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THE BOSTON CONSULTING GROUP

Climate Paths and Sector Coupling

MIT - CEEPR Meeting

Berlin, July 2/3, 2018

Climate Paths for Germany

Unique fact base

All sectors

Analysis level: individual GHG reduction measures

Optimized to minimize GHG abatement costs

Investments, costs, GDP-effects

Broad validation of results

68 industry associations and companies

~ 200 industry experts

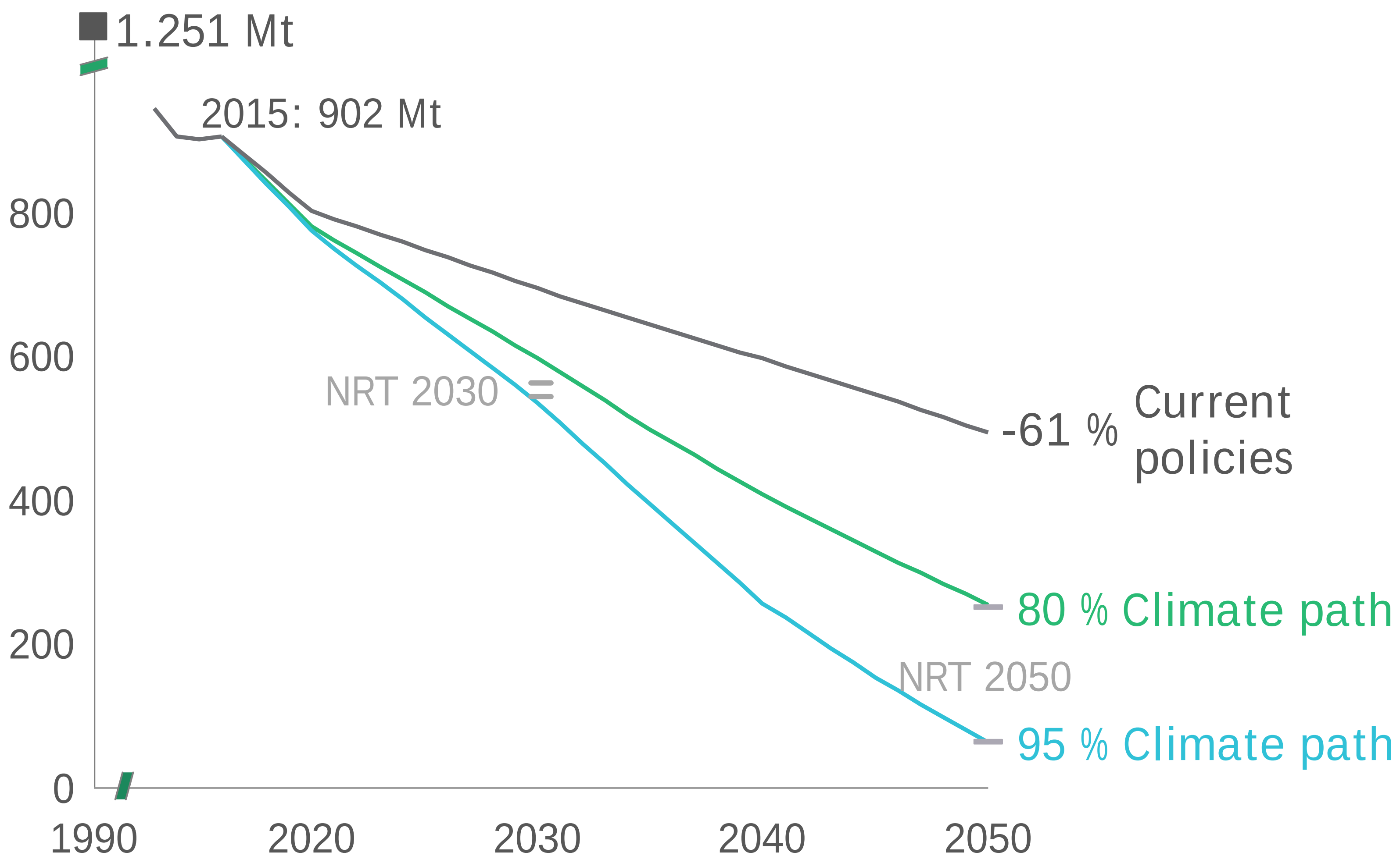
~ 40 workshops

Scientific board

61 % greenhouse gas reduction even under a 'current policies' scenario, but a major gap to national reduction target remains

Greenhouse Gas (GHG) Emissions in Germany

Mt CO_2e



NRT = National reduction targets of German government (corridor)

80% path achievable with existing technologies

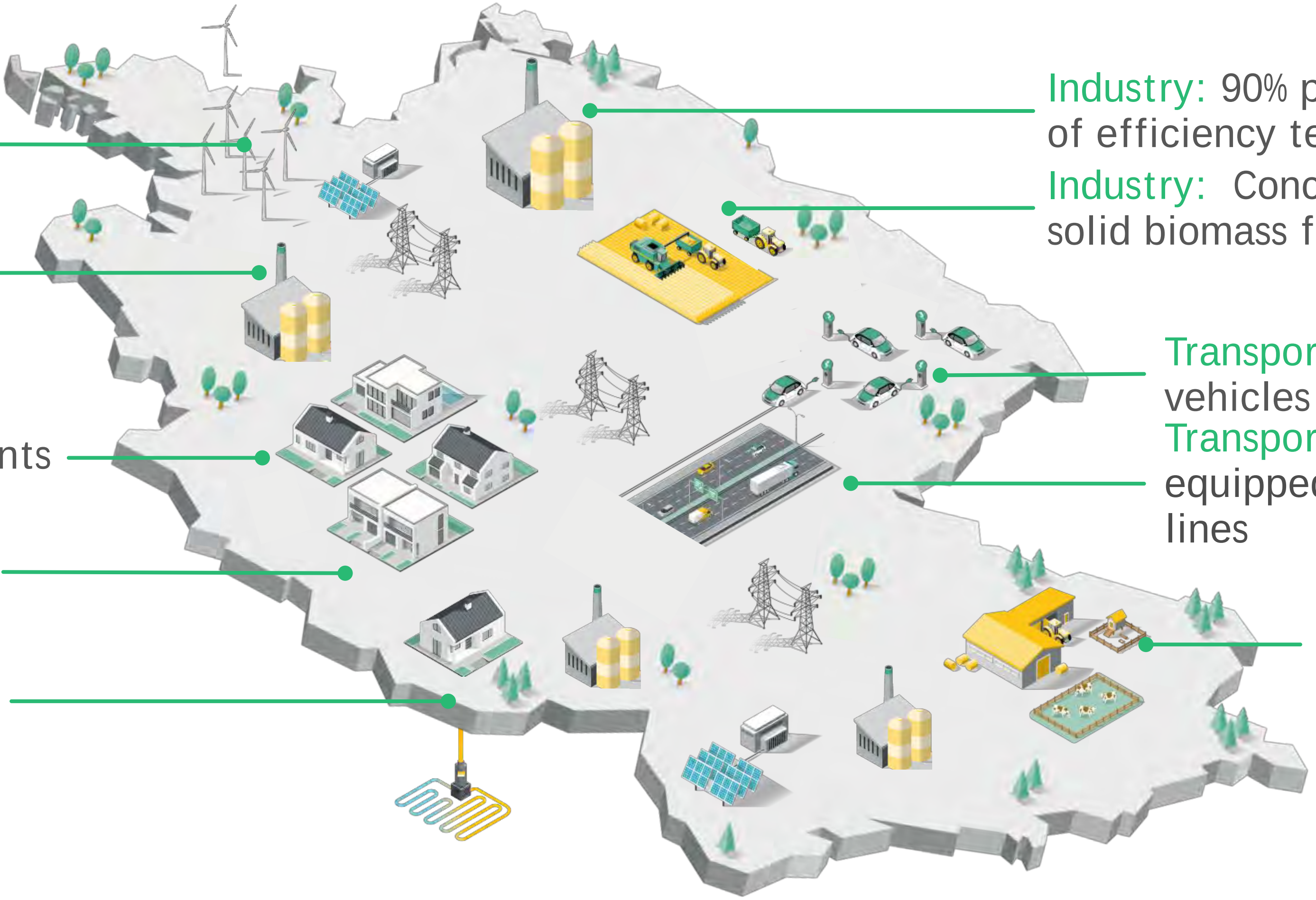
Energy: 240 GW wind and PV, grid expansion

Energy: Gradual replacement of coal with gas

Buildings: 50% more insulation/refurbishments (1.7% p.a.)

Buildings: Expanded urban district heating

Buildings: 14M heat pumps, mainly in 1- to 2-family homes



Industry: 90% penetration of efficiency technologies

Industry: Concentration of national solid biomass for heat < 500°C

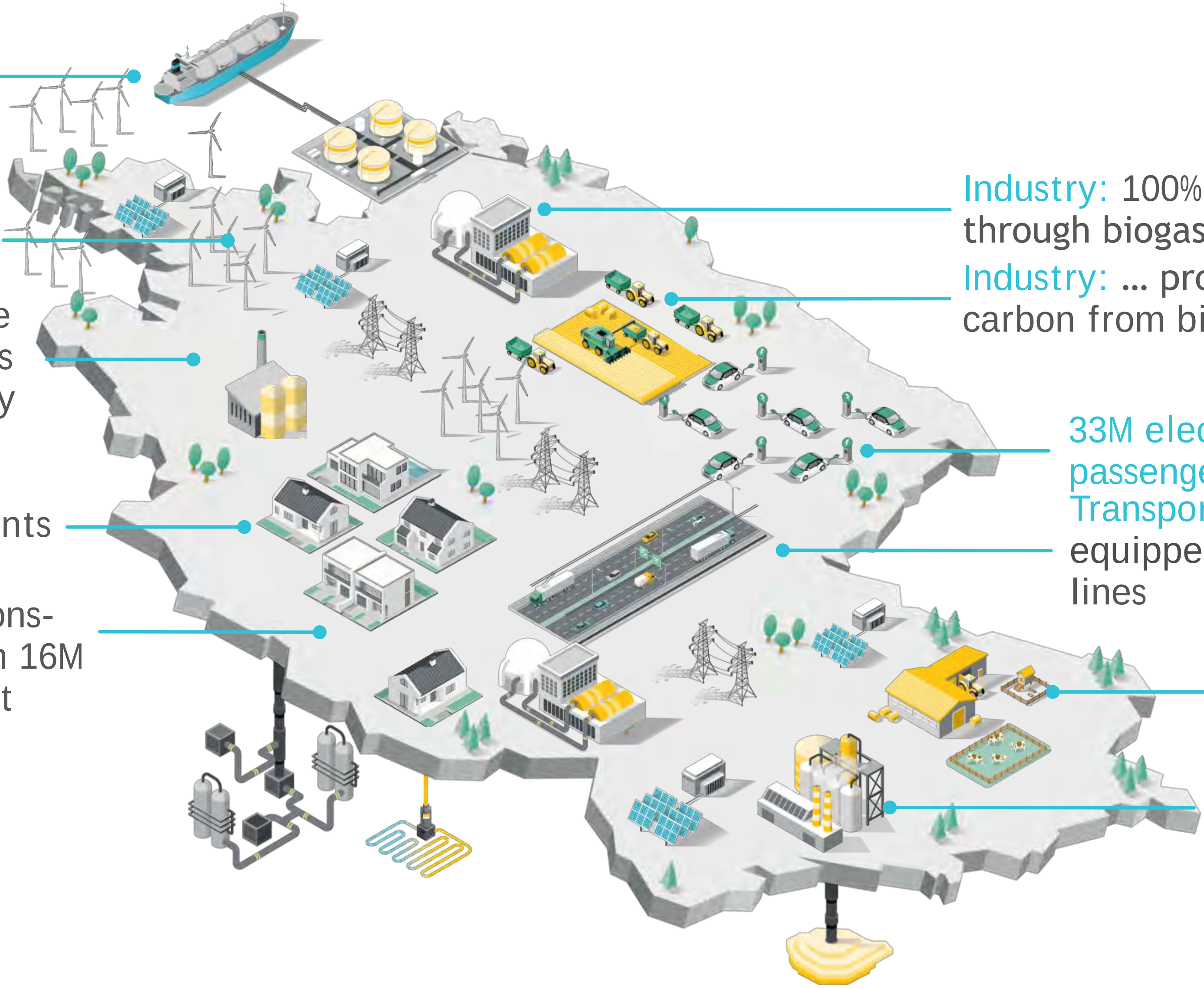
Transport: 26M electric vehicles, 2/3 of passenger cars

Transport: 4,000 km of freeway equipped with truck overhead lines

Agriculture: More efficient use of fertilizer

PV = photovoltaics
All figures refer to 2050

95% path pushes boundaries of technology and acceptance



340 TWh imports of renewable fuels (PtL, PtG)

Energy: 292 GW wind and PV, grid expansion

Energy: 100% renewable through PtG, gas grid as seasonal storage facility

Buildings: 70% more insulation/refurbishments (1.9% p.a.)

Buildings: 100% emissions-free heat (esp. through 16M heat pumps and district heating)

Industry: 100% renewable heath through biogas/PtG ...

Industry: ... produced with recycled carbon from biomass combustion

33M electric vehicles, 4/5 of passenger cars

Transport: 8,000 km of freeway equipped with truck overhead lines

Agriculture: "Methane pill" for the cattle population

Carbon capture and storage for steel, cement, steam reforming, refineries, and waste incineration

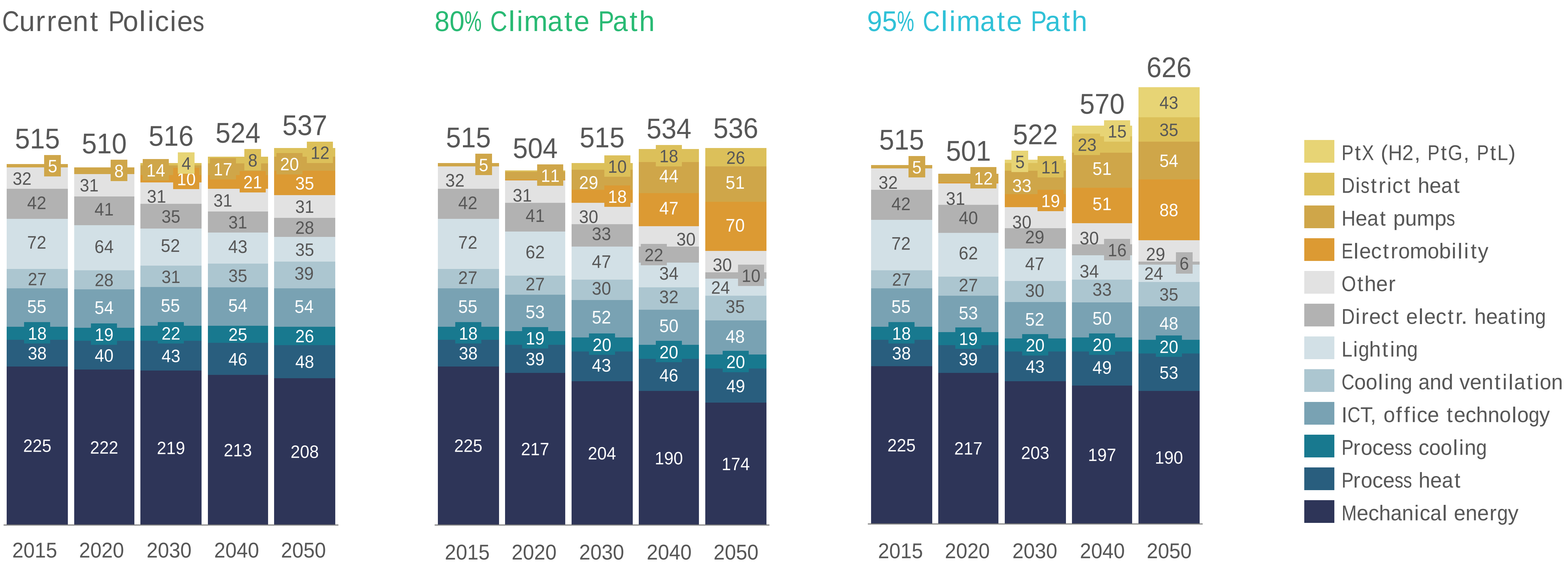
PtL = power-to-liquid, PtG = power-to-gas
All figures refer to 2050

95 % target requires zero emissions in most sectors

Bubbles: Mt CO_2e % change vs. 1990	1990 (dark) vs. 2015 (light)	2050 Current Policies	2050 80 % climate path	2050 95 % climate path
Power sector	-22 %	-71 %	-89 %	-100 %
Industrial processes	-36 %	-41 %	-51 %	-87 %
Industrial heat / steam	-32 %	-52 %	-72 %	-99 %
Transport	-2 %	-44 %	-73 %	-100 %
Buildings	-39 %	-70 %	-92 %	- 100 %
Agriculture, other	-46 %	58 %	-70 %	-74 %
Σ	1990: 1.251 2015: 902 (-28 %)	493 -61 %	254 -80 %	62 -95 %

Net electricity consumption increases only moderately

Net electricity consumption by application (in TWh)



Power flexibility 'merit order': PtX needed for long-term storage

1. **Expand power grids and interconnections**
   Increase amount of generated power that matches given demand; avoid grid related curtailments

2. **Flexibilize 'direct' consumers, i.e. Power-to-Heat, heat pumps electric vehicles**
   Focus demand on periods with sufficient available renewable power

3. **Secure short term storage**
   Batteries and pump storages important elements to bridge short-term production and demand peaks

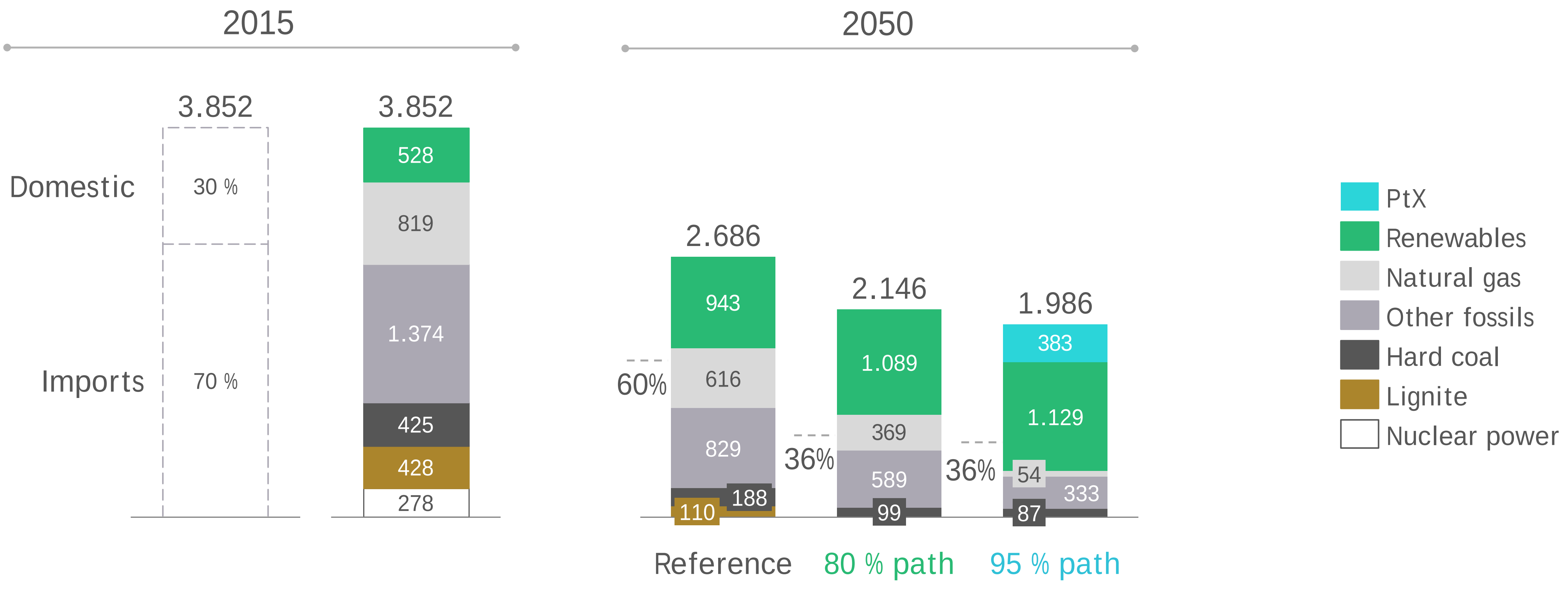
4. **Accept curtailments of renewables, which are concentrated on very few hours per year**
   Technologies built only around such 'excess power' are not economically viable

5. **Secure carbon-neutral long-term storage (and fully decarbonize other sectors)**
   Hydrocarbons needed for interseasonal power storage and for decarbonizing 'beyond' electrification

Source: BCG analysis

Fundamental change in energy mix, significant import reduction

Primary energy consumption across all German sectors (TWh)



Remarks: including international bunker fuels
Source: Prognos; BCG

„Demystification” of German climate paths

			H_2		
Myth	"Tech break-through needed"	"All electric society"	"Hydrogen economy"	"Large amounts of excess power"	"Import dependency"
Study outcome	More than 80 % GHG reduction with current technologies	Electrification is important for GHG reductions, but power demand hardly increases	Broad use of hydrogen would require futher cost degression	Grid expansion, power trade, and flexibilization limit curtailment need for renewables	Energy imports reduced by up to 80 %; but: no energy autarky either

Technology breakthroughs in PV, H_2 or storage would increase option space

80% economically feasible—95% only possible globally

	80% Climate Path	95% Climate Path
Additional investments[1]	€1,500B (energy €430B)	€2,300B (energy €620B)
Additional cost to the economy[1]	€470B (energy €156B) Avg. €15B annually	€960B (energy €196B) Avg. €30B annually
GDP effect	At least a breakeven in all scenarios	Breakeven in case of global cooperation

80% Climate Path

Major investment effort

Feasible on a macroeconomic level

95% Climate Path

Major social and technological effort

Only feasible with a global consensus

1. Cumulative for the years 2015 to 2050; including investments and additional costs of the reference; Capital costs calculated with a macroeconomic interest rate of 2%, imports at border-crossing prices

Summary

No new technologies needed

- G20 nations could close at least two thirds of the gap between current-policies emissions and their 2°C contributions with proven technologies
- Also for the remaining gap solutions exist today

Systemic, economically optimized approaches required

- All countries should install systemic economic optimization as guiding principle.
- Many countries can take significant unilateral action without suffering an early-mover disadvantage
- All could benefit economically from moving closer to its 2°C emission target

Time to move

- Policymakers should take a systemic view across sectors and develop national mitigation agendas that maximize economic gain
- Companies need to prepare for a world with accelerated growth in carbon-neutral technologies and declining fossil fuel consumption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