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Case study: biomass co-firing in the lignite sector of SEE

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CPERI
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Co-firing in general (1/2)

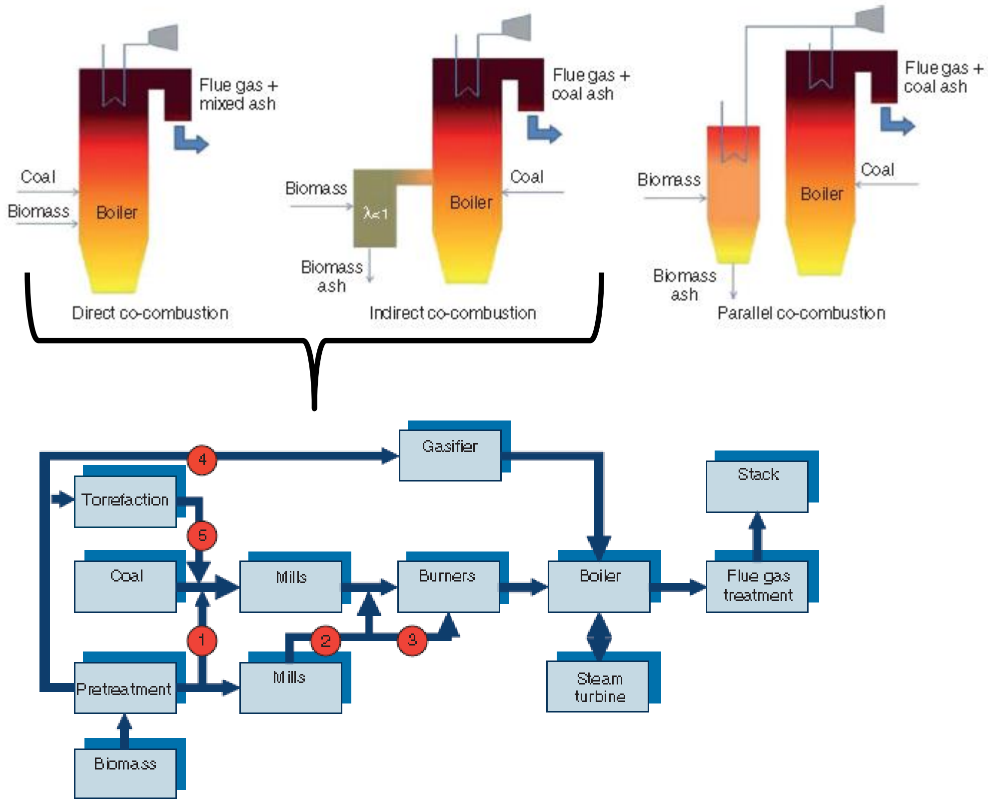
- Co-firing definition: <u>“simultaneous combustion of two or more fuels in the same energy plant in order to produce one or more energy carriers”</u>
  - Most common application: partial substitution of coal in large-scale pulverized-fuel power plants with solid biofuels (or waste derived fuels)

- **Advantages**
  - Low investment cost (typically 50 – 300 EUR/kWe compared to 2,500 – 5,000 EUR/kWe for dedicated biomass combustion), short implementation time
  - Thermal process - produces renewable energy on demand
  - Higher electrical efficiency (36% in OECD countries, > 43% in state-of-the-art coal-fired plants) compared to dedicated biomass combustion (average 25%, max. 36.5%)

- **Disadvantages**
  - Continued reliance on coal use
  - Cost difference between biomass / coal → (biomass) requires financial support
  - Mobilization of large amounts of biomass
  - Potential technical / environmental impact from biomass combustion in coal-fired furnaces (slagging, fouling, corrosion, ash utilization, etc)

Co-firing in general (2/2)

Technical options for implementation of biomass co-firing



Source: DNV Kema, 2009

In most cases: main fuel is hard coal, biomass fuel is wood pellets, sourced from the international market (sea trade)

- Direct co-firing
  - Different options to feed biomass in the coal furnace with different complexities / costs (e.g. new dedicated mills / burners)
  - Typical biomass thermal share: 10 - 20%
  - Overall, lowest implementation costs, easiest solution
- Repowering: converting coal-fired plants to 100% biomass combustion
  - Drax PP, United Kingdom . 4,000 MWe / 3 out of 6 units converted to 100% biomass use
  - 5.9 Mt/y biomass consumption (2015), wood pellets
  - Extensive retrofit, implemented under stable legislative conditions
- Biomass torrefaction
  - Still in demonstration phase
- Indirect (gasification) co-firing
  - Installation of biomass gasifier
  - Reduced impact of biomass on coal boiler, may avoid extensive cleaning of syngas
  - Higher capital costs
- Parallel co-firing
  - Avedøre Unit 2, Denmark. 800 MWth multi-fuel boiler (wood pellets, HFO, NG), 105 MWth straw boiler, gas turbines, electrical efficiency 42 – 49%
  - Integration on steam side
  - Higher complexity / costs

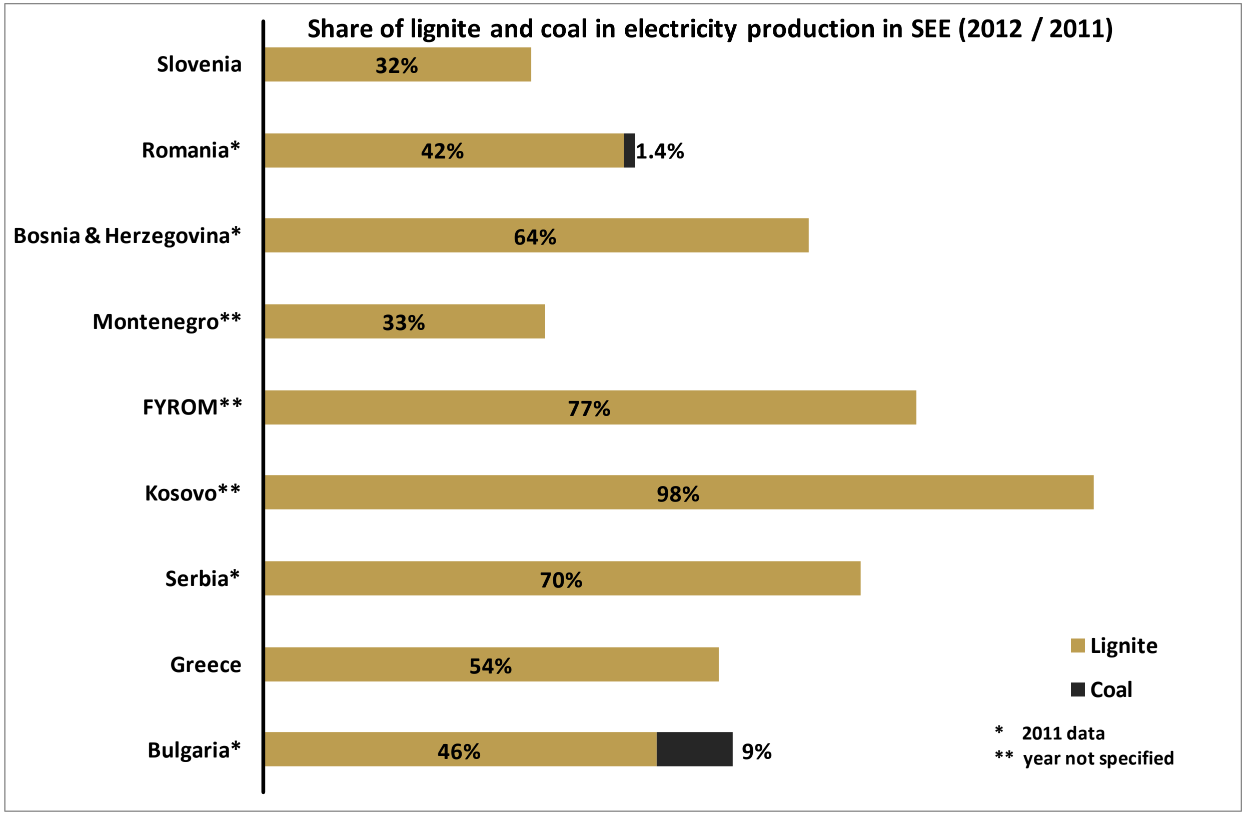
Biomass co-firing with lignite

- Lignite is major fossil fuel for the electricity sector in several EU countries
- Disadvantages / issues of co-firing lignite with biomass:
  - Unfavorable legislative framework in several lignite using countries
  - The fundamental cost difference between hard coal - biomass is higher in the case of lignite - biomass
  - Lignite units are usually landlocked – can't easily access imported biomass
- Advantages of co-firing lignite with biomass:
  - In terms of heating value, biomass in an improvement over lignite → **use of biomass as support fuel for partial load operation, start-up, etc**
  - Large size of lignite furnaces can ensure sufficient residence time for combustion of large biomass particles
  - High ash and sulfur content of lignite can mitigate negative impacts of biomass ash / alkali content

Coloured by lignite installed capacity
Red > 2 GWe, Orange < 2 GWe
Source: booz&co., Understanding lignite generation costs in Europe, 2014

- Direct co-firing is the easiest option to implement - consider the peculiarities of the lignite milling system (e.g. flue gas recirculation)

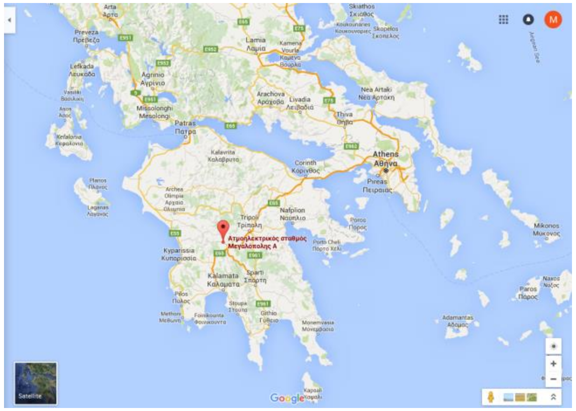
Lignite sector in SEE



Data from EURACOAL, 2013

- Dominant fuel for electricity production in most of the SEE countries
  - contributes to lower electricity prices / high per capita GHG emissions
- Lignite fleet generally of old age and low efficiency
  - plans for new generation capacity in several countries
- Small RES shares in some countries, but general trend is increase
  - change in operation of the energy system (already happening in Greece)

The Megalopolis co-firing case



Source: METKA

Megalopolis Unit IV	
Gross capacity	300 MWe
Commissioning	1992
Operation	Till 2032 (mine to run out)
Air pollution control devices	Wet FGD
Lignite consumption	~ 4.5 Mt/y
Lignite characteristics	LHV: 3.6 – 4.6 MJ/kg Water: 57.5 – 65.0 % ar Ash: 12.3 – 23.5 % ar Sulfur: 0.9 – 1.8 % ar

- Low reported efficiency (< 30% electrical)
- Will remain in operation for grid stability reasons
- Burns extremely poor quality lignite
- <u>For co-firing: utilize a local agro-industrial resource (olive kernels)</u>

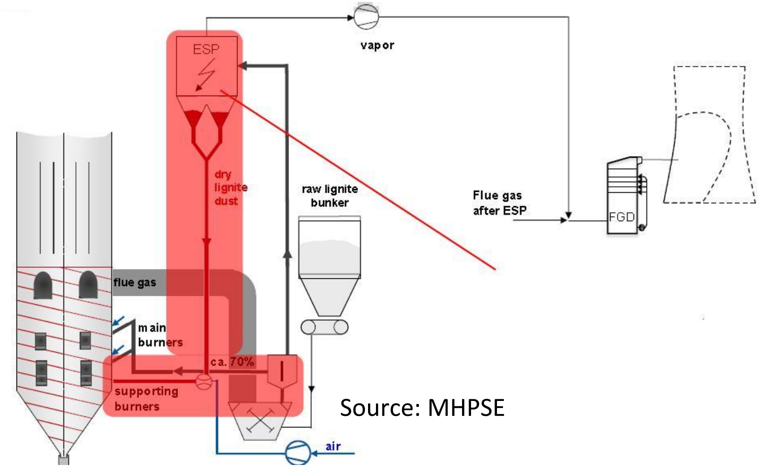
The Megalopolis co-firing case

Olive kernels

- Residue from olive kernel oil mills
- Volume of production depends on olive oil production
  - Estimated between 60,000 – 100,000 t/y
- Low moisture (< 12 – 15 % ar), high heating value, small particle size, ash ~ 5% db, chlorine content
- Currently used in heating applications (domestic sector, small-scale industrial uses, greenhouses, etc)
  - Reduced heat demands in southern Greece, faces competition from fossil fuels
  - Currently low cost (60 – 80 EUR/t at plant gate , comparable with lignite cost)
- Could support permanent co-firing applications ≥ 5% thermal share
- Cofiring could also reduce NO_x emissions

Technical implementation

- “Easy” solution”
  - mixing of biomass / lignite in the coal yard
- “Advanced” solution
  - modification of milling system (partial vapour separation)
  - Installation of new burners (also suitable for dry lignite)
  - Highest flexibility, potential to reduce the technical minimum load below the current limit
  - Also, partial substitution of oil as start-up fuel



Source: MHPSE

Co-firing in Western Macedonia: the lignite sector

The Agios Dimitrios PP, Source: PPC

The Meliti PP, Source: PPC

	Agios Dimitrios	Amyntaio	Kardia	Ptolemaida	Meliti
Gross Capacity (MWe)	2 x 300, 2 x 310, 1 x 375	2 x 300	2 x 300, 2 x 306	1 x 660	1 x 330
Commissioning	1984 – 1997	1987	1974 - 1981	> 2019	2003
Operation till	Unit V even after 2040	Operating in opt-out regime since 01.01.2016		> 2040	> 2040
Lignite consumption (estimated)	17 Mt/y	N/A	N/A	6 Mt/y	2.5 Mt/y
Lignite characteristics (average)	LHV: 5.6 MJ/kg Water: 56 % ar Ash: 12.8 % ar Sulfur: 0.4 % ar				LHV: 9.2 MJ/kg Water: 40 % ar Ash: 16.8 % ar Sulfur: 0.7 % ar

- Main lignite & electricity production region in Greece
- Five lignite-fired power plants
  - Decommissioning of older units in process, one new unit (Ptolemaida V) under construction
- Continental climate, high heat demand
  - DH systems supplied by heat from lignite plants
- Agricultural area, agricultural residues or energy crops interesting for co-firing

Co-firing in Western Macedonia: demonstration and research

- Co-firing demonstration (FP7 DEBCO Project)
  - Cultivation of cardoon (cynara cardunculus) on 400 ha
  - Harvesting of biomass and delivery to Kardia PP
  - Co-firing of cardoon / lignite at Unit I for 3 ½ days
- Additional research activities
  - Detailed fuel characterization
  - Co-firing tests at semi-industrial scale facility (500 kWth)
  - CFD modeling of the furnace
- Conclusions
  - Agrobiomass co-firing is technically feasible, without major operational problems
  - Potential to reduce NO_x emissions by up to 10%
  - Economically attractive for plant operators with the current level of feed-in tariff
  - Issues: low yield of cardoon in first years of cultivation, business model followed for biomass supply (several small-scale farmers, one large utility, intermediate entity lacking), land area required for cardoon cultivation
  - Investigations of other biomass supply options (straw, imported wood pellets)


Καθαρή ενέργεια από την αγριαγκινάρα

Η αγριαγκινάρα έχει τριπλάσια θερμογόνο δύναμη από τον λιγνίτη. Συγκεκριμένα, 4.500 θερμίδες ανά κιλό έναντι 1.260 θερμίδων ανά κιλό

4.000 στρέμματα καλλιεργήθηκαν

1.600 τόνοι η συγκομιδή (αναμένονταν 5.500 τόνοι)

€ 51 τον τόνο αγοράζει την αγριαγκινάρα η ΔΕΗ

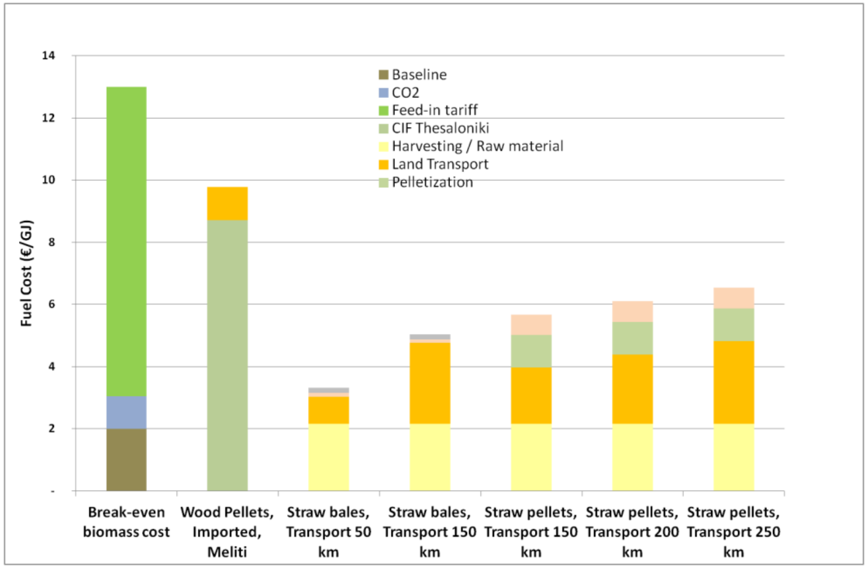
€ 200 ανά στρέμμα ήταν η επιδότηση από τη νομαρχία

1,5 έως 2 τόνους αγριαγκινάρα δίνει ένα στρέμμα σε φυσιολογικές συνθήκες

4 Επιστήμονες του Ινστιτούτου Τεχνολογίας και Εφαρμογών Στερεών Καυσίμων (ΙΤΕΣΚ) μετρούν τη θερμοκρασία και τα ποσοστά οξυγόνου όταν το μείγμα φθάνει από την ταινία στον λέβητα

Co-firing in Western Macedonia: straw supply for Meliti PP

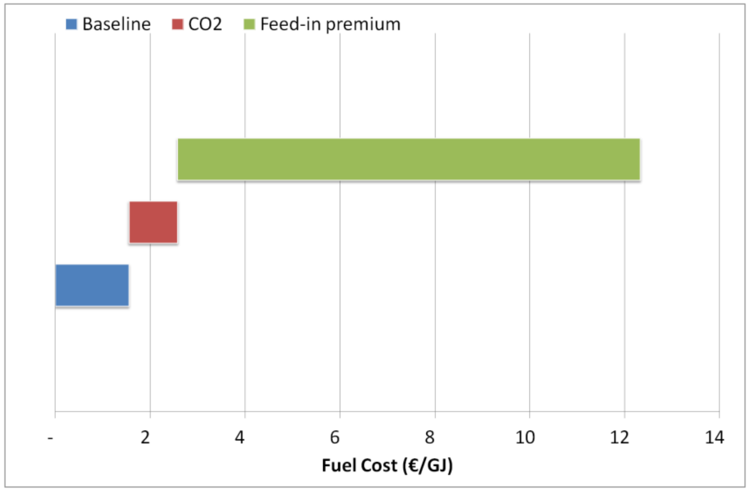
- Sourcing of straw
  - 130,000 – 150,000 t/y are required for 10% co-firing
  - Requires transport distances of up to 300 km
  - Investigation of sourcing options: bales vs pellets
  - Calculation of fuel cost and GHG savings
- Infrastructure requirements
  - Agricultural machinery for straw harvesting / baling
  - Storage areas for bales / pellets
  - Pellet plants (up to 9 units with capacity of 3 t/h)



- Conclusions
  - Weighted fuel delivery cost around 6 EUR/GJ
  - Cheaper option than imported wood pellets (due to high quoted CIF price for Thessaloniki)
  - Little difference in fuel cost between pellet and bale options
  - Economically feasible even with reduced feed-in tariff price

The Šoštanj Unit 6 co-firing case: some considerations

Šoštanj Unit 6	
Net capacity	545.5 MWe
Yearly operation	6,500 hours
Lignite consumption	~ 2.9 Mt/y
Lignite characteristics	LHV: 10.3 MJ/kg
Emissions factor	1.061 kg CO_2 / kg lignite
Net efficiency	42.6%
For 10% biomass thermal share: ~ 3 mil GJ/y (corresponding to 182 kt of wood pellets)	



Biomass "break-even" fuel cost

- Baseline: Lignite cost + co-firing investment retrofit (300 EUR/kWe)
- CO_2: Savings from CO_2 emissions reduction (10 EUR/t)
- Feed-in premium: 82.43 EUR/MWhe for biomass co-firing in Slovenia

Considerations

- Assuming delivery costs to Koper as in Rotterdam (140 EUR/t) and transport costs to Šoštanj (20 EUR/t), break-even for imported wood pellets with ~ 75% reduced feed-in tariff
- Investigation of local biomass resources with S2Biom toolset

Conclusions / Remarks

- Biomass co-firing is a well demonstrated, easy to implement technology for the reduction of GHG emissions for coal-fired power plants
- SEE countries rely mostly on lignite-fired power plants: the adoption of co-firing has certain peculiarities compared to applications in Western Europe
- Technical compatibility even with "difficult" biomass types has been demonstrated
- Major issues: biomass availability / financial support
- Imported wood pellets are an option but are they acceptable?
- Investment in other infrastructure required: e.g. port facilities, storage areas, pellet plants….
- Co-firing is possible even with reduced feed-in tariffs / premiums
- Is there enough local biomass to implement co-firing in large-scale? How much does it cost? → **Further investigations using the S2Biom toolboox**
- Is co-firing considered as option in RES financial support mechanisms? Under what conditions?
- Other options: biomass as start-up fuel / partial firing support / reduction of minimum load → substitution of oil, not lignite

- **For stakeholders interested in a specific power plant case study: contact us for further information!**

Thank you for your attention!

www.s2biom.eu

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