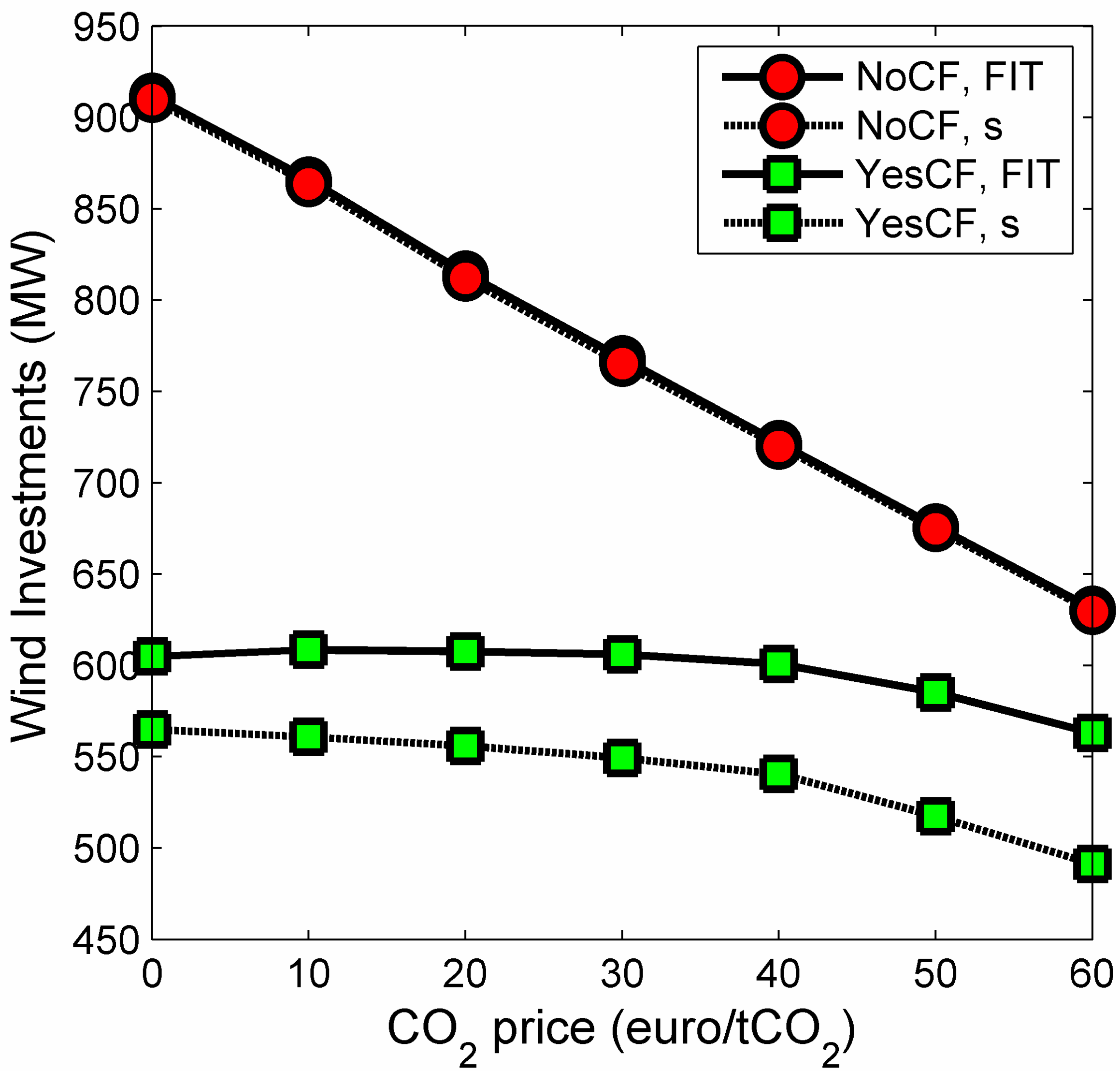
RESULTS (2) - DEMAND & CO_2 INTENSITY



RESULTS (3) - FUEL USES



RESULTS (4) WIND INVESTMENTS



CONCLUSIONS (1)

- The inclusion of co-firing into RES-E promoting policy scheme:
  - Increases the utilization of biomass
  - Lowers investment levels into wind turbines
  - Decreases the tariff and subsidy values that are needed to reach the RES-E requirement
  - Does not systematically increase the carbon intensity of the power generation

- With two RES-E technologies it might be possible to find more efficient RES-E production allocations than with only one

CONCLUSIONS (2)

- The differences between feed-in tariff and renewables subsidy:
  - Appear to be minimal when biomass co-firing is not subsidized
    - In wind power production, there is no production decision
  - Occur, when biomass co-firing is subsidized
    - Biomass is an almost perfect substitute for peat and a substitute for coal
    - The input/production decisions vary between instruments
    - The feed-in tariff prevents the pass-through effects of climate policy from subsidized RES-E producers

THANK YOU!

APPENDIX

LITERATURE

- The study combines/extends two previous studies:
  1) Fisher & Newell. 2008. Environmental and technology policies for climate mitigation. JEEM.
     - The impacts of different policies in two period eletricity market model. No co-firing power plants.
  2) Kangas, Lintunen & Uusivuori. 2009. The co-firing problem of a power plant under policy regulations. EP.
     - The endogenous fuel-mix choise of a co-firing power plant. Exogenous energy markets.

THE MODEL - CO-FIRING POWER PLANTS

- The co-firing plant makes a fuel mix, production and investment decision:

$$\Pi^{cf}(\boldsymbol{x}, I) = \sum_{t \in \{0,1\}} H_t \delta^t \left(\sum_{\tau=1}^{4} \left[R_{\tau t}(\boldsymbol{x}_{\tau t}) - TC_{\tau t}(\boldsymbol{x}_{\tau t}) \right] \omega_\tau \right) - c^{inv}(I)$$

$\boldsymbol{x}_{\tau t}$	Fuel mix
t, τ	Period, sub-period
H_t	Hours/period
$\delta = 1/(1+r)$	Discount factor
ω_τ	Weight of sub-period $\sum_\tau \omega_\tau = 1$
$R_{\tau t}(\boldsymbol{x}_{\tau t}) = \sum_{i \in Y} p_{i\tau t}^{eff}(\boldsymbol{x}_{\tau t}) \eta_i \sum_{f \in F} x_{f\tau t}$	Revenues, $i \in Y = \{el, heat\}$, $p_{i\tau t}^{eff}(\boldsymbol{x}_{\tau t})$ effective price, η_i efficiency
$TC_{\tau t}(\boldsymbol{x}_{\tau t}) = C_{\tau t}(\boldsymbol{x}_{\tau t}) + \sum_{f \in F} p_t^{ec} \varepsilon_f x_{f\tau t}$	Total costs (production and emissions costs)
$c^{inv}(I)$	Investment costs

THE MODEL - CO-FIRING POWER PLANTS

- Co-firing costs:
  - Technically optimal biomass ratio σ_{bio}
    - FBC: positive; PF: zero or negative
  - Assumed to be quadratic around technical optimum

  → Substitutability of fuels varies with biomass ratio

$$c^{co}\left(\frac{x_{bio,\tau t}}{\sum_{f\in F} x_{f\tau t}} - \sigma_{bio}\right)^2 \sum_{f\in F} x_{f\tau t}$$

THE MODEL - CO-FIRING POWER PLANTS

- The optimization is restricted by period-wise capacity constraints

$$X_{max} \geq \sum_{f \in F} x_{f\tau 0} \quad \forall \tau \in \{1, 2, 3, 4\}$$

and

$$X_{max} + I \geq \sum_{f \in F} x_{f\tau 1} \quad \forall \tau \in \{1, 2, 3, 4\}$$

THE MODEL - SINGLE FUEL PLANTS

- The single fuel power plant makes a fuel use and investment decision

- The plants are aggregated through their efficiency coefficients

$$\Pi^s(\boldsymbol{x}) = \sum_{t\in\{0,1\}} H_t \delta^t \left(\sum_{\tau=1}^{4} \left[\sum_{i\in Y} p_{i\tau t} \int_0^{x_{\tau t}} \eta_i(X)dX - TC_{\tau t}(x_{\tau t}) \right] \omega_\tau \right)$$

- The amount of output generated

$$q_i(x) = \int_0^x \eta_i(X)dX$$

THE MODEL – EFFICIENCY AGGREGATION

- Efficiency function: $\eta_i(X)$
  - Represents efficiency coefficients of the aggregate
  - Locus approximated by a differentiable function
  - Merit order assumption: decreasing in X
  - Linear efficiency function ↔ quadratic costs

- Investments:
  - Specific technology (constant efficiency)

THE MODEL - WIND POWER PLANTS

- No production decision
  - the investments on new capacity are optimized

$$\Pi^{wind}(I) = \sum_{t\in\{0,1\}} H_t \delta^t \left(\sum_{\tau=1}^{4} \omega_\tau R_{\tau t}^{wind} - C_t^{wind} \right) K_t(I) - c^{inv}(I)$$

POLICIES

- RES-E policy instruments:

1) **Feed-in tariff (FIT)**

- Co-firing power plant $$p_{el,\tau t}^{eff}(\boldsymbol{x}) = p_{el,\tau t} + \frac{x_{bio,\tau t}}{\sum_{f \in F} x_{f\tau t}} \max\{0, p_{fit,t} - p_{el,\tau t}\}$$
- Wind power plant $$p_{el,\tau t}^{eff}(\boldsymbol{x}) = p_{el,\tau t} + \max\{0, p_{fit,t} - p_{el,\tau t}\}$$

2) **Renewables subsidy (s)**

- Co-firing power plant $$p_{el,\tau t}^{eff}(\boldsymbol{x}) = p_{el,\tau t} + \frac{x_{bio,\tau t}}{\sum_{f \in F} x_{f\tau t}} s_t$$
- Wind power plant $$p_{el,\tau t}^{eff}(\boldsymbol{x}) = p_{el,\tau t} + s_t$$