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ENERGY

Overview of global experience with biomass co-firing and coal to biomass conversions

Technology, fuel supply, byproducts and regulation, economics

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IEA Bioenergy NEDO METI 経済産業省 Ministry of Economy, Trade and Industry RENEWABLE ENERGY INSTITUTE

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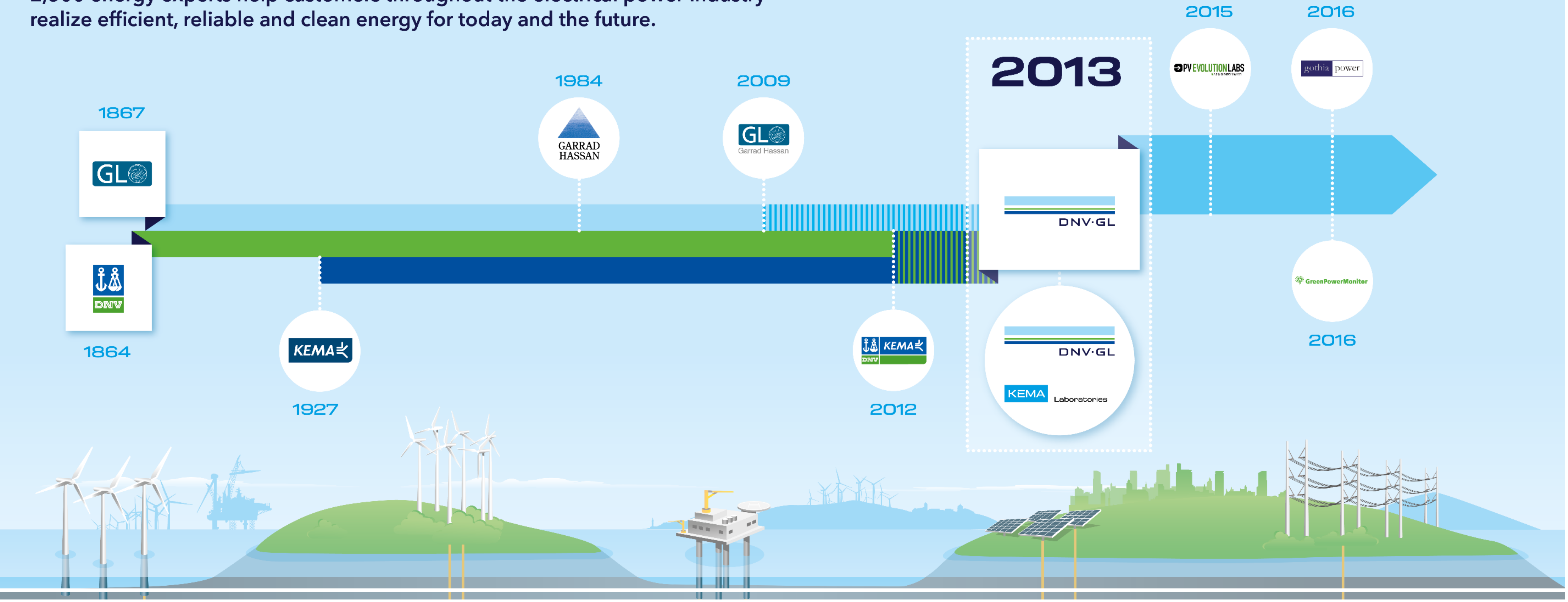

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Biomass (co-)firing in power generation

Sustainability targets and CO_2 reduction – the role of biomass

POLICY MAKERS AND REGULATORS

(National) targets, incentives

MARKETS

Power market, alternative sustainable technologies, dispatchable power > **BIOMASS**

UTILITIES

Business case, implementation

Biomass co-firing and full conversion

What is considered high percentage co-firing ?

- Is it >**10%** …
- or is it >**30%** …
- or is it >**50%** …
- or is it >**80%**

Full conversion is the limit

Bio-CCS as a CO_2 sink

Fuel coal to biomass conversion

TECHNOLOGY & EXPERIENCES

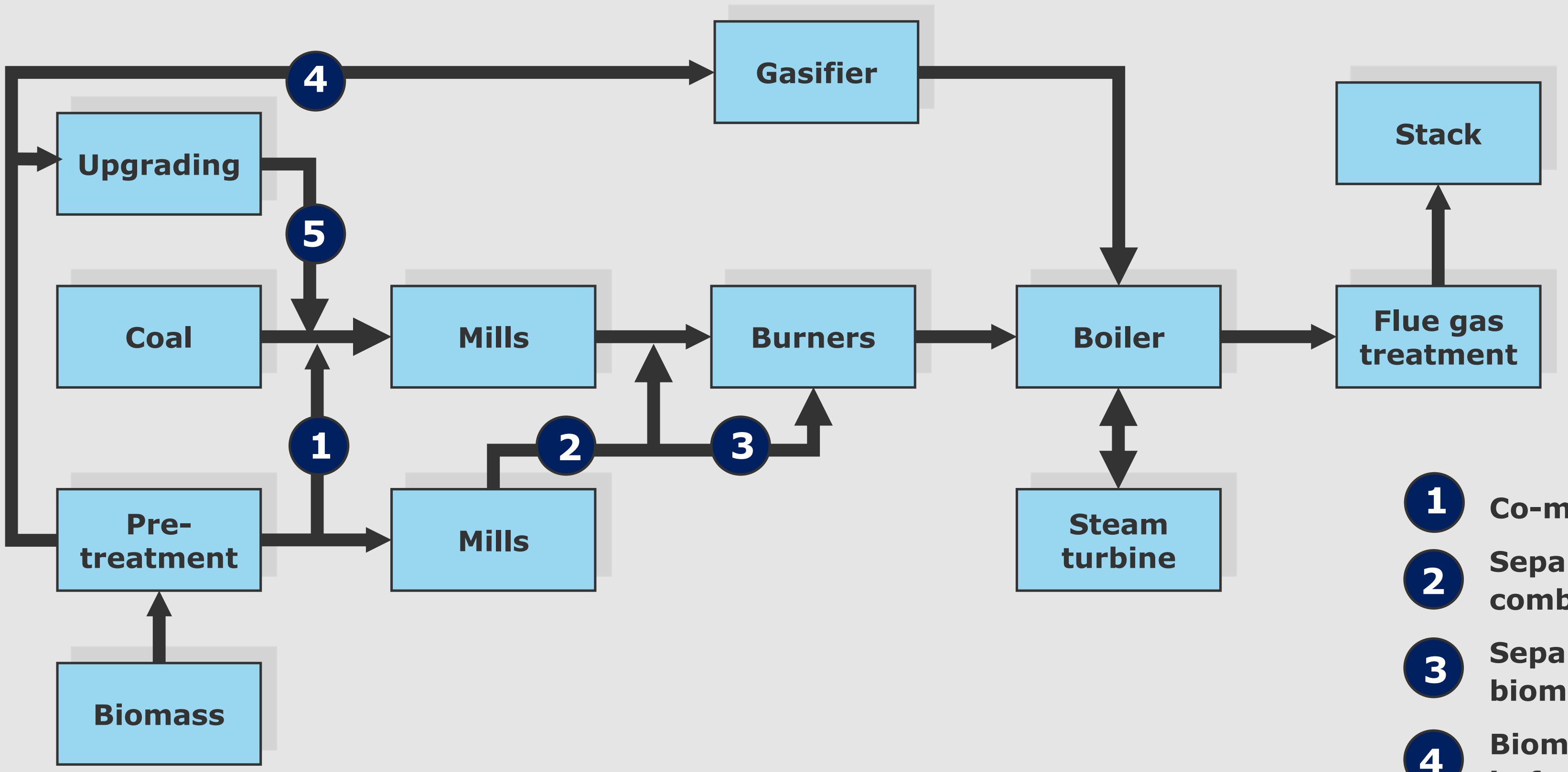
FUEL SELECTION

REGULATIONS & BY-PRODUCTS

ECONOMICS & CO_2 FOOTPRINT

Technology and experiences

Applied biomass co-firing routes



1. Co-milling of biomass with coal
2. Separate milling, injection in pf-lines, combustion in coal burners
3. Separate milling, combustion in dedicated biomass burners
4. Biomass gasification, syngas combusted in furnace boiler
5. Co-milling of torrefied/steam exploded biomass with coal

Each co-firing route has its own (unique) operational requirements and constraints and specific demands on the fuel quality

Experiences with biomass co-firing and repowering

UNITED KINGDOM	▪ Drax, Ferrybridge, Fiddler's Ferry, Tilbury, Ironbridge, Lynemouth ▪ Various fuels: wood, crops, residues
DENMARK	▪ Avedore, Amager, Ensted, Studstrup ▪ Wood chips, wood pellets, straw(pellets)
BELGIUM	▪ Rodenhuize, Les Awirs, Ruien ▪ Mainly wood-based fuels
THE NETHERLANDS	▪ Geertruidenberg, Rotterdam, Nijmegen, Borssele ▪ Wood pellets, agro- and industrial residues, meat and bone meal
CANADA	▪ Atikokan, Thunder Bay ▪ Wood pellets, steam explosion pellets

Power plant components affected by biomass (co-)firing

STORAGE	▪ Piles ▪ Bunkers
LOGISTICS	▪ Conveyors ▪ Feeders ▪ Mills
STEAM PLANT	▪ Burners ▪ Furnace section ▪ Convection section
FLUE GAS	▪ Flue gas cleaning system ▪ Stack

Power plant components affected by biomass (co-)firing

STORAGE

- Dedicated storage or storage on coal yard?
- Dust emissions and explosion risks!
- Odor…

LOGISTICS AND MILLING

- Coal conveyors suitable?
- Low co-firing: pre-mixing and co-milling
- High co-firing: modified or dedicated mills/classifiers
- Dust explosion risks
- Primary air temperature

STEAM PLANT (PULVERIZED FUEL BOILER)

- Particle size > combustion
- Deposition on burners; slagging and fouling
- Soot blowers, water jets, sonic horns, explosive cleaning
- Corrosion risks

FLUE GAS CLEANING

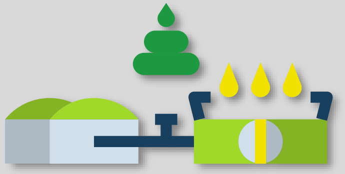
- SO_2 and dust (no major issues)
- No_x
  - ✓ dependent on fuel
  - ✓ SCR deactivation

Fuel selection

Fuel selection criteria

Low co-firing rate or EFLH	High co-firing rate or EFLH
Low investments	Higher investments
More expensive fuel	Cheaper fuel

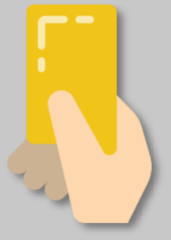
ELIGIBILITY OF BIOMASS FUEL



Meeting subsidy requirements

- Sustainability criteria
- Additional requirements

REGULATORY AND PERMIT ASPECTS



Biomass waste?

- Emission requirements

Biomass pre-treatment and upgrading

Steam explosion pellets
(courtesy Arbaflame)

Torrefied pellet production
(courtesy Torrcoal)

Wood pellet production
(courtesy Enviva)

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Choose your co-firing fuel

	Wood chips	Wood pellets	Torrefaction pellets	Steam explosion pellets	Coal
Moisture content (% wt)	30 – 45	7 – 10	1 – 5	? - 11	10 – 15
Calorific value (MJ/kg)	9 – 12	15 – 16	20 – 24	17 – 19	23 – 28
Volatiles (% db)	70 – 75	70 – 75	55 – 65	70 – 80	15 – 30
Fixed carbon (% db)	20 – 25	20 – 25	28 – 35	17 - ?	50 – 55
Bulk density (kg/l)	0.2 – 0.25	0.55 – 0.75	0.75 – 0.85	0.65 – 0.78	0.8 – 0.85
Energy density (GJ/m³)	2.0 – 3.0	7.5 – 10.4	15.0 – 18.7	11.0 – 15.0	18.4 – 23.8
Dust	Limited	Average	Average/high	Average/high	Limited/average
Hydroscopic properties	Hydrophilic	Hydrophilic	Hydrophobic	Hydrophobic	Hydrophobic
Biological degradation	Yes	Yes	No	Potentially	No
Milling requirements	Special	Classic/special	Classic	Classic	Classic
Handling properties	Special	Special/easy	Easy	Easy	Easy
Transport cost	High	Average	Low	Low/Average	Low

Regulatory and by-products

Meeting emission limits

Dependent on local regulations and emission standard

ESP/baghouse filter

- ash content
- resistivity

FGD

- low SO_2, high HCI load

SCR

- deactivation
- use of coal fly-ash

Co-firing of

- clean wood: limited impact on emissions
- specific types of biomass: potential impact on emissions

What about the ashes (IEA Task 32 study)

Application	Requirements/challenges
Disposal/landfill	Minimum standard (Directive 2008/98/EC) and preferred solution in many cases
Use in forestry	Leaching of heavy metals
Fertilizer/soil amendment	Leaching of heavy metals, strict legislation
Addition to compost	Up to 3-5%, REACH registration in EU
Cement, raw meal constituent	Requirements in bi-lateral contracts
Cement and concrete fillers	EN 450 standard applicable in EU
Asphalt concrete filler	Dependent on technical product regulation
Underground mining	Particularly for bottom ashes
Civil engineering, road construction	Particularly for bottom ashes

Economics and carbon footprint

Costs of co-firing and repowering (for illustration only)

Imaginary case:
100 MW_e, 40% efficiency, 5,000 equivalent full load hours

Additional costs from co-firing:

- Fuel costs
- Capital costs
- O&M costs

Revenues from co-firing:

- CO_2 credits
- Subsidies

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Case: 100 Mw_e, 40% efficiency, 5,000 equivalent full load hours

GENERAL DATA

Annual power production:

500,000 MWh/a

Annual fuel consumption:

4.5 PJ/a

INCREASED FUEL COSTS (co-firing)

Coal:

3 EUR/GJ

Wood pellets:

9 EUR/GJ

Δ Fuel costs:

6 EUR/GJ

Annual Δ fuel cost:

27 MEUR/a

Δ Specific fuel costs: 54 EUR/MWh

Case: 100 Mw_e, 40% efficiency, 5,000 equivalent full load hours

CAPITAL EXPENSES	O&M COSTS	TOTAL CAPITAL AND O&M
200 kEUR/MW_{th} installed > 50 MEUR	6% of investment costs: 3 MEUR/a	8 MEUR/a
Capital expenses: 5 MEUR/a (linear depreciation, 10 years)		Δ Specific capital and O&M costs: 16 EUR/MWh

Case: 100 Mw_e, 40% efficiency, 5,000 equivalent full load hours

Revenues

- CO_2 emission reduction: 0.5 Mt/a
- CO_2 @ 10 EUR/t: 5 MEUR/a (current)
- Δ specific costs = -10 EUR/MWh

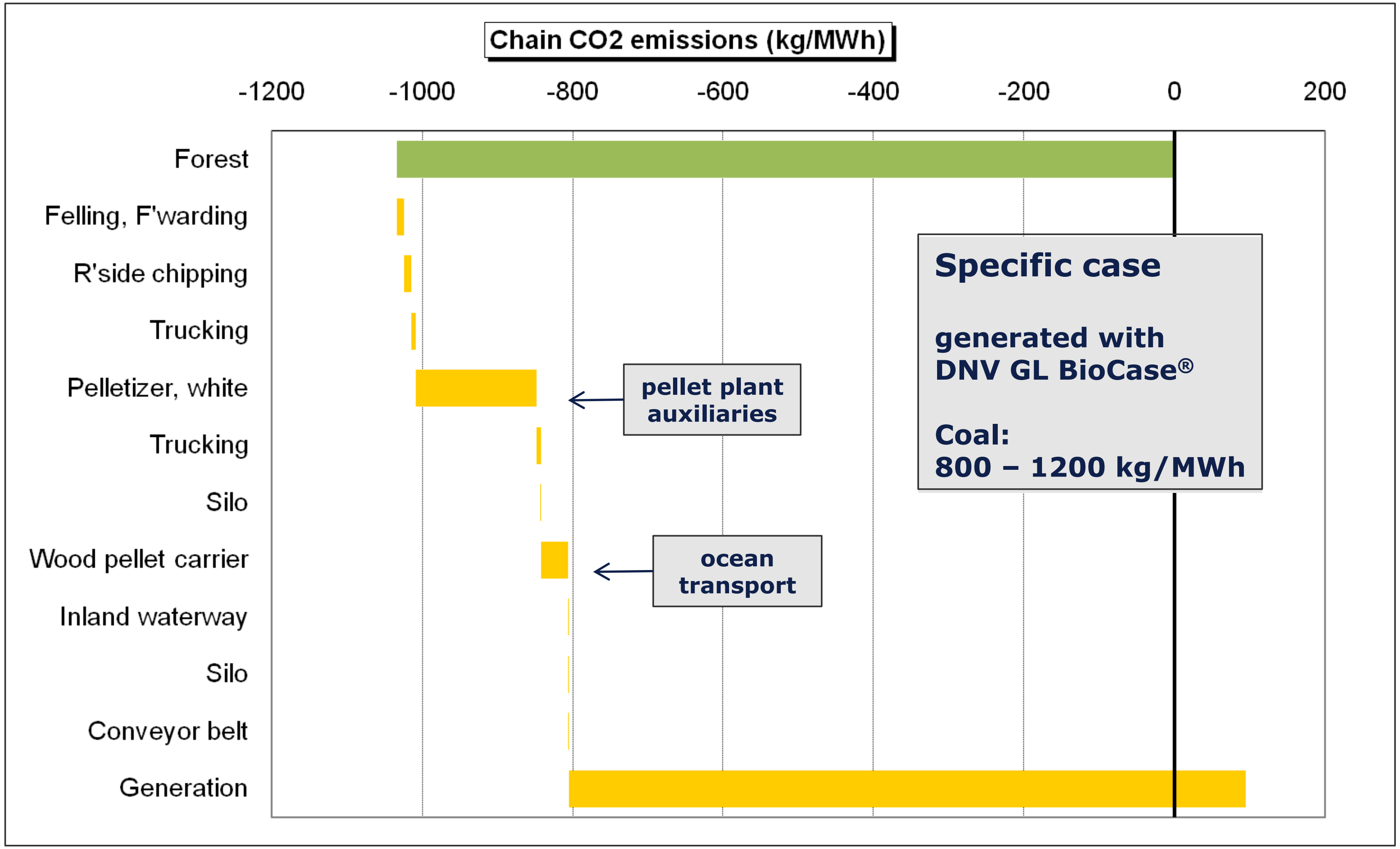
Δ overall costs = 54 + 16 - 10 = 60 EUR/MWh (8,000 JPY/MWh)

Typical range in detailed business cases: 50 - 80 EUR/MWh → minimum subsidy level required

Co-firing of waste streams:

- Low or negative price
- Limited co-firing rate; additional emission standards

Supply chain (CO_2 per MWh of electricity generation)



Conclusion

- Biomass co-firing and full coal to biomass conversion are proven technology
- Biomass fuels
  - ✓ white wood pellets commodity fuel
  - ✓ strong developments on processed biomass
  - ✓ opportunity fuels and biomass waste streams
- Biomass selection based on required co-firing rate and EFLH
- Impact on emissions to be addressed case by case
- Utilization of ashes requires further development
- Economics: prices of biomass, investments, subsidies, CO_2 price
- Carbon footprint: discussions regarding sequestration in forests

Biomass can provide dispatchable capacity to support intermittent solar and wind power

Thank you for your attention

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