

Existing power plants are part of the future solution – conversion as a bridge to climate neutrality

Fuel switch concepts

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1. Introduction

2. Fuel Switch Concepts

3. Technical Implementation

4. Economic Analysis

5. Summary & Conclusion

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Since 2023, freelance engineer specializing in consulting, business development, and bid & project management in plant and mechanical engineering in the energy sector.



INTRODUCTION

1. Introduction

Initial situation

- The energy transition requires new, flexible power plant capacities – **new federal law and introduction of capacity market mechanisms.**
- Planned new power plants predominantly as combined cycle gas turbine (CCGT) plants and peaker plants (OCGT) – **auctions in September & December 2026 in Germany**
- **Only short operating times expected:** economical operation shows major challenges
- Modern coal-fired power plants (USC units) are threatened with closure by at the latest 2033 (Germany), followed by demolishing and disposal.

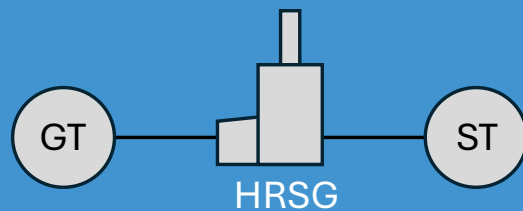
Alternative option to new construction

- **Conversion of suitable coal-fired power plants** to natural gas, and later possibly to hydrogen.
- **Additionally: Gas turbine topping** - Gas turbine replaces the primary air fan and supplies combustion air as well as additional electrical power
 - **Increase in plant output and efficiency of the coal-fired power plant**
 - **Quick start capability, grid support**

FUEL SWITCH CONCEPTS

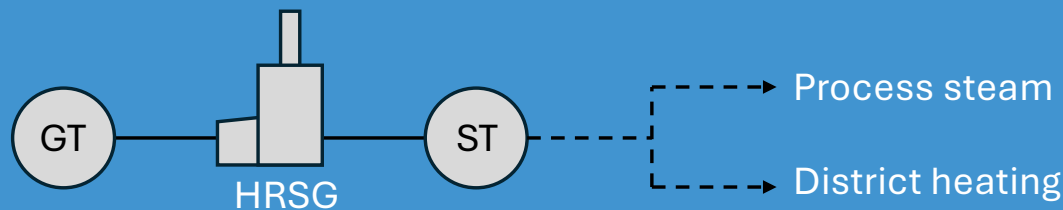
2. Fuel Switch Concepts: Construction of new CCGT units

1. New combined cycle power plants (pure electricity production), possibly reuse of existing steam turbines after retrofit.



Modern power classes approx. 550 MW to approx. 900 MW; efficiency in new condition and at 100% load: approx. **60% to max. 63%** (net)

2. New combined cycle gas turbine (CCGT) plants / combined heat and power (CHP)



Modern power classes approx. 600 MW to 900 MW
fuel utilization rates ~ 85% net (depending on the electricity/heat ratio)

Abbreviations:

GT Gas turbine / ST Steam turbine

HRSG heat recovery steam generator / SG steam generator (coal-fired before conversion)

Note: Performance and efficiency must be investigated on a case-by-case basis

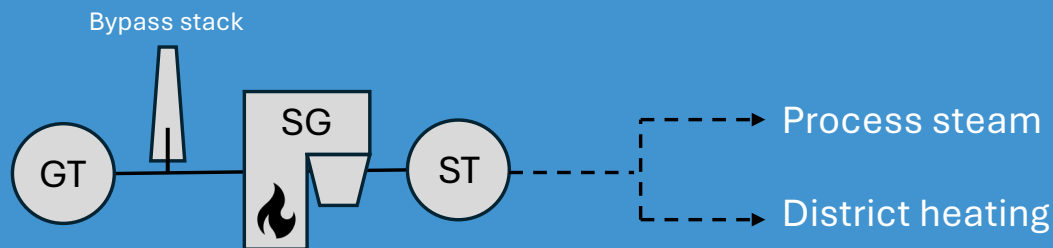
2. Fuel Switch Concepts: Conversion of existing coal units

3. Existing (coal) plants converted to natural gas / H₂



Power classes up to approx. 1,100 MW depending on the existing system; net efficiencies after conversion (pure electricity production, 100% load) **approximately 45% to 50%, depending, for example, on steam data**; fuel utilization rates approximately 70% (net, depending on the ratio electricity / heat)

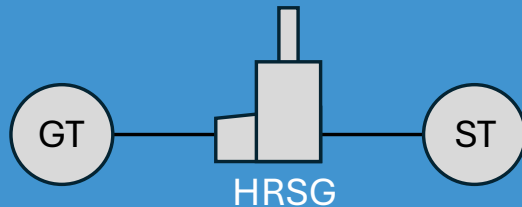
4. Existing (coal) plants converted to natural gas / H₂ + new topping GT



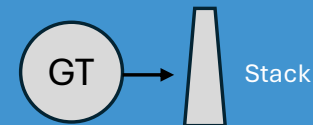
Modern power classes up to approx. 1,300 MW; net efficiencies approx. 53-56% for modern USC units; fuel utilization rates ~ 70% net (depending on the ratio electricity/heat)

2. Fuel Switch Concepts: Conversion of existing coal units

5. New GTCC (electricity production) and Grid Support System

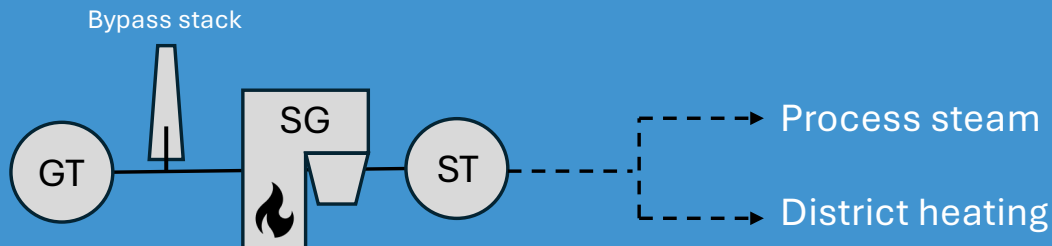


Modern CCGT : approx. 550 MW to approx. 900 MW
Efficiency (new) and 100% load: approx. 60% to max. 63% net



Grid security (open cycle): **approx. 40 MW to approx. 300 MW** -
Efficiency levels in new condition and at 100% load: approx. **40%** net

6. Existing (coal) plants converted to natural gas / H₂ + new topping GT



Modern power classes up to approx. 1,600 MW - Efficiencies (new) at 100% load: approx. 53-56% net
Grid support: GT oversizing e.g. approx. 200 MW (1 GT)
Waste heat recovery during GT rapid start via bypass stack for preheating the steam section is possible; thus reducing start-up losses.

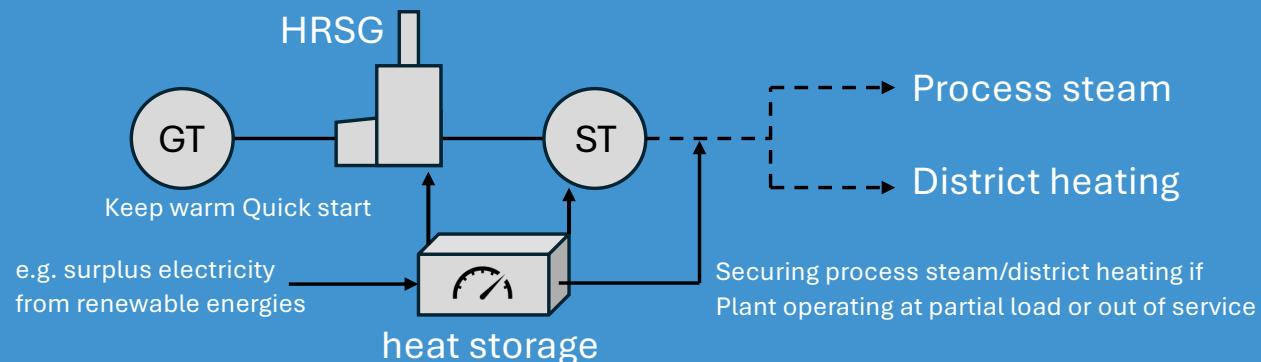
FUEL SWITCH CONCEPTS

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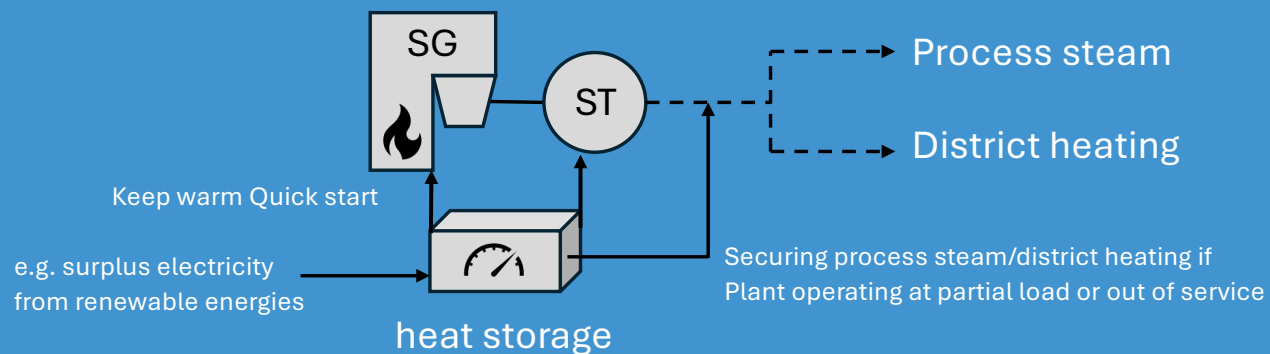
Integration of Heat Storage Systems

2. Fuel Switch Concepts: Integration of Heat Storage Systems

2B. New combined cycle gas turbine (CCGT) plant with combined heat and power (CHP)

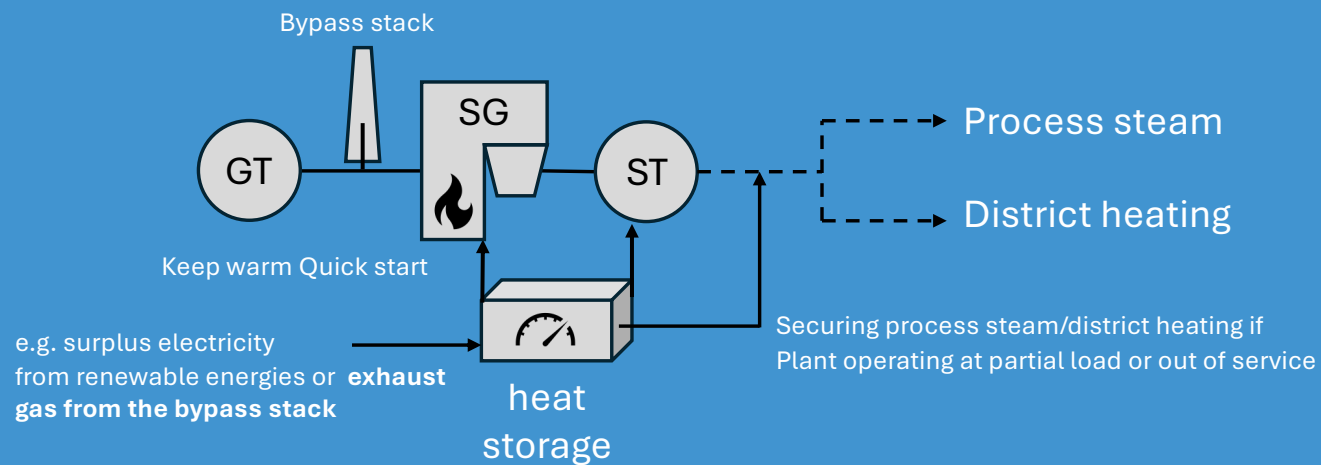


3B. Existing unit (coal) converted to natural gas / H₂



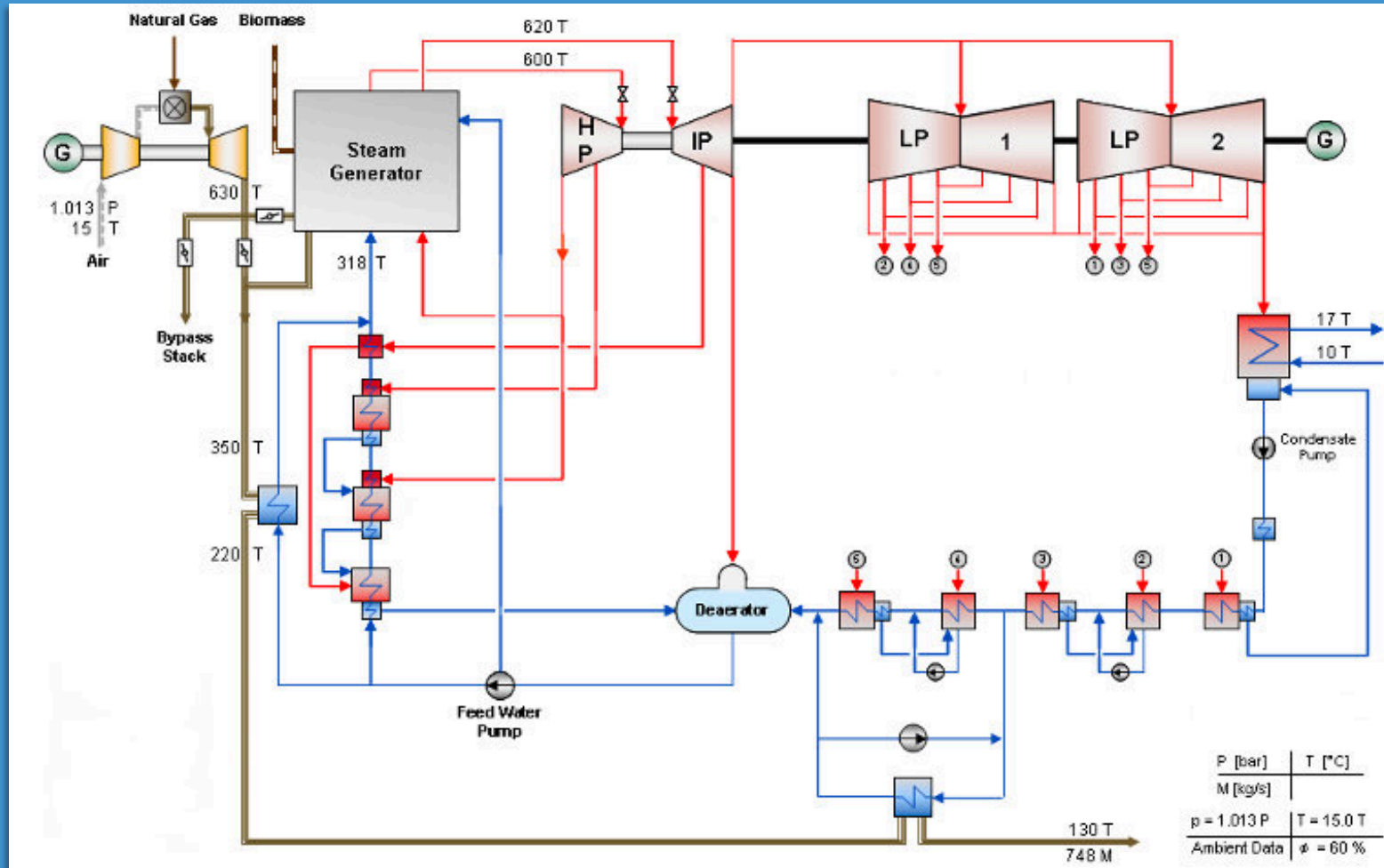
2. Fuel Switch Concepts: Integration of Heat Storage Systems

4B. Existing plant (coal) converted to natural gas/ H₂ and topping gas turbine

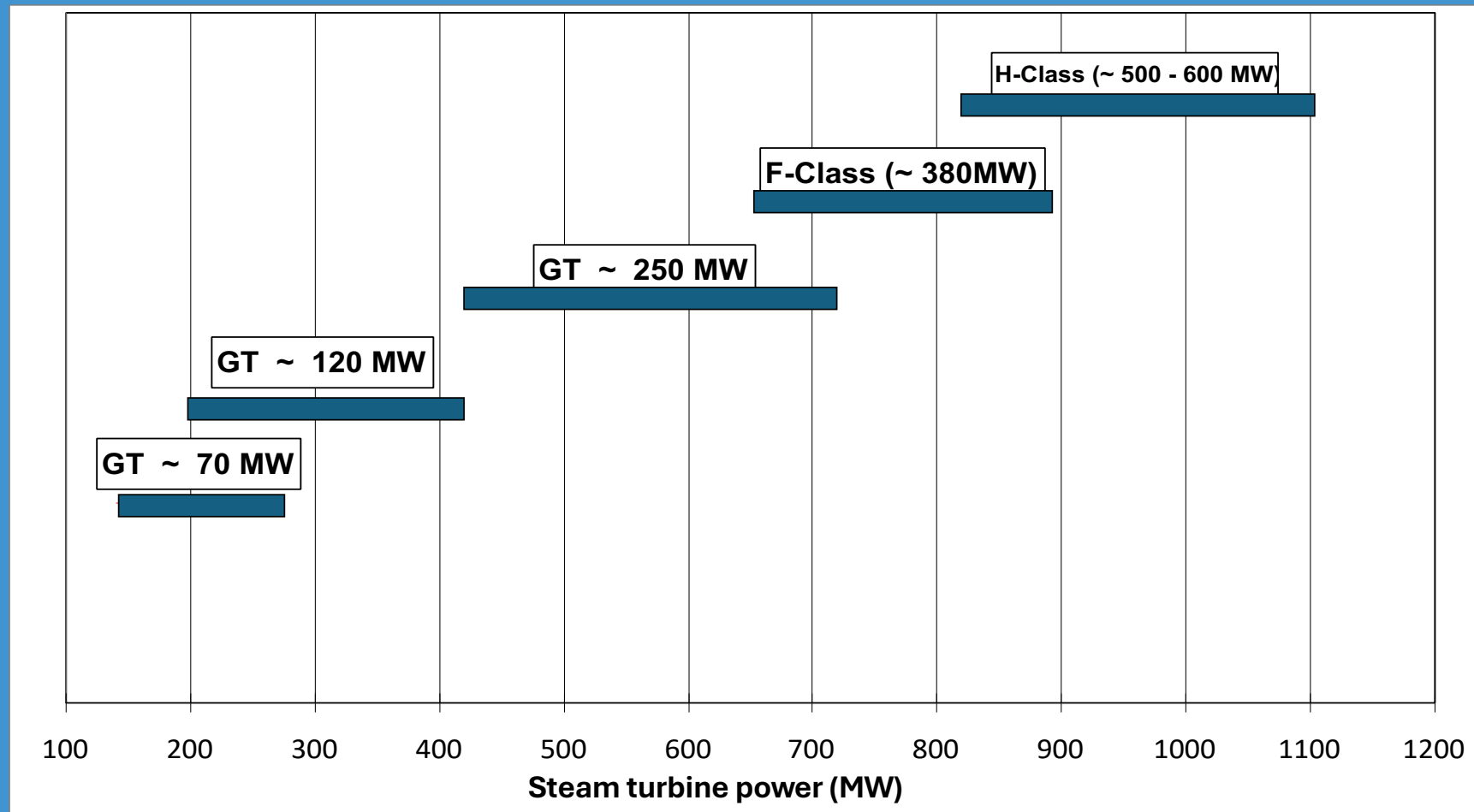


Proposed concept — FUEL SWITCH WITH TOPPING GT

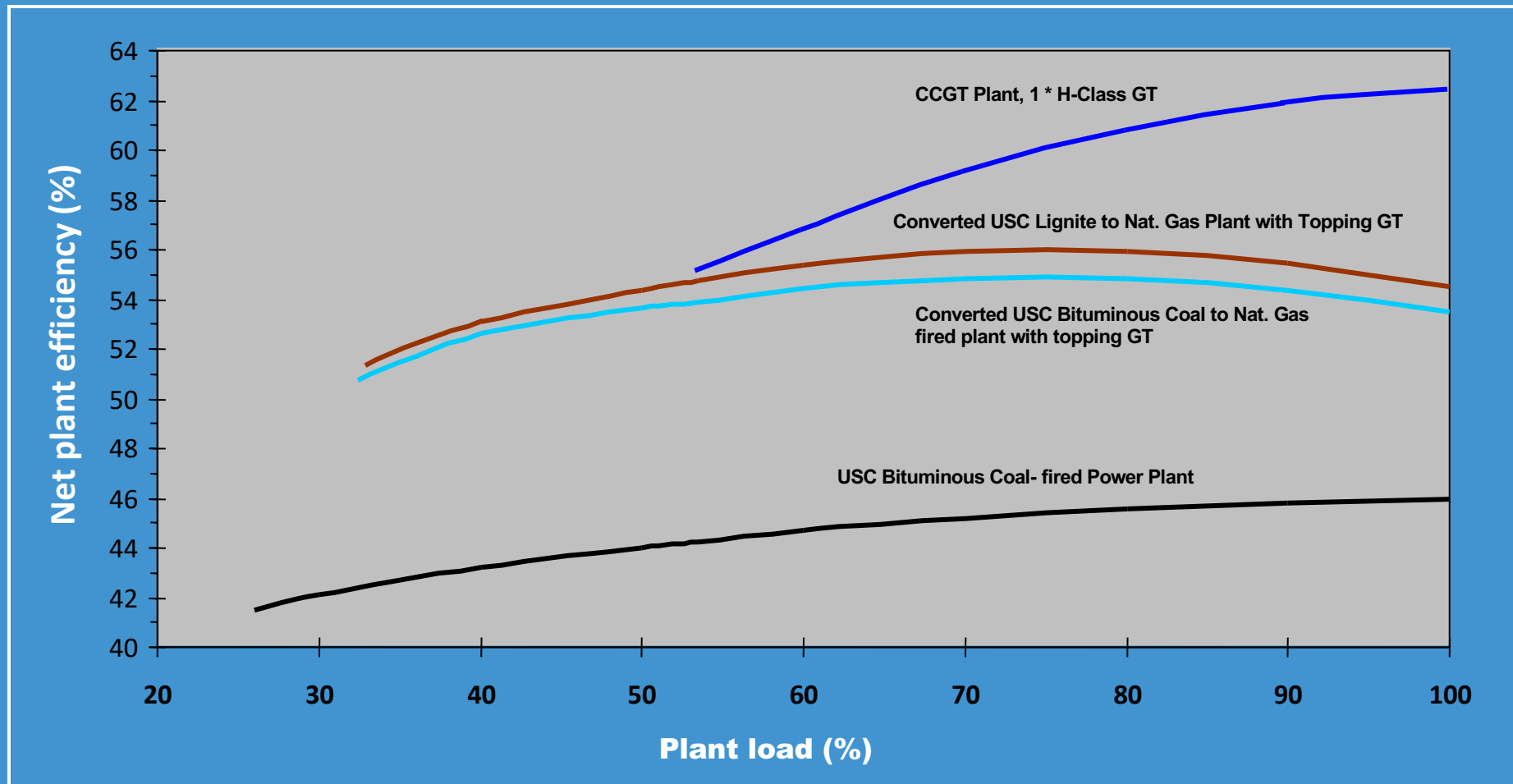
2. Fuel Switch Concepts: Example: Plant diagram with topping gas turbine



2. Fuel Switch Concepts: Selection diagram: GT output vs. ST output



2. Fuel Switch Concepts: Net plant efficiency vs. plant load



2. Fuel Switch Konzepte: Comparison Plant Concepts

	Electrical net output (electrical power)	Net efficiency (electrical power)	Net fuel utilisation (CHP operation)
	MWe	%	%
New CCGT-Plant with 1 GT	800 - 900	62 - 63	
New CCGT-Plant, 1 GT, CHP operation	800 - 900	62 - 63	up to approx. 85 (depending on heat production)
Existing unit (USC-Coal) converted to gas/H ₂	750 - ~ 1.050	~ 50	up to approx. 70
Existing unit (USC-Coal) converted to gas/H ₂ with topping GT (Performance depending on existing unit)	1.200 – 1.600	~ 57	up to approx. 70 (GT only higher figure)
	Data refers to modern 500-600 MW gas turbines (smaller gas turbines also possible)		
	Heat storage equipment is not considered		

TECHNICAL IMPLEMENTATION

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**Price development –
Cost estimate – Conversion Schedule**

3. Technical Implementation: Contract Price Development CCGT (2019-2025)

country	power plant	MWe performance	# lines	Year	EPC Price (M Euro)	Euro/kWe
Greece	Agios Nikolaos	826	1	2019	€322	€390
Poland	Dolna Odra	1,366	2	2020	€1,126	€824
Italy	Tavazzano	800	1	2021	400 €	500 €
Poland	Grudziadz	560	1	2022	€470	€839
Poland	Adamov	560	1	2024	€636	€1,136
UK	Teeside	742	1	2025	955 €	€1,287
Poland	Kozienice	1,336	2	2025	€1,499	€1,122

Source: Own projects or press reports/Internet

3. Technical Implementation: CAPEX Estimate for a new 800 MW CCGT Unit

Component / System	Relative share of total investment	Cost at 900 €/kW scenario	Cost at 1,100 €/kW scenario
GT/ST + Generator + Auxiliaries	38%	274 MEuro	334 MEuro
HRSG	13%	94 MEuro	106 MEuro
ET/LT	11%	79 MEuro	97 MEuro
BoP (incl. SCR), pipelines, cable trays	15%	108 MEuro	123 MEuro
Construction (foundations, buildings, roads, lightning protection...)	12%	86 MEuro	106 MEuro
Assembly, commissioning, testing, HSE, documentation	11%	79 MEuro	114 MEuro
	100%	720 MEuro	<u>880 MEuro</u>

3. Technical Implementation: Planning and Implementation

1. **Permit requirements:** Change of use, environmental and operating permits
2. **Planning for the possible dismantling/demolishing of coal-related facilities**
3. **Boiler/combustion system refurbishment or replacement:** including conversion/replacement of burners, boiler geometry modification
4. **Structural modifications:** including new GT engine house, bypass stack
5. **Assembly and integration of gas turbine and bypass stack**
6. **Steam generation and conditioning:** Checking steam lines, feedwater and condensate systems
7. **Gas supply:** gas connection / hydrogen supply / gas metering / safety fittings ...
8. **Auxiliary systems**
9. **Electrical / Control and Automation Integration**

3. Technical Implementation: Time Required for Pre-planning and Implementation

FUEL SWITCH

Preliminary planning / permitting and change of use / engineering:

approx. 15 months

Preparation / procurement

approx. 9-12 months

Conversion / IBS / Tests (during block shutdown)

approx. 8 months

Typical total duration

approximately 32 months

+ INTEGRATION “Gas turbine” (depending on GT availability) + 12-18 MONTHS

NEW CONSTRUCTION OF CCGT AND OCGT PLANTS

OCGT / Peaker : - currently: typical total duration **up to 36 months**

- GT availability is time-critical

CCGT: - currently: typical total duration **up to >72 months**

- Availability of major components is critical (gas and steam turbines, generators, transformers), some items will only be available from >2028 onwards; slot reservation is required

3. Technical Implementation: CAPEX Estimate for the Conversion of Coal to Gas

work package	Costs [million €]
Conversion of an 800 MW coal-fired power plant to gas, including the necessary dismantling work; H ₂ Ready	< 100
Integration of a 500 MW gas turbine/generator and auxiliary systems	approx. 285
Gas connection, exhaust gas purification, bypass chimney	75
Engineering, permits, PM	40
TOTAL (approx.)	<u>≤ 500</u>

Considering the aforementioned CAPEX a SPECIFIC CAPEX of **385 Euro/ kWe** results for a plant capacity of approximately **1,300 MWe**. In contrast, the specific CAPEX is **1,250 Euro/ kWe** for a new CCGT unit with a capacity of **800 MWe**.

✓ **Specific CAPEX is reduced by approx. 70%**

ECONOMIC ANALYSIS

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Comparison:

800 MW CCGT vs. 1,270 MW conversion incl. topping GT

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NPV Analysis – Levelized cost of electricity – CO₂ Emissions

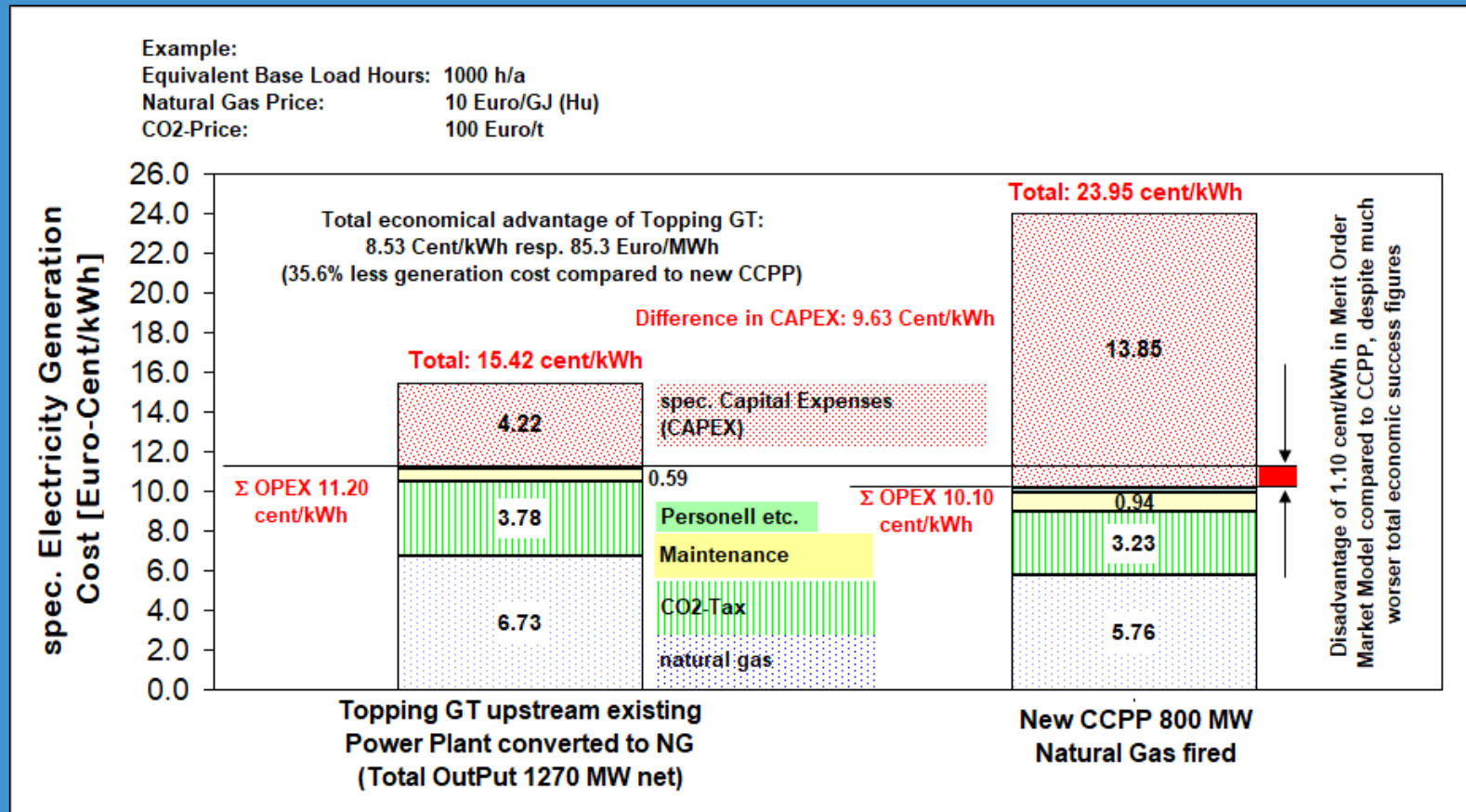
4. Economic analysis: Net present value analysis

Natural Gas Price: 10,0 Euro/GJ CO ₂ -Price: 100 Euro/t						
equiv. Full Load Hours	Minimal Electricity Sales Price for CCGP reaching break even		Results for Topping-GT + Existing Plant 1270 MW			Result for new CCGT 800 MW
			Net Present Value	Rate of Return	Pay-Back Period	Net Present Value (Break Even) Rate of Return: 8.0 %, Pay-Back Period: 25 yrs
h/a	Cent/kWh	Euro/MWh	Mill. Euro	%	Years	Mill. Euro
1000	22,35	223,50	883,1	22,5	4,3	0
2000	15,67	156,70	726,2	20,4	5,0	0
3000	13,45	134,50	570,0	18,2	6,0	0
4000	12,33	123,30	413,2	15,7	7,5	0

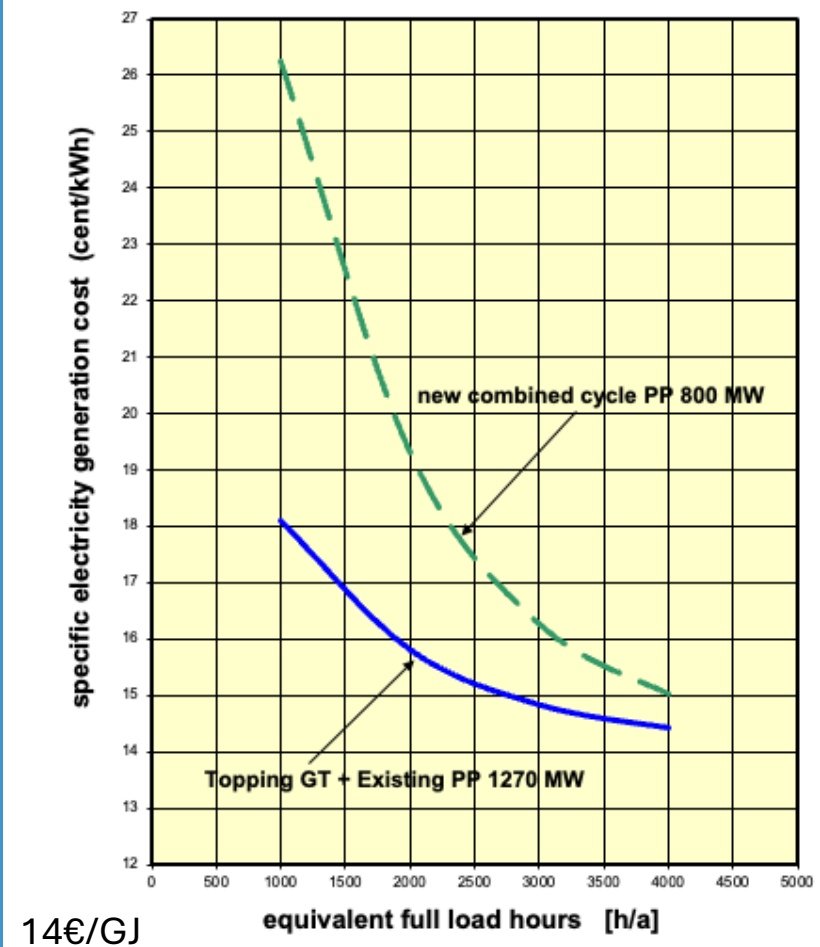
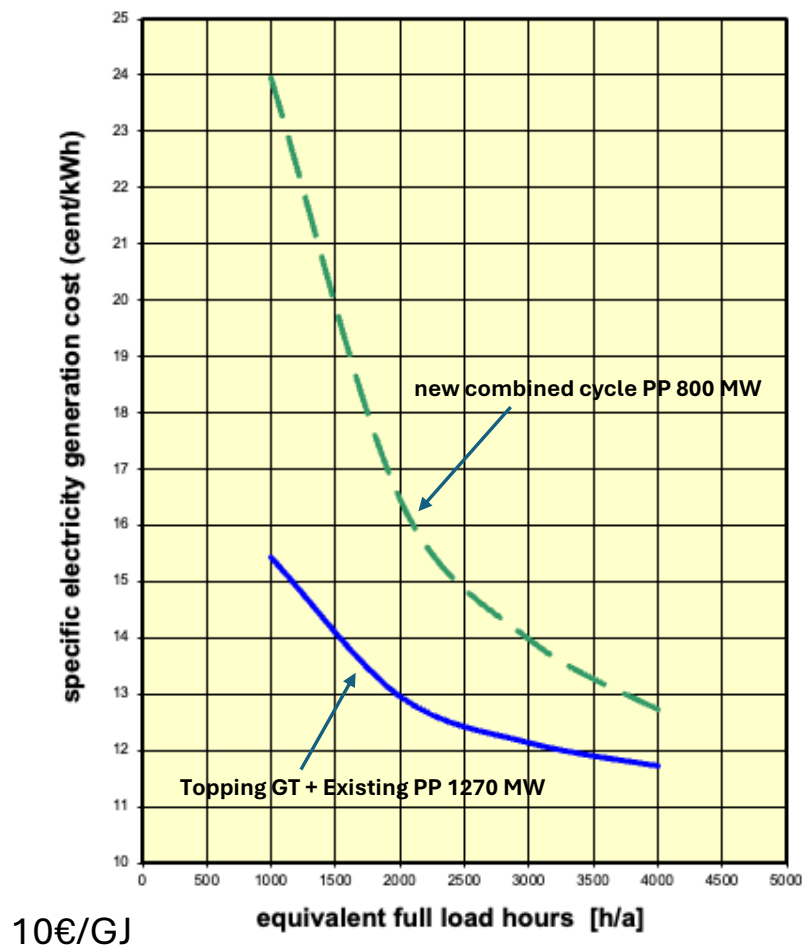
Natural Gas Price: 14,0 Euro/GJ CO ₂ -Price: 100 Euro/t						
h/a	Cent/kWh	Euro/MWh	Mill. Euro			Mill. Euro
1000	24,66	246,60	843,2	22,0	4,5	0
2000	18,46	184,60	668,1	20,9	5,0	0
3000	15,75	157,50	449,5	16,3	7,1	0
4000	14,64	146,40	252,5	13,0	10,1	0

1. Despite assumptions against the GT topping option, the NPV values shown (profit over 25 years as present value) are always higher for this variant.
2. Future market models (capacity market) and consideration of e.g. partial load operation modes favor the NPV type with topping GT and the existing but converted plant.

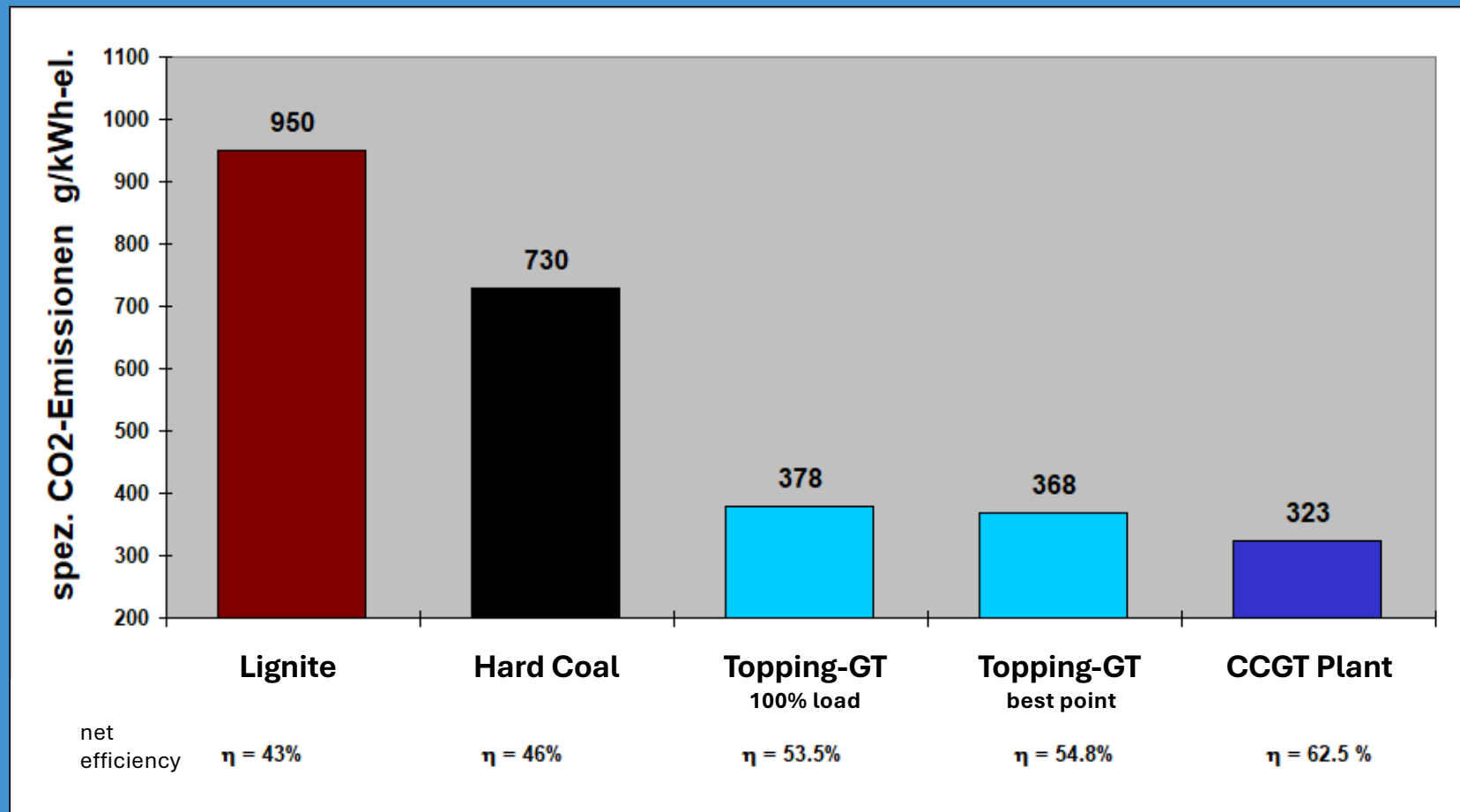
4. Economic analysis: Comparison of electricity generation costs



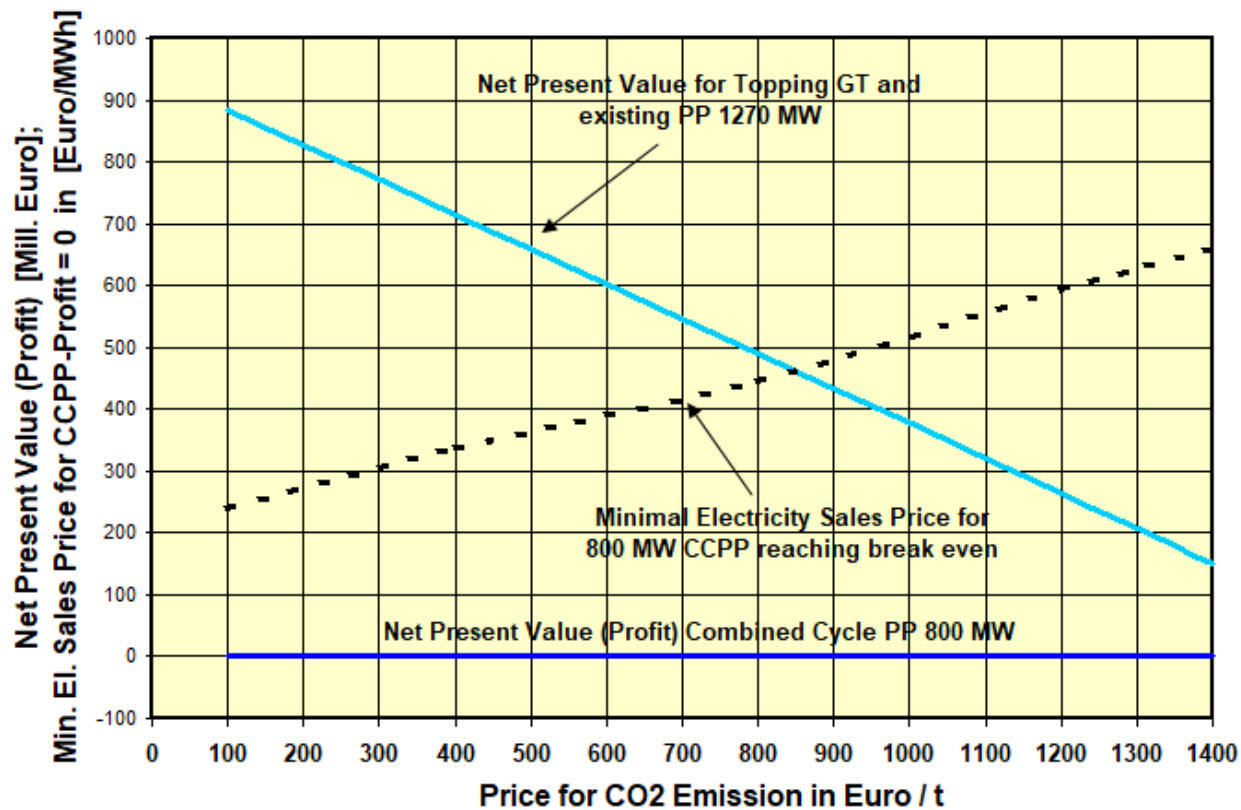
4. Economic analysis: Levelized cost of electricity based on full load hours



2. Fuel Switch Concepts: Specific CO₂-Emissions



2. Fuel Switch Concepts: Net Present Value vs. CO₂-Emission Price



To prevent the NPV for a new 800 MW CCGT power plant from slipping into negative territory, the electricity sales price must be in line with the dashed line.

If this electricity sales price is also used for the investigated variant with GT topping, the NPV for the GT topping solution is shown in the diagram.

SUMMARY

6. Summary

1. The economic data are initially calculated using a simplified approach based on full-load operation. **Considering load profiles, rapid start-up characteristics, and high load ramp-up times reveals advantages of the GT topping solution.**
2. **Gas turbines with a bypass stack** can be **started quickly with high gradients**, without having to consider the start-up time of the steam generator or steam turbine.
3. **High flexibility, operation at very low loads** either solely via the gas turbine or via the boiler without a gas turbine using the existing fresh air fan and induced draft fan . **Minimum load is lower with gas firing compared to coal.**
4. **Low specific investment costs** (< 70% compared to new CCGT plants) increase profitability and result in **low specific electricity generation costs.**

6. Summary

5. **GT topping is particularly suitable for systems with heat extraction**, since the existing district heating infrastructure can be further used. The new installed flue gas economizers can be used for economic district heat generation.
6. The **plant can be gradually converted and operated on hydrogen**, initially only the boiler, later the gas turbine can be operated with H_2 . The converted unit can be planned as 'Hydrogen-Ready', what has to be considered during the design phase (material selection, plant layout, safety etc.).
7. **A combination of market power plant and grid backup system is possible**, including possible preheating of the steam section via the GT exhaust gases (increased fuel utilization, reduced start-up cost).

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