Hearing of the Consultative Commission on Industrial Change

Modern Use of Lignite

Michael Eyll-Vetter, Vice President Mine Planning

Brussels, 14 September 2015

RWE

The energy to lead

Rhenish lignite mining area -
3 billion tons of lignite reserves approved for extraction

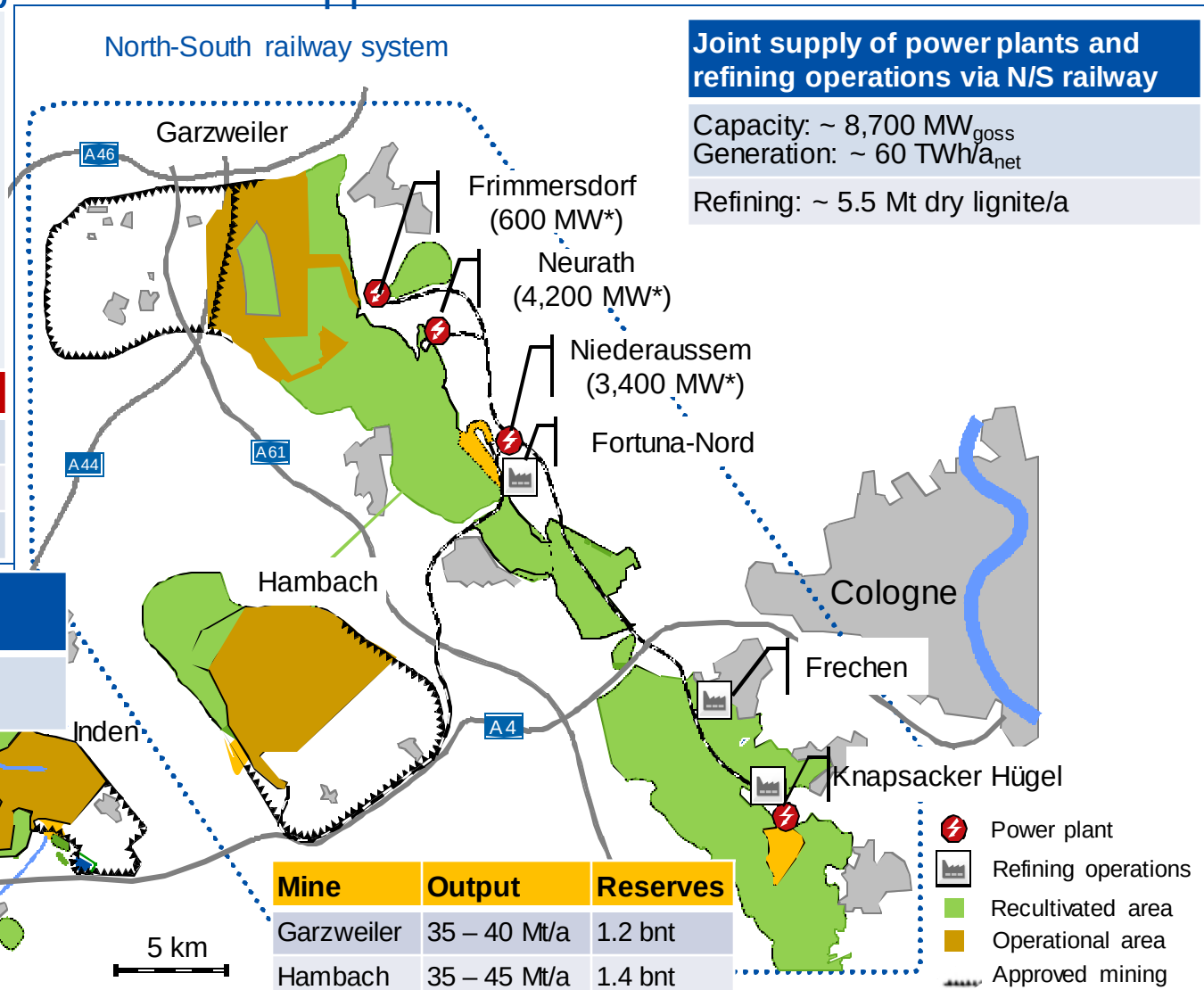
Lignite system

- Lignite output: ~ 90 – 100 Mt/a
- Power generation$_{net}$: ~ 70 – 75 TWh/a
- Refined products: ~ 5,5 Mt/a for distributed use
- ~ 10,500 employees (incl. trainees)

Unit class	Share
300MW	1/3
600MW	1/3
1,000MW (BoA)	1/3

Weisweiler/Inden isolated operations

Capacity: ~ 1,900 MW$_{gross}$,
Generation: ~ 14 TWh/a$_{net}$



Joint supply of power plants and refining operations via N/S railway

Capacity: ~ 8,700 MW$_{goss}$
Generation: ~ 60 TWh/a$_{net}$

Refining: ~ 5.5 Mt dry lignite/a

Mine	Output	Reserves
Garzweiler	35 – 40 Mt/a	1.2 bnt
Hambach	35 – 45 Mt/a	1.4 bnt
Inden	20 – 25 Mt/a	0.3 bnt

*according to unit classes

Modernisation of the power plant fleet resulting in substantial CO_2 reductions

Key contents of the 1994 power plant renewal programme

> Power plant renewal using the best technology available at the time
  - Optimised concepts
  - Optimum fuel use
  - Significant contribution to climate protection
  - Reduction of other emissions

> Step by step until 2030

> With economic efficiency as a prerequisite

> RWE investment volume: about €10 billion

So far, the programme has been implemented as planned (BoA 1-3 etc.) with investment totalling over €4.3 billion

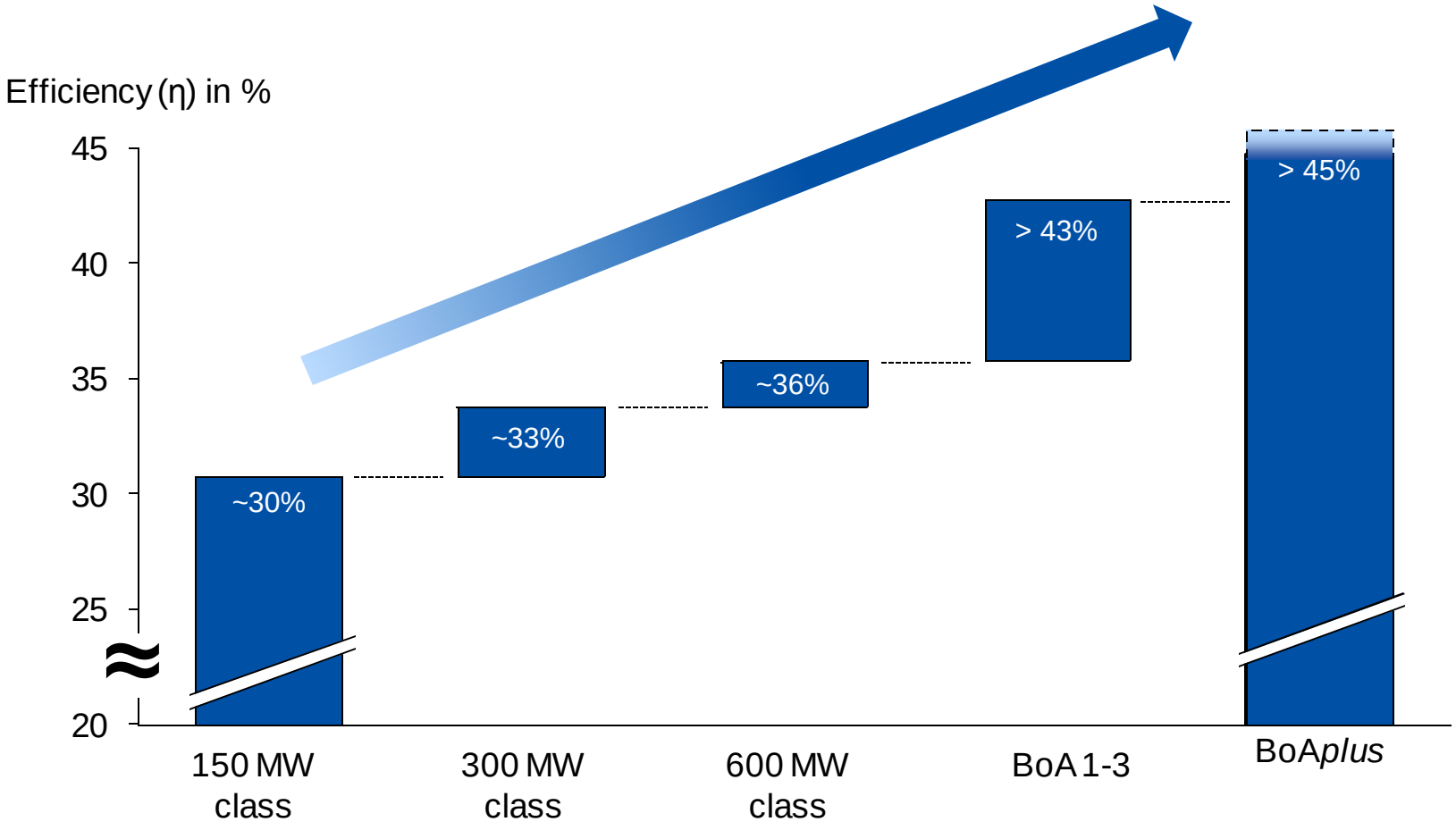
Power plant renewal progressing as planned
BoA* 1-3 make lignite fit for the future

- 3,000 MW in new-build units (BoA 1-3) started operation between 2003 and 2012; highest standard for lignite-fired plants world-wide
- All **sixteen** 150 MW units in the Frimmersdorf, Niederaussem and Weisweiler power plants were finally closed down on 31/12/2012
- CO_2 savings of some 9 Mt/a

Approval procedure for BoA*plus* involving a further efficiency boost is underway

* **B**raunkohlenkraftwerk mit **o**ptimierter **A**nlagentechnik
(lignite-fired power plant with optimised plant engineering)

Continuous efficiency increase



With its integrated firing concept, BoA*plus* is setting a new efficiency standard for lignite-based power generation world-wide

Flexible lignite-fired power plants

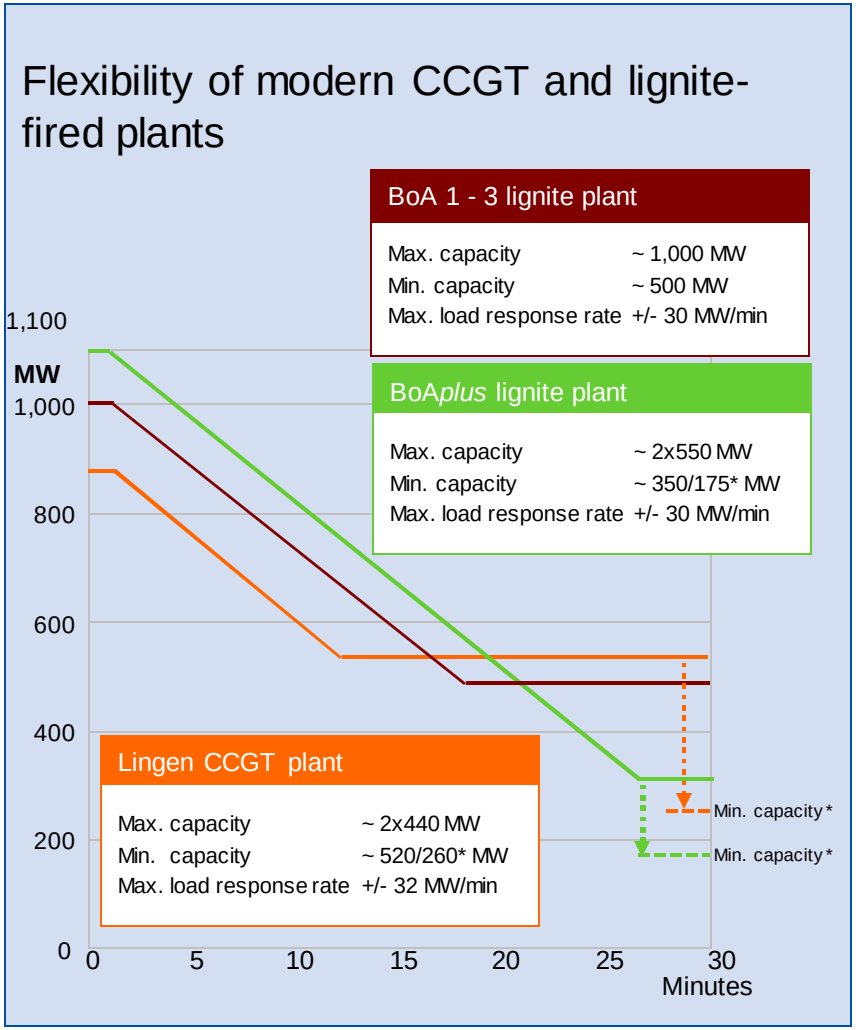
BoA 1-3 new-builds

Planning and approval of BoA*plus*

Mondernisation of existing power plants

Lignite is becoming a strong and reliable partner to renewables, balancing fluctuating PV- and wind-based power generation

Flexibility of modern CCGT and lignite-fired plants



BoA*plus*
Less lignite consumption, less CO_2, less emissions

Higher efficiency: over 45%

Increase in efficiency of about 30% to an overall efficiency of > 45%

Result

Fuel input: 30% less

> Compared with the four 300 MW units to be shut down, fuel input is reduced by 30%

CO_2 emissions: 30% less

> Compared with the four 300MW units to be shut down, CO_2 emissions are reduced by approximately 30% or 3 Mt/a

Less emissions

Sulphur oxides, nitrogen oxides, particulate matter (examples)

The refining business offers additional markets

Raw lignite input of ~ 15 Mt/a

Refining to make pulverised lignite and fluidised-bed lignite, lignite briquettes and lignite coke of about ~ 5.5 Mt/a

Generation and external marketing of ~1.1 TWh_{th} heat/a

Power generation (net) of 1.9 TWh/a

Refining offers opportunities for value creation outside the electricity market

Research and Development potential – Focus on three key areas

Stabilising current business– high-performing partner

Maintaining acceptance – most trusted partner

Responding to shrinking power market – create value-adding products

1 Lignite use

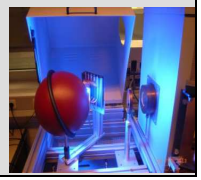
- Lignite preparation and drying
- Lignite demineralisation
- Biomass preparation
- Lignite slurry

- Coal-to-Gas
- Coal-to-Liquid

2 Power plant technology

- Flexibility increase
- Efficiency boost
- Plant concepts
- System evaluation
- Combustion
- Co-combustion

- Coal quality
- Ash landfills
- Damage analysis

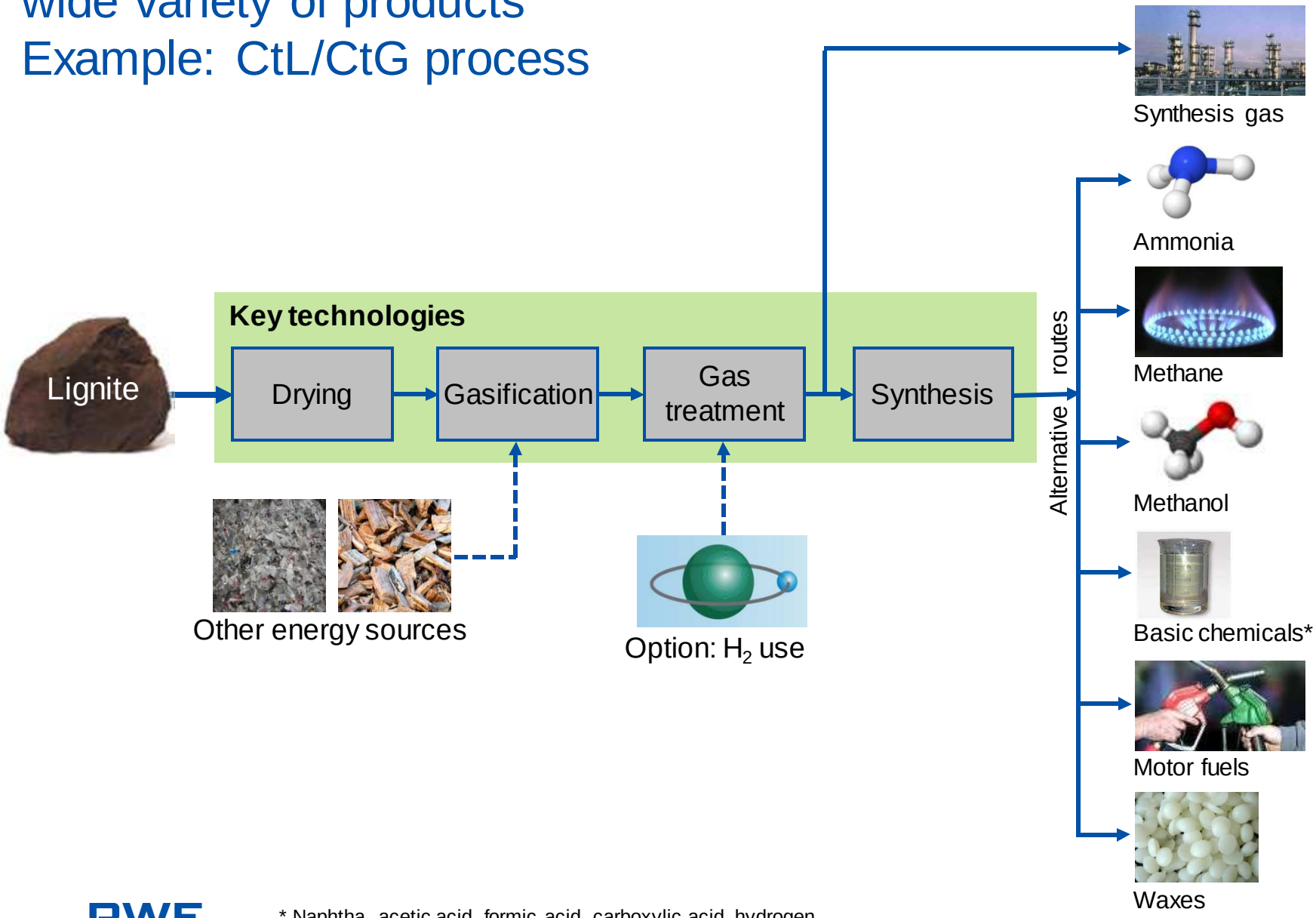


3 Flue gas cleaning

- CCS strategy
- CO_2 transport and storage
- PCC pilot plants
- CO_2 filling station

- Particulate removal
- Desulphurisation
- NOx removal
- Mercury reduction
- *REAplus* pilot plant

Lignite can help replace gas and oil in the manufacture of a wide variety of products
Example: CtL/CtG process



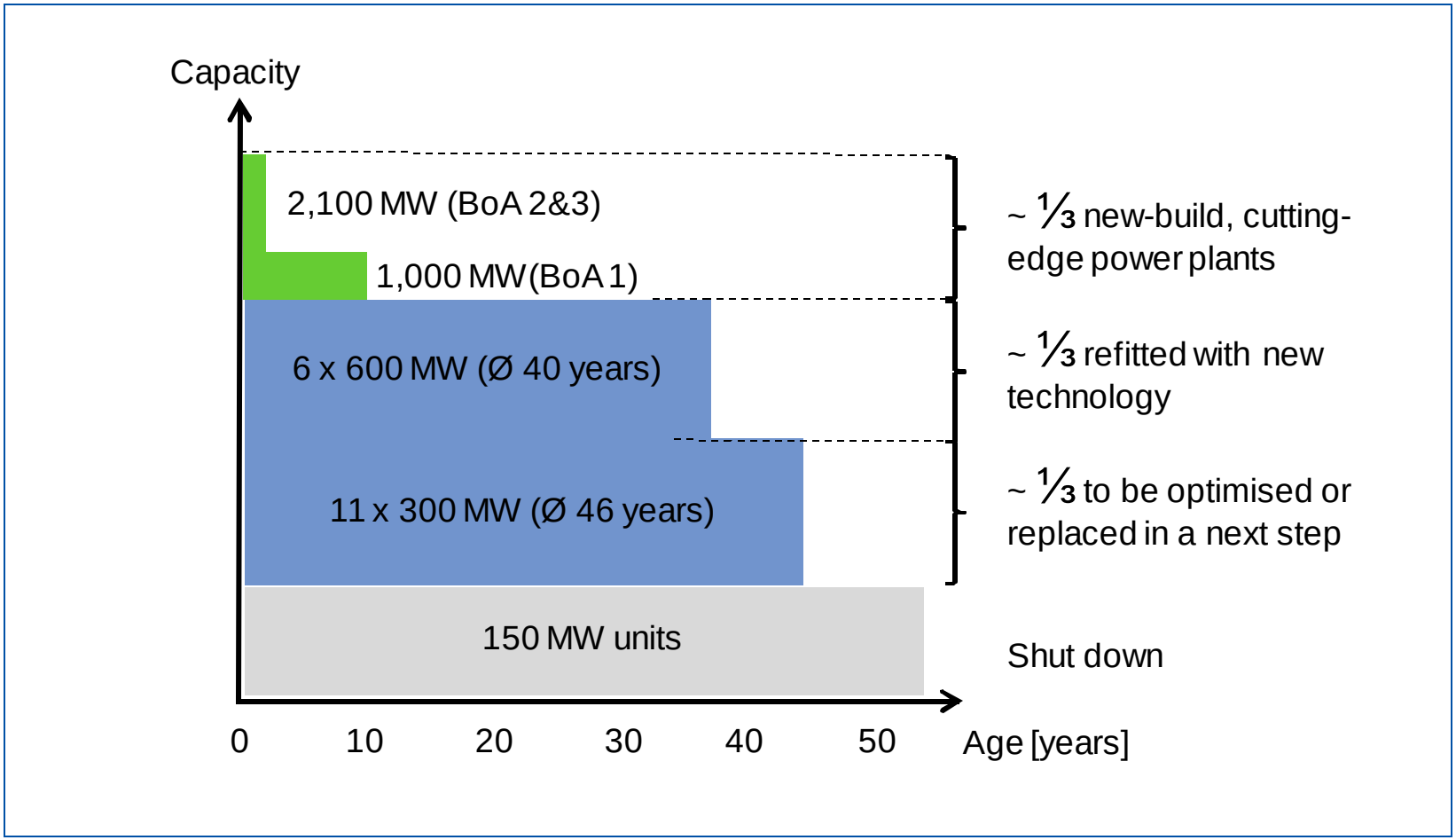
* Naphtha, acetic acid, formic acid, carboxylic acid, hydrogen, …

Lignite can make important contributions to long-term security of supply

- Approved reserves form a sound basis for cost-efficient lignite mining and use
- Lignite-fired power plants are as flexible as modern gas stations, which makes them an ideal partner to renewables
- According to current studies, lignite continues to be necessary in terms of energy policy and energy management for the supply of Germany/North Rhine-Westphalia to secure their viability as industrial locations over the long term
- As a domestic raw material, lignite reduces Germany's import dependence
- Power plant renewal is to be continued
- Lignite is converted by refining into a wide variety of secondary products, e.g. pulverised lignite for use in large industrial combustion plants, and has the potential to replace mineral oil and natural gas in the (petro)chemical industry

Back-up

Overview of the power plant fleet



Binding commitment to shutdowns

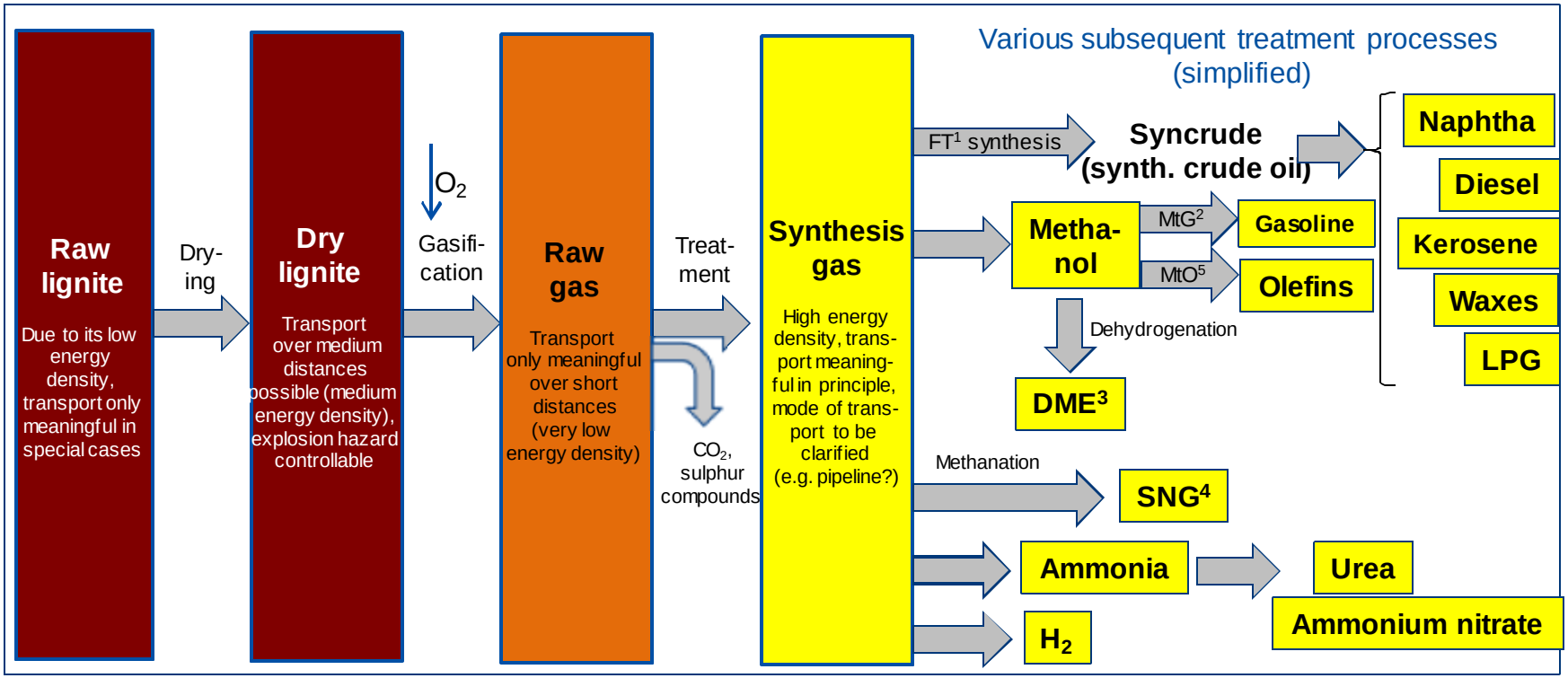
Upon the start of commercial BoA*plus* operation, more than the same capacity (four 300 MW units) will be shut down

Lignite utilization options exist far beyond power production

- Domestic lignite is a large energy and raw material source, which currently serves the power and heat market
- RWE owns significant lignite assets in NRW
- Due to the increase of efficiency of our lignite power plant fleet and a projected decrease of power production from lignite, it is expected that significant amounts of mining capacities will be available in the mid- to long-term
- To sustain a cost competitive power production from lignite it is helpful to keep a high degree of capacity utilization in our lignite mines
- Free mining capacities should therefore be used for alternative routes of lignite utilization if economically feasible
- Conversion of lignite to basic chemical materials, fuels, or other energy carriers via gasification is an option to make use of millions of tons of lignite in the mid- to long-term
- RWE does have significant know-how in gasification and synthesis of chemicals or energy carriers from lignite
- Bandwidth of products from lignite is large, e.g.: synthetic natural gas, naphtha, ammonia, urea, methanol, fuels, waxes, …
- **Lignite bears the potential to substantially replace crude oil and natural gas in (petro-) chemical industry, thus alternative use of lignite can help to stabilize current exploitation rates of our open cast mines**

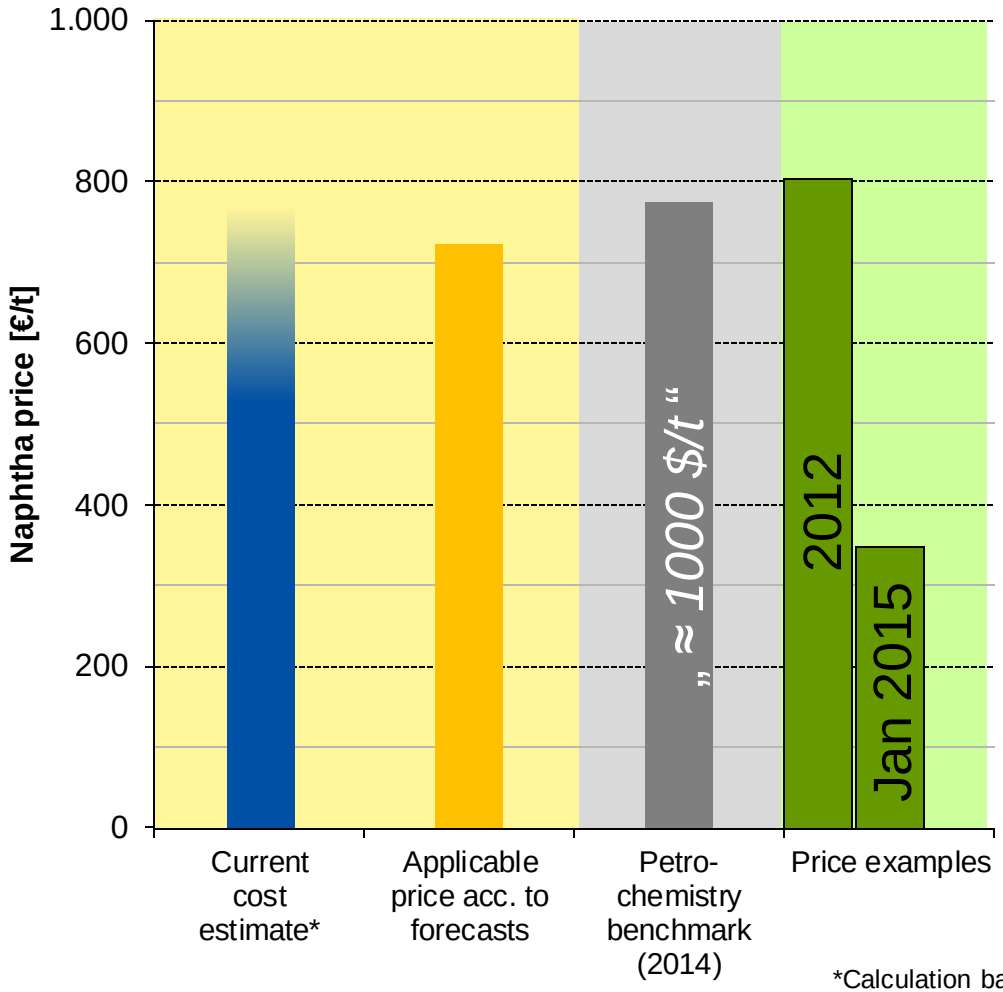
Lignite can help replace gas and oil in the manufacture of a wide variety of products

- In principle, supply ranging from raw lignite via intermediate products to various end products is conceivable
- Important intermediate product is synthesis gas (hydrocarbon mixture) that is produced by lignite gasification and further treatment and can be used as a basic substitute for crude oil or natural gas



[1]Fischer-Tropsch, [2]Methanol-to-Gasoline, [3]dimethyl ether, [4]synthetic natural gas, [5]Methanol-to-Olefins

The economic perspectives of CtL are good
Example: Fischer-Tropsch naphtha



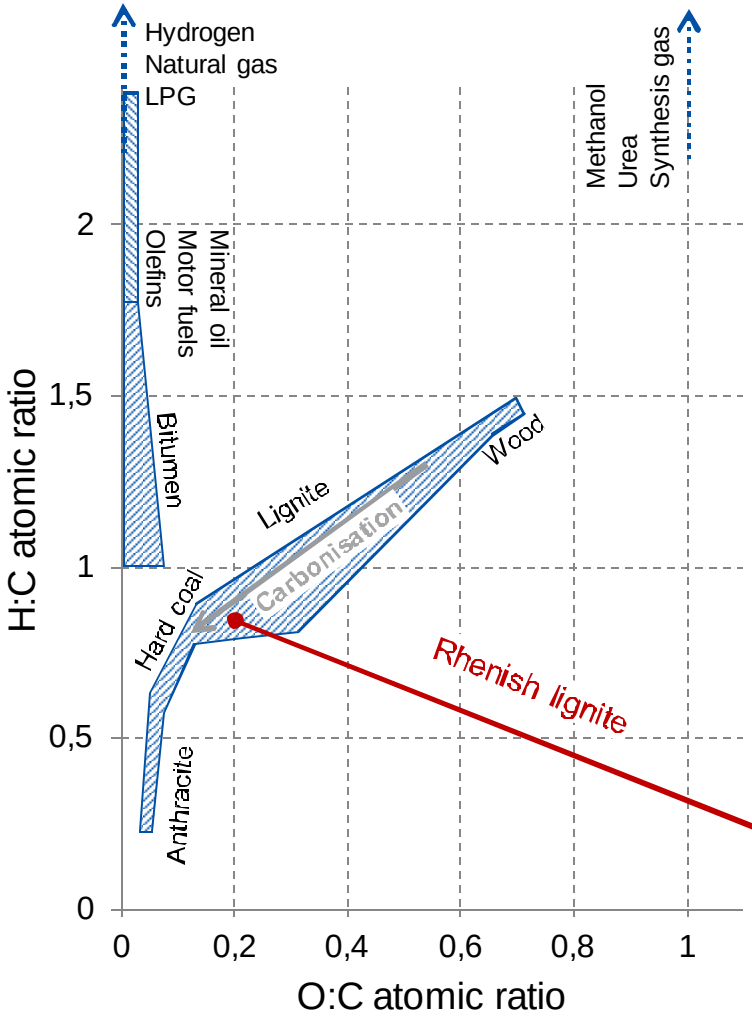
- Economic efficiency possible under certain boundary conditions
- Important levers:
  - Euro exchange rate
  - Financing options/ interest rate
  - Economies of scale/use of existing infrastructure
  - CO_2 allowances costs
  - Shale gas/shale oil in Europe
  - Oil price shocks and dips

*Calculation basis: 500MW_{th}, 1.3Mt dry lignite/a, €525m in capex, annex concept

- Economic perspective is seen for CtL/CtG in the medium to long term.

Transformation of carbon sources

van Krevelen diagram



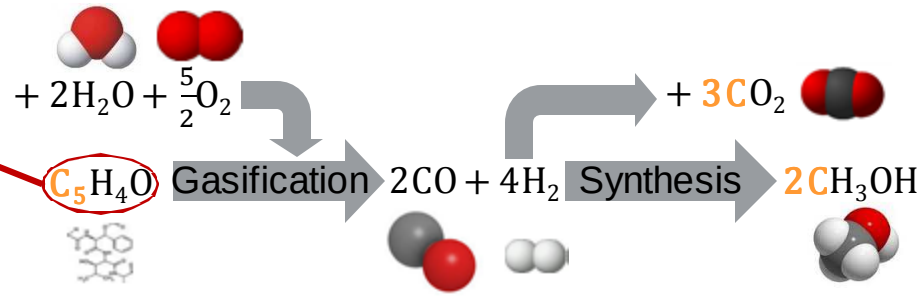
Challenge for lignite:

- Conversion of solid fuels into liquid or gaseous secondary energy sources
  ≙ Adjustment of the H:C:O ratio
- Solid fuels with "too much" oxygen (O) and carbon (C) and "too little" hydrogen (H)
  → Change in ratio, among others through shift reaction
  → Addition of renewables-based H_2 also conceivable

Opportunity:

- Manufacture of carbonaceous products from lignite reduces emissions (carbon sink) compared with combustion

Methanol production (example):



⇒ min. 40% carbon sequestration

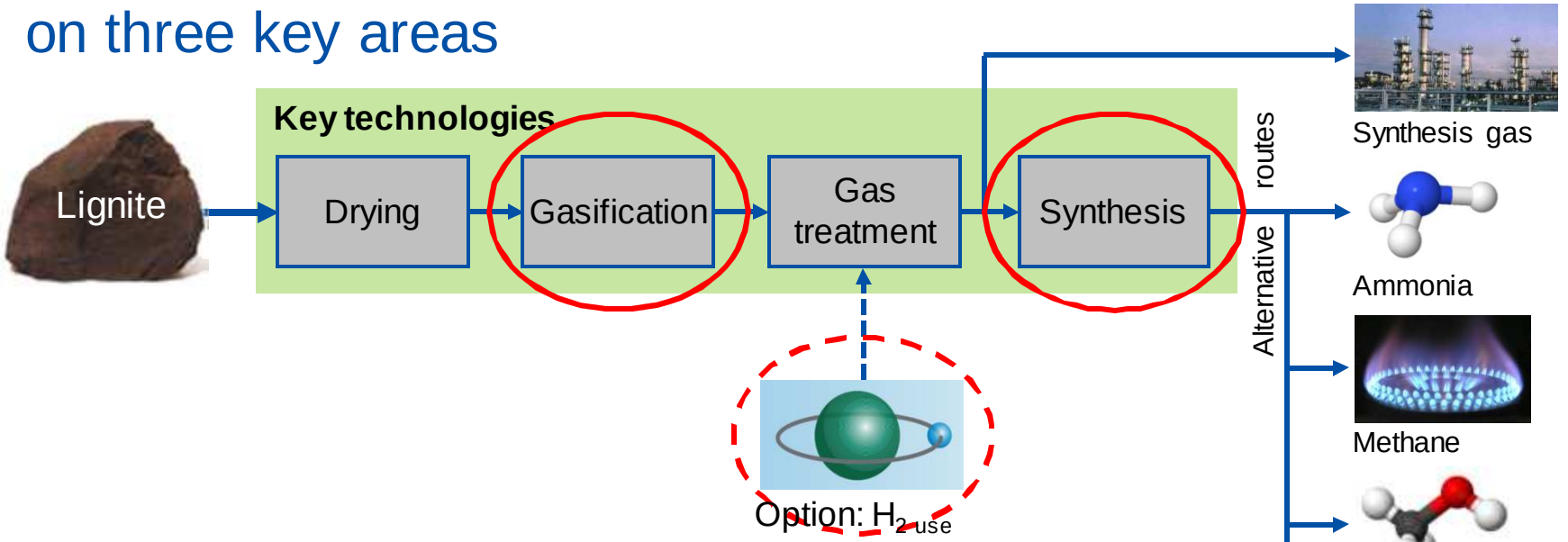
Product yield and market shares for an input of 10 million tons of raw lignite

Lignite product	Typical end product/sales market	Yield	Market share (country)
FT products *incl.*:*		9Mbbl *incl. e.g.:*	
▪ *naphtha*	*Plastics*	*3Mbbl*	e.g. naphtha 2% (D)
▪ *waxes*	*Lubricants, candles, cosmetics*	*3Mbbl*	
▪ *middle distillates*	*Diesel, kerosene*	*3Mbbl*	
Acetic acid	Paints, adhesives, artificial silk	3.9Mt	30% (global)
Formic acid	Solvents, textile and leather processing	7Mt	1,000% (global)
Motor fuel	Gasoline	6.0Mbbl	3.5% (D)
Urea	Fertiliser	4.0Mt	3% (global)
Hydrogen	Energy source, refining of hydrocarbons	0.5Mt	25% (D)
Syngas	Heat market, synthesis gas production, electricity	2.0Mcbm	2% (D)

▪ Products from domestic lignite can replace some of the oil and gas product quantities used.

* Product breakdown depends on the catalyst used and can vary substantially

For CtL/CtG implementation, R&D must focus on three key areas



Coal gasification – lever for capex optimisation

- Increase in efficiency, robustness, economy of scale
- Confirmation of functioning with domestic lignite

Syntheses – lever for the manufacture of high-quality products

- Process adjustment to customers' product requirements
- Efficiency boost by avoiding intermediate products

Hydrogen supply – lever for emission reduction

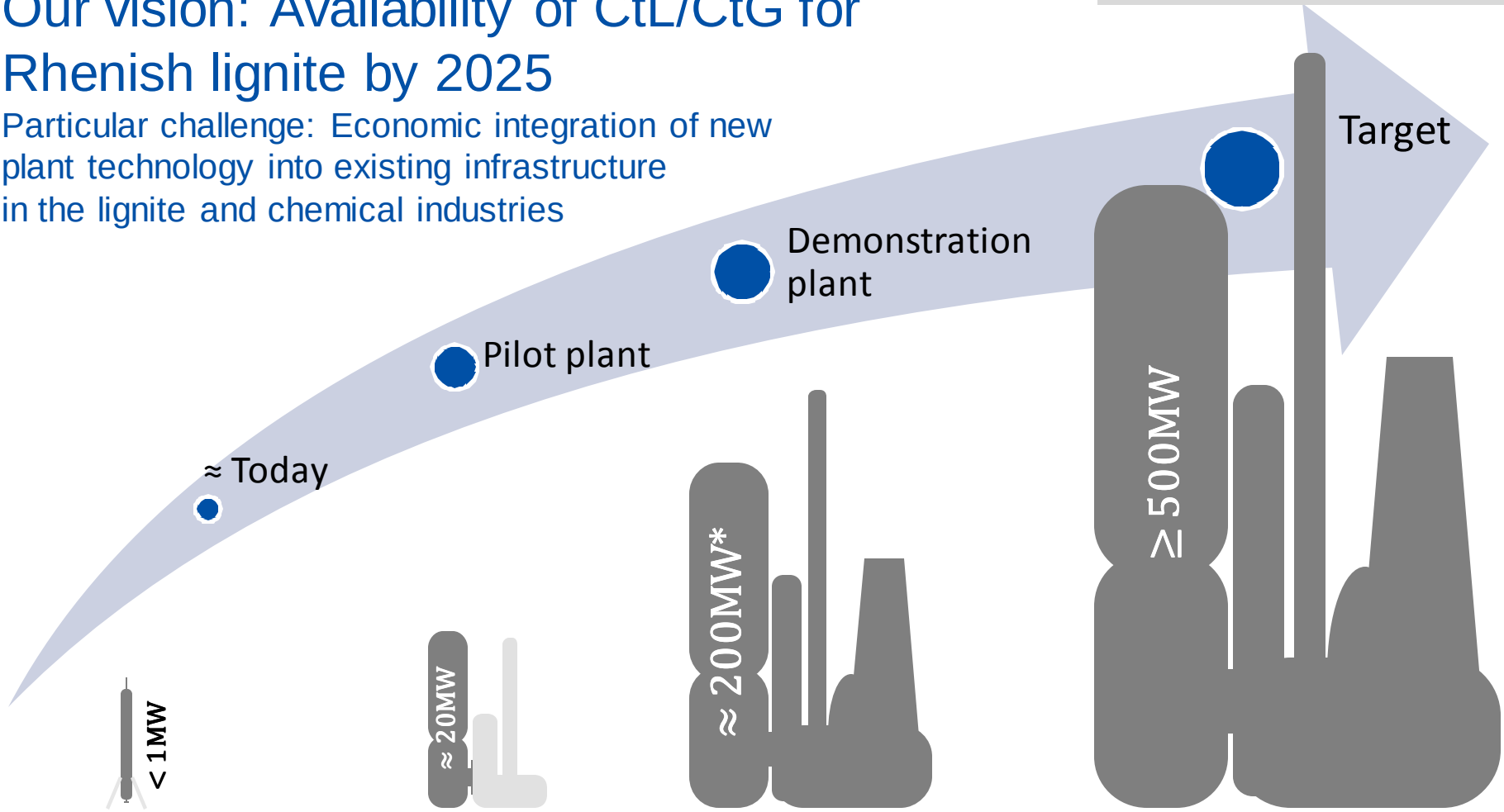
- Future use of renewables-based hydrogen calls for the development of low-cost electrolyses

* Naphtha, acetic acid, formic acid, carboxylic acid, hydrogen, …

R&D / Use a raw material

Our vision: Availability of CtL/CtG for Rhenish lignite by 2025

Particular challenge: Economic integration of new plant technology into existing infrastructure in the lignite and chemical industries

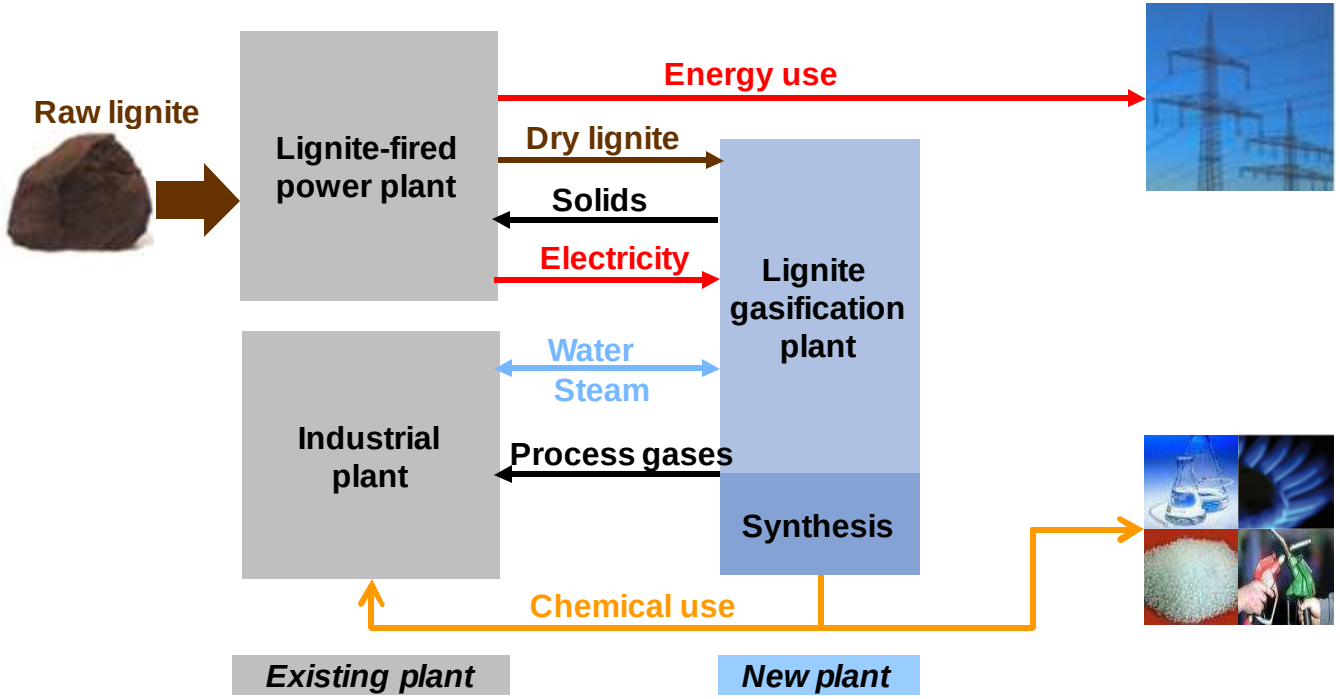


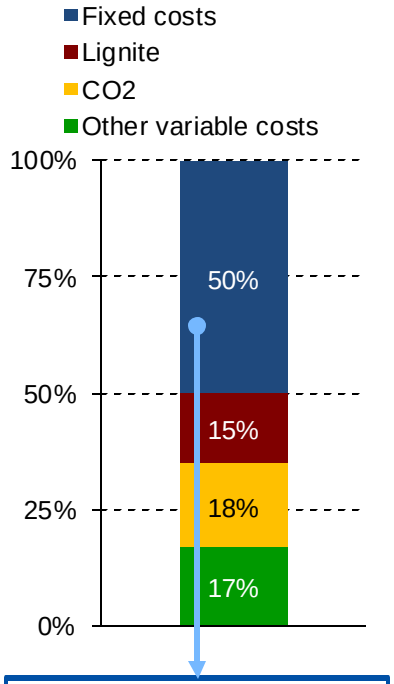
- The technologies used in CtL/CtG plants are commercially available in principle.
- But adjustment to the Rhenish lignite's typical characteristics and to requirements in Germany plus testing is required.

* Thermal gasifier capacity is a reference value for overall plant size

Annex principle: Integration of CtL/CtG plants into existing site infrastructure …

- reduces investment costs compared with a stand-alone solution
- offers new use/operating options for existing infrastructure



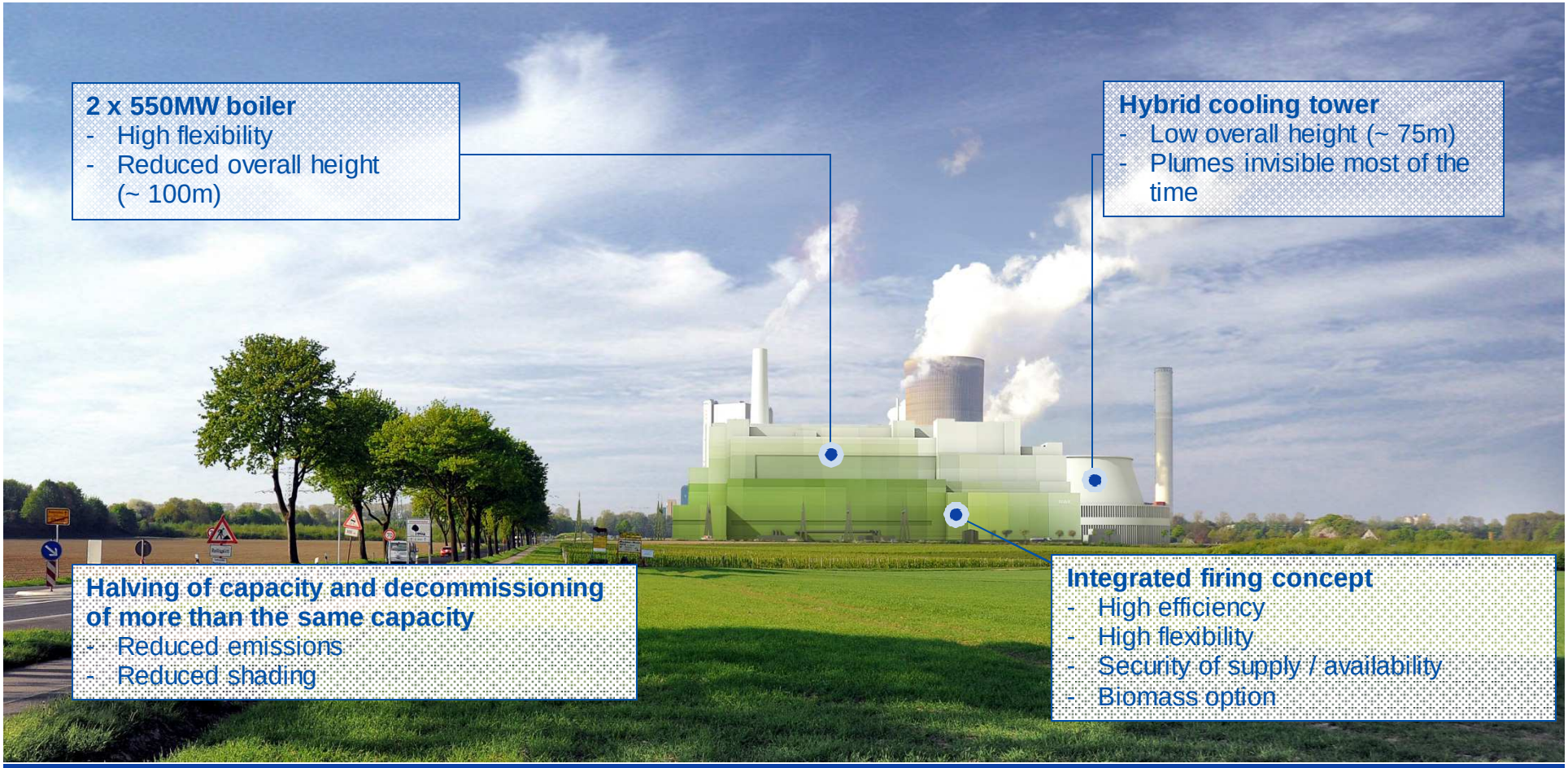


Reduction of investment costs is the biggest economic lever

→ **R&D activities for innovative plant concepts are important**

- Power plant and industrial sites offer potential for annex solutions.
- RWE is looking for partners to develop and implement CtL/CtG options.

BoA*plus* Niederaussem
Cornerstones of the further-developed concept



BoA*plus* steam generators and the hybrid cooling tower will again be substantially reduced in height

Lignite can make important contributions to security of supply

In power generation and refining today:

- Lignite-fired power plants are as flexible as modern gas stations, which makes them an ideal partner to renewables
- Lignite-based refining products are used in private households and industry
- As a domestic raw material, lignite reduces Germany's import dependence

As a carbon supplier in future:

- Raw material supply of the chemical industry is largely based on mineral oil and natural gas today
- Mineral oil reserves are becoming scarcer and their quality is declining
- Chemical industry can diversify its raw material base with lignite, with prices remaining stable over the long term

→ Rhenish lignite also offers options for replacing imported energy sources and for supplying the chemical industry with carbons in the long run