Decarbonizing energy-intensive industries: empirical insights into the aspirations for electrification and flexibilization of industrial processes

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eceee summer study on energy efficiency
10-15 June 2024
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Decarbonization of German energy-intensive industry

Electrification and temporal shift of energy consumption play central roles in all scenarios

Scenario results for electrification

Electrification

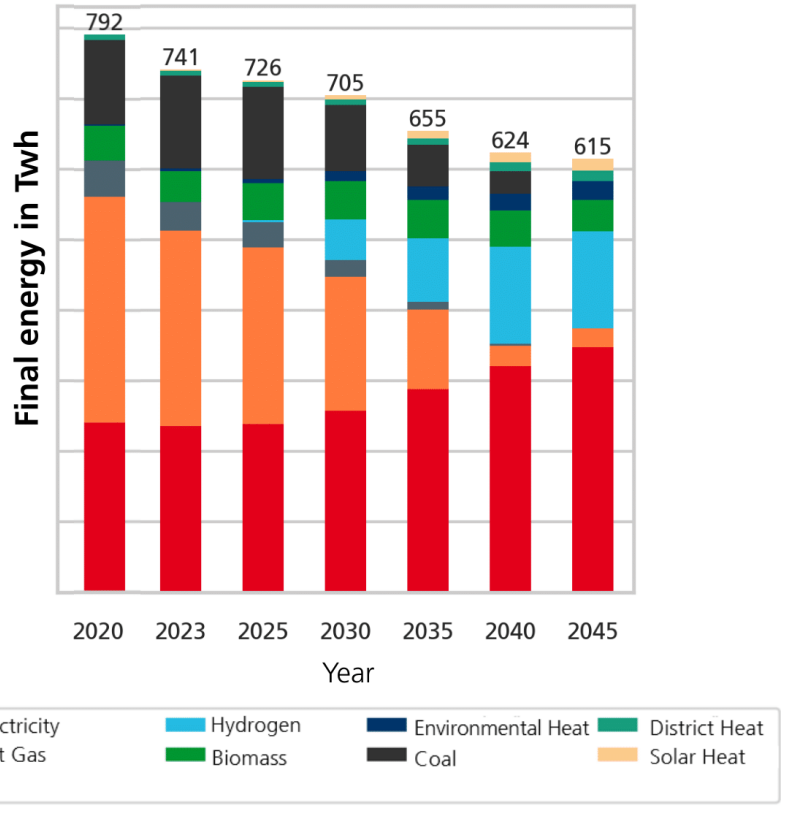
- Direct (electricity) and indirect (e.g., H2) electrification of industrial processes is relevant for decarbonizing energy-intensive industry.
- However, an energy system based on RE is characterized by fluctuations in RE production and therefore also electricity prices.

Flexibility

- can help to reduce the burden on the power grid and
- enables industry to profit from low eletricity prices in times of high electricity generation *(Palensky & Dietrich, 2011; Fridgen et al., 2017)*

What are the electrification and flexibilization aspirations of German energy-intensive companies?

Energy demand in industry sector



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IND-E Project social-science research

Analysis of stakeholder-specific decarbonization strategies and challenges to industrial decarbonization

Research questions

- What decarbonization strategies do energy-intensive companies overall pursue?
- What factors influence industry decarbonization?
- What energy carriers are currently used for industrial processes and how will this change in the future?
- To what extent is demand response already applied in companies? And do perceive companies this to be a relevant topic for the future?

Methodology

- 14 qualitative interviews in 2023
- Online survey (*N*=82) among energy-intensive companies in February 2024


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What factors influence industry decarbonization?

Results from literature, interviews and survey in a cultural-institutional approach (based on Koenig, 2020)

Macro level
Institutional

Regulative	Techno-infrastructural	Economic & financial	Market & demand	Political-normative
Network charge regulation (§19, 2)	Availability of green electricity, H2 & infrastructure	High costs of investments in innovative technologies	International competition	Energy transition ambitions
Bureaucracy	Increasing volatility of grids due to RE	Limited availability and accessibility of subsidies	Lack of demand for climate-neutral products (especially at beginning of the value chain)	Lacking intent & instruments for regulation on power cut-off
	Market maturity of innovative technologies	High OPEX	Electricity vs. fossil fuel prices	

Meso level
Energy-intensive industrial company

Company culture	Work and organizational practices	Material environment
Sense of responsibility	Knowledge/awareness on decarbonization options	Technological conditions & feasibility
Existence of climate neutrality strategies & goals	Competences (e.g., skills, experience, knowledge & training on new technology/flexibilization)	Company size and type
Innovation culture	Complex personnel planning, 3 shift operation	Size of the systems and units
Motivation/ambition of top management	24/6 and 24/7 production	Location
		Complexity of prod. processes & conversions

Micro level
Individual employees/employers

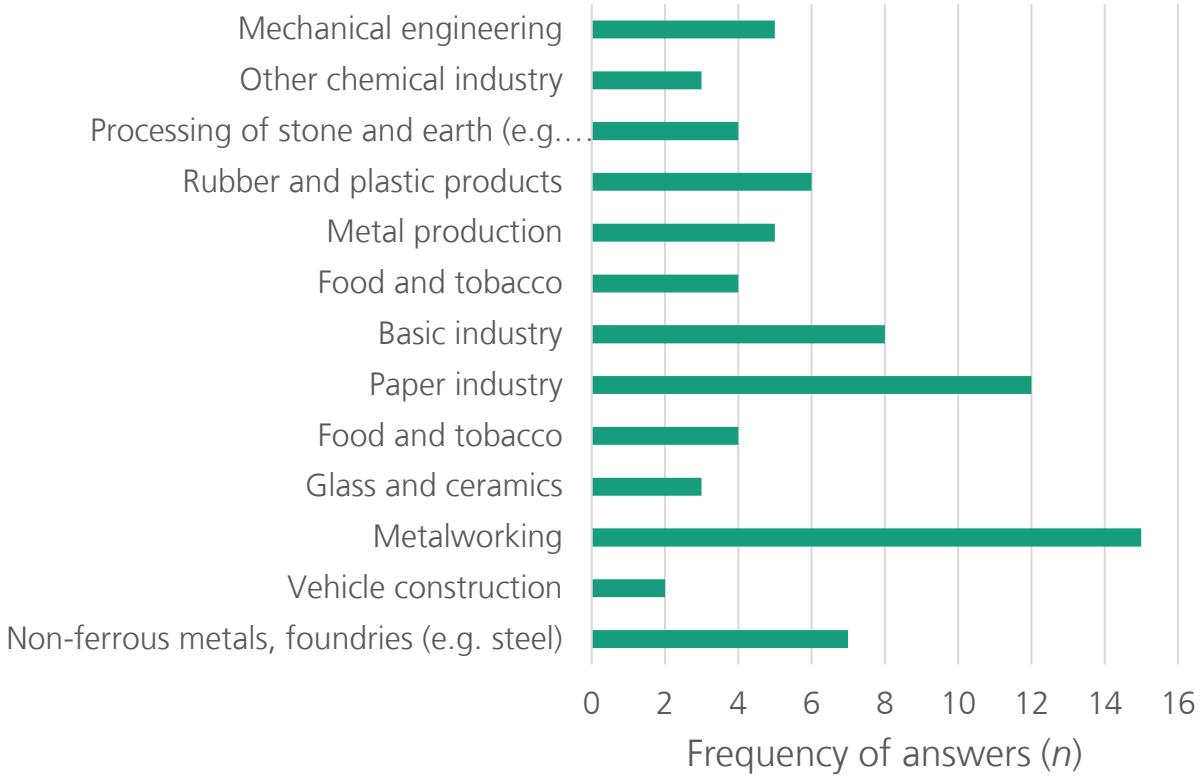
Abilities & competences	Acceptance & legitimacy
Behavioral changes and competence development of staff	Acceptance of changes in staff behavior (e.g., new work tasks & processes)

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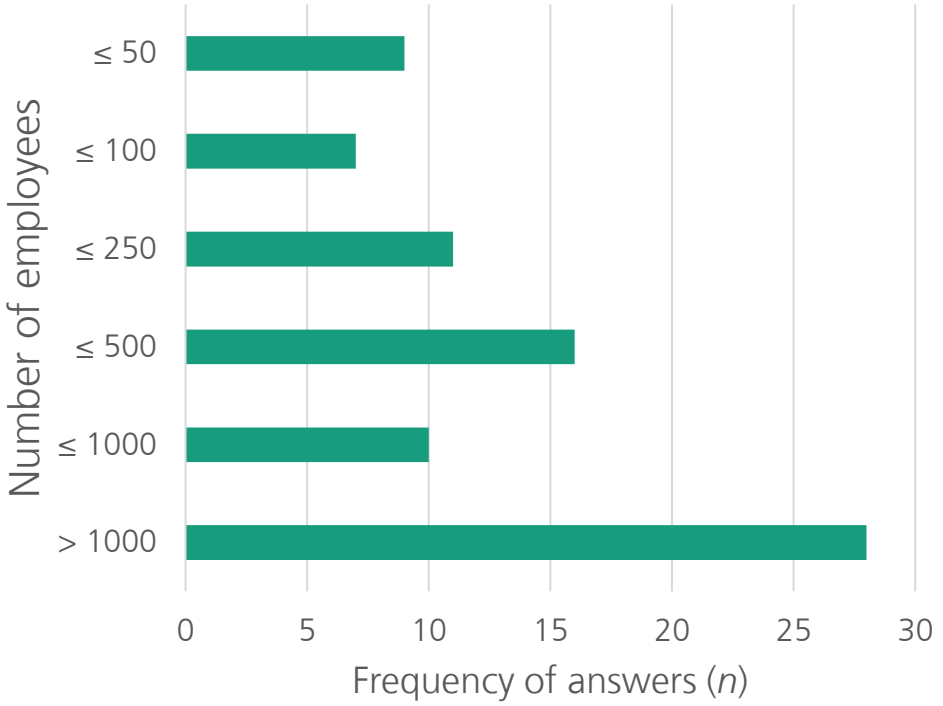
Results from online survey – demographic variables

We reached a diverse sample of German energy-intensive companies

In which sector is your company located?



How many employees work in your company?



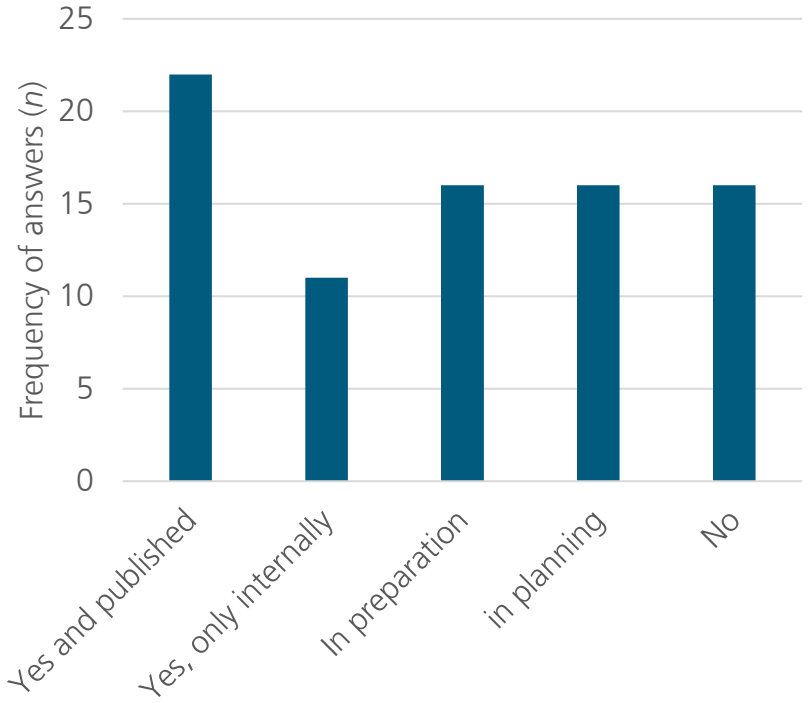
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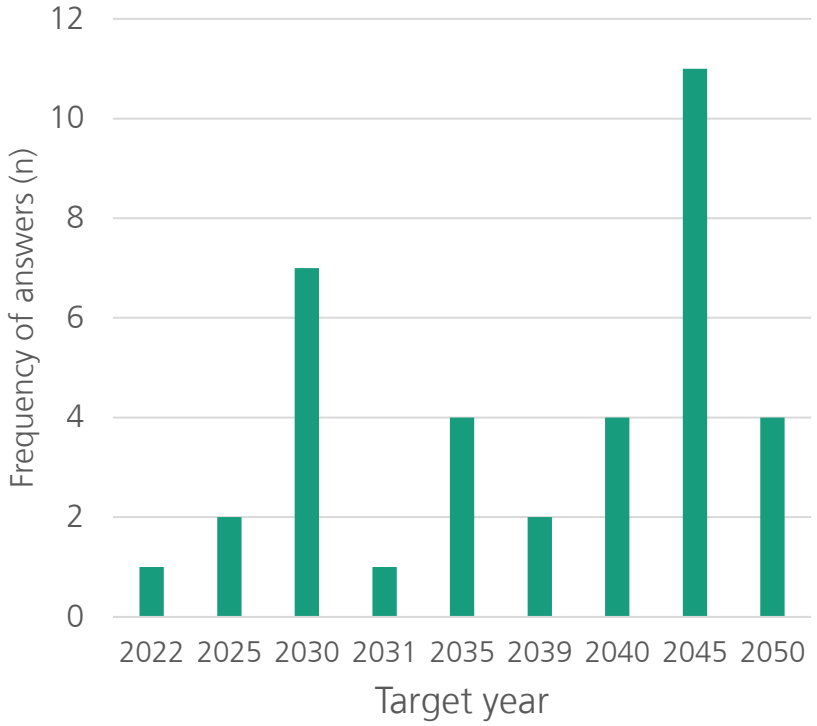
Climate-neutrality strategies

Companies are at different stages of progress in their ambitions for climate-neutrality

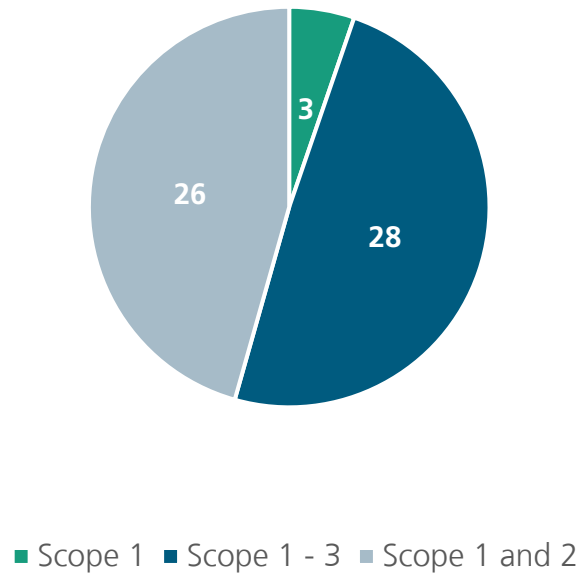
Has your company already formulated a climate neutrality strategy?



By what target year does your company intend to achieve climate-neutral production?



Which scopes are covered by your company's climate neutrality strategy?



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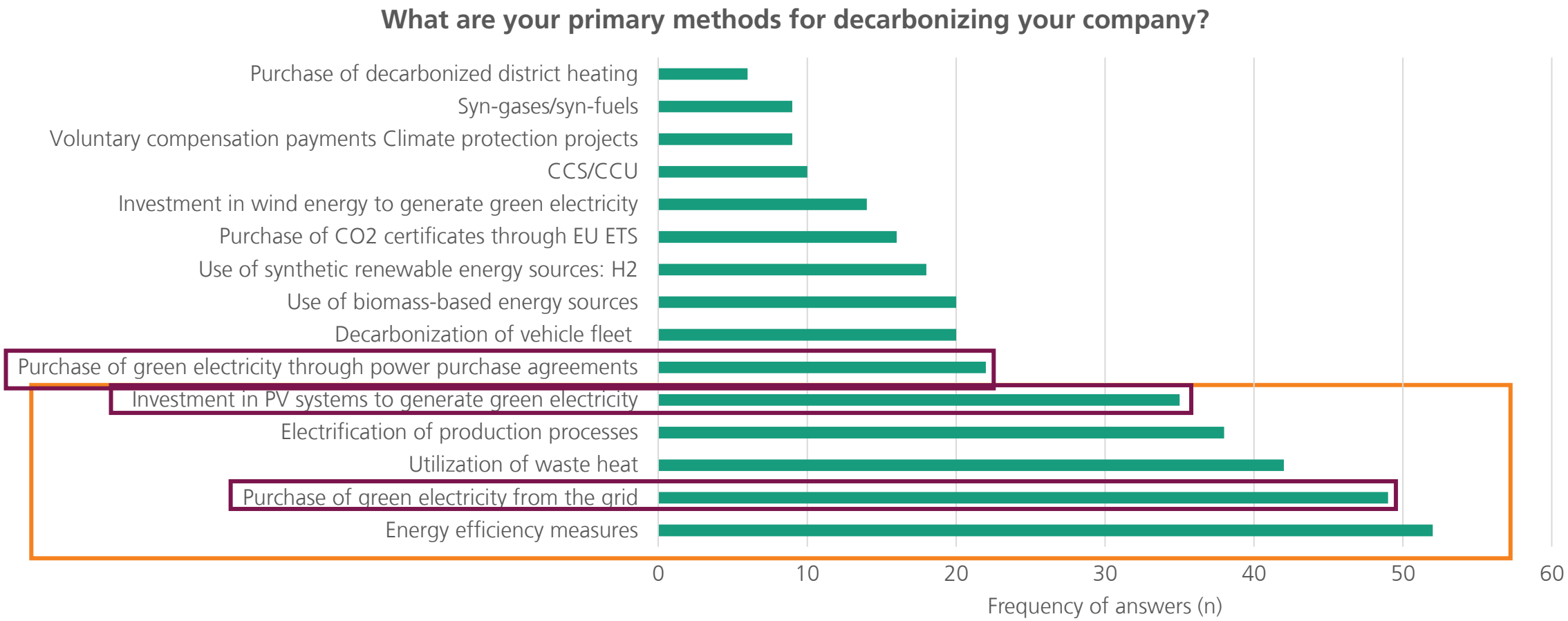
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More than 50% of our sample indicated to have invested in the decarbonization of their production processes already.

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Targeted methods for decarbonization

Green electricity, efficiency measures and direct electrification are the most relevant methods

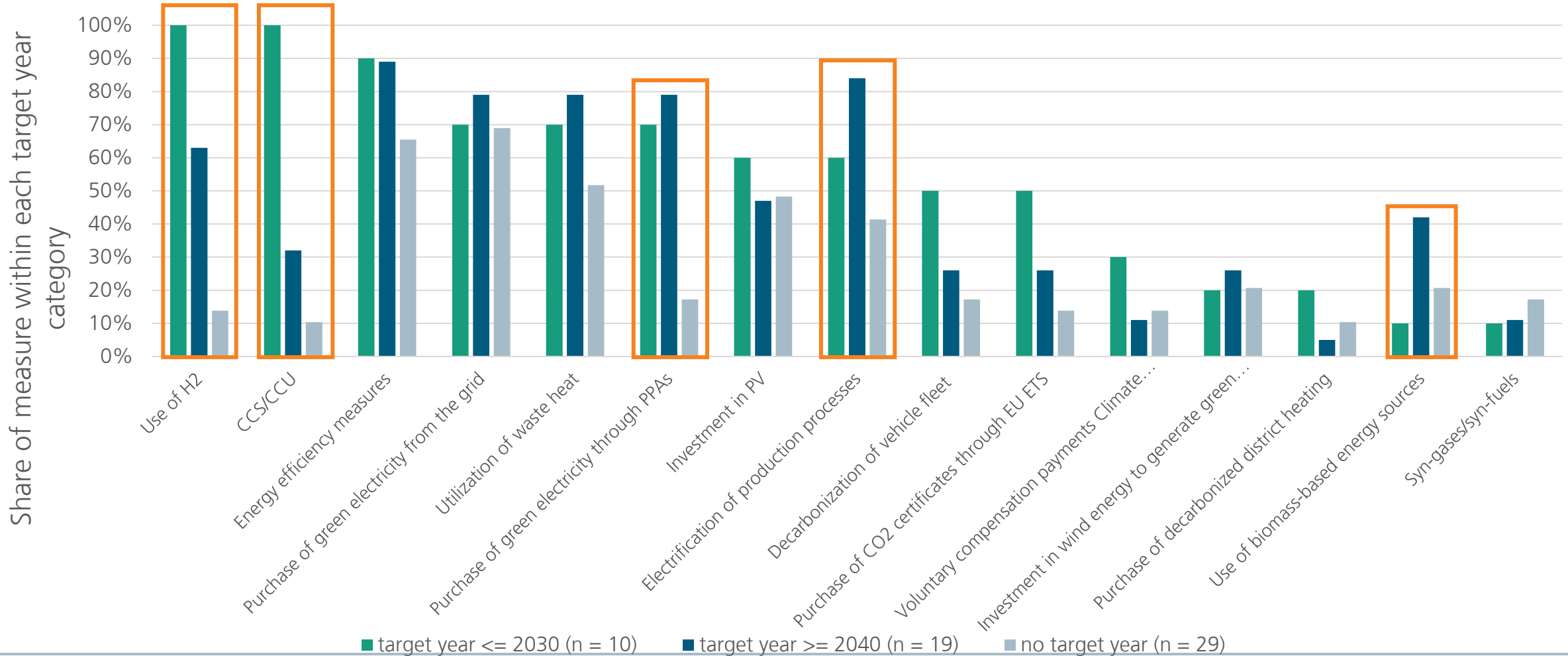


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Targeted methods for decarbonization – depending on strategy

How do the climate neutrality strategies differ between companies with no target year, 2030 vs. 2045?

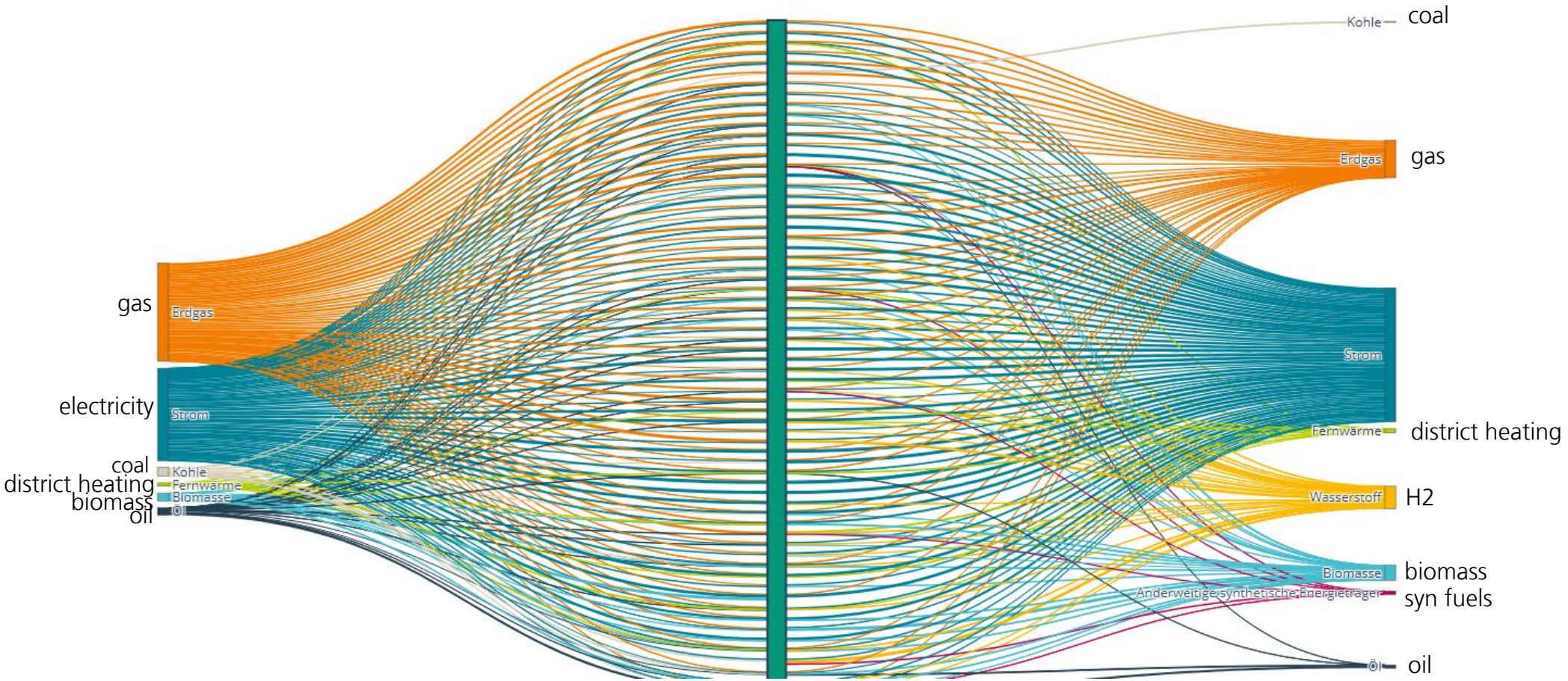


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Use of energy sources – today and future in comparison

Fewer companies use gas, oil, and coal in the future, increases in biomass, hydrogen, and syngases/fuels

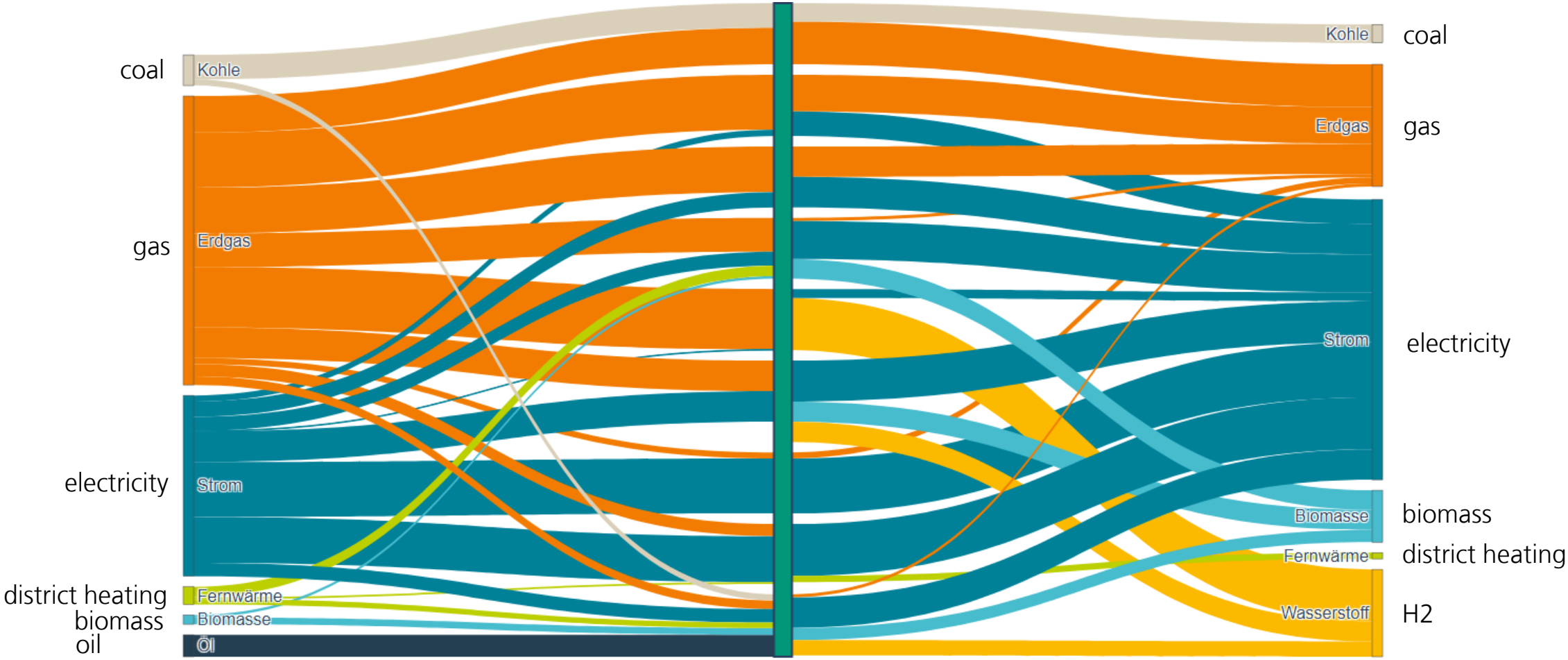


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Energy sources in pulp & paper industry – today and future in comparison

Less gas and coal in the future, increases in electricity, biomass, hydrogen



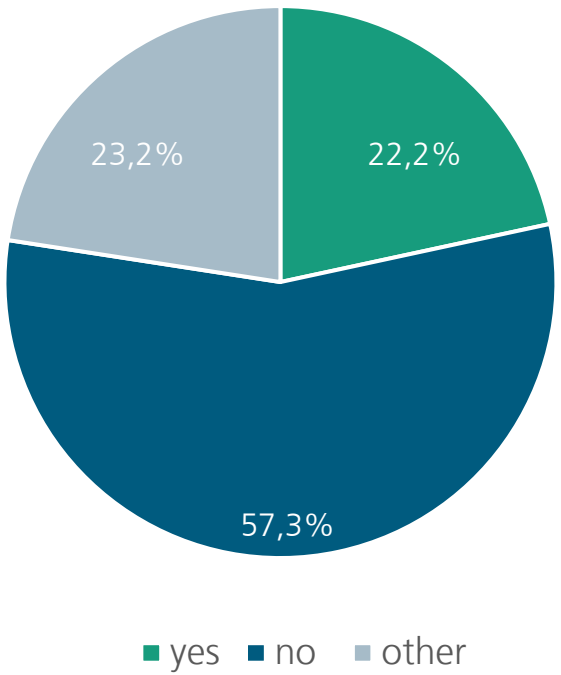
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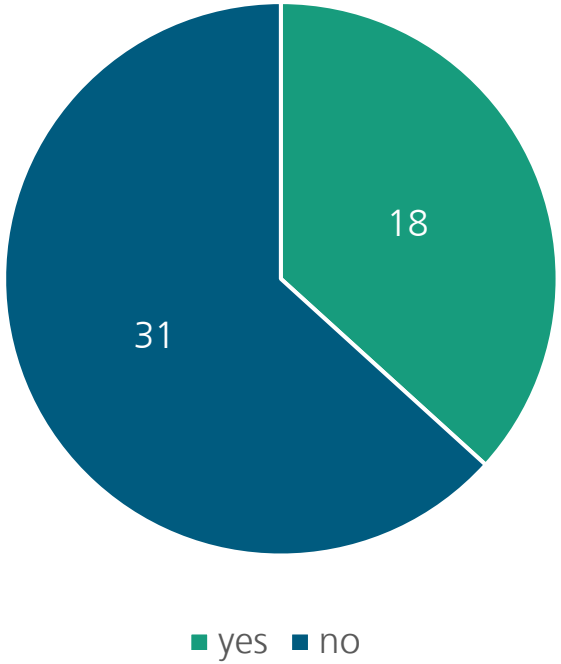
Flexibilization of industrial processes

However, only few companies currently consider demand response as relevant topic for the future.

Demand response is already applied

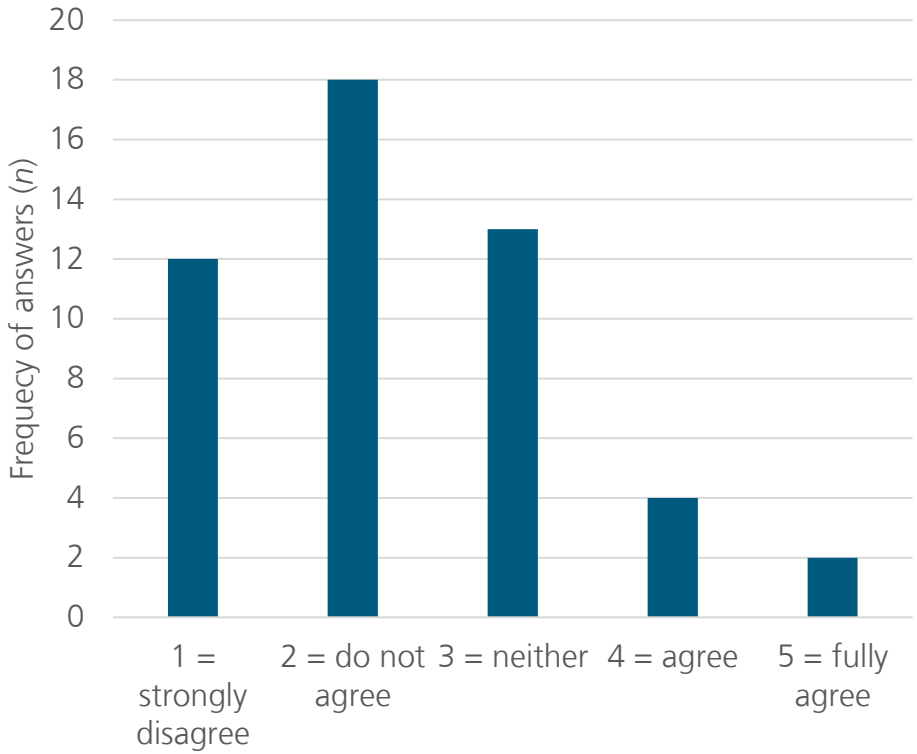


From no and other: has already looked into demand response.*



* Only companies that indicated no or other

"Flexibilization of industrial processes will be a relevant topic in the future."

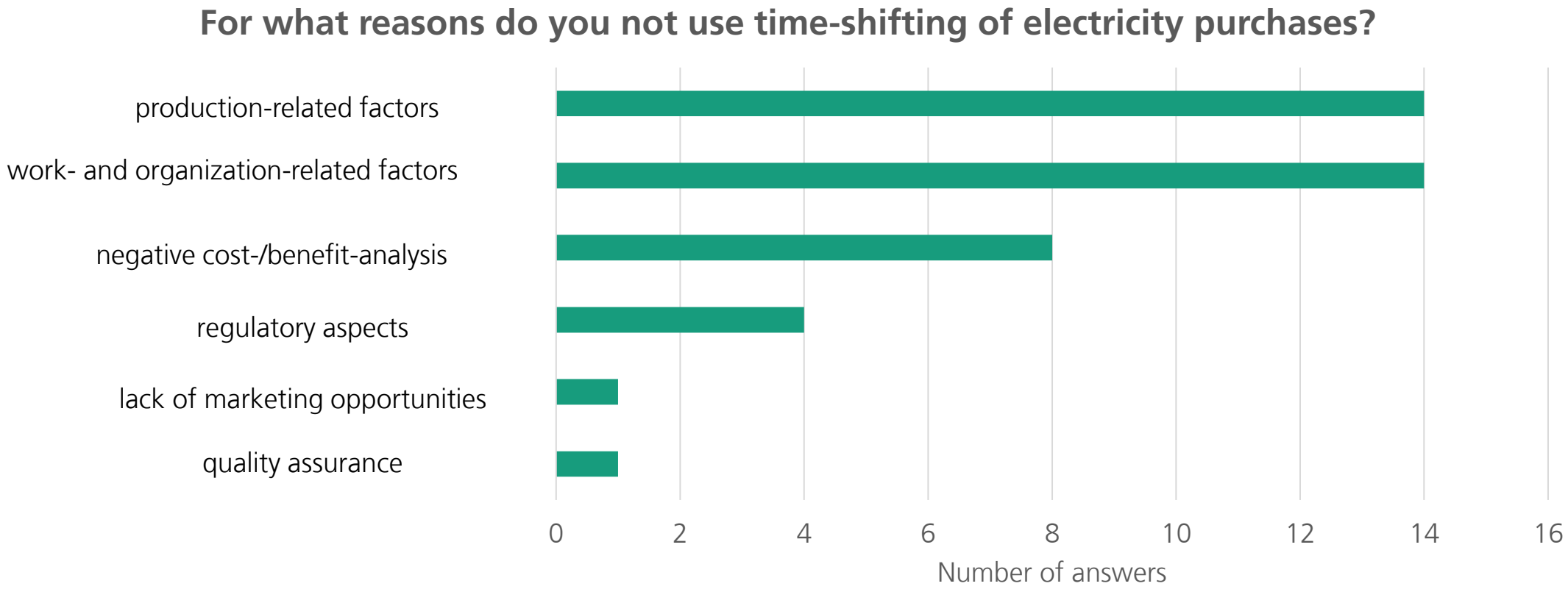


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Demand response

Reasons against time-shifting of electricity purchases



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Demand response

Why shifting the timing of electricity consumption is problematic for production

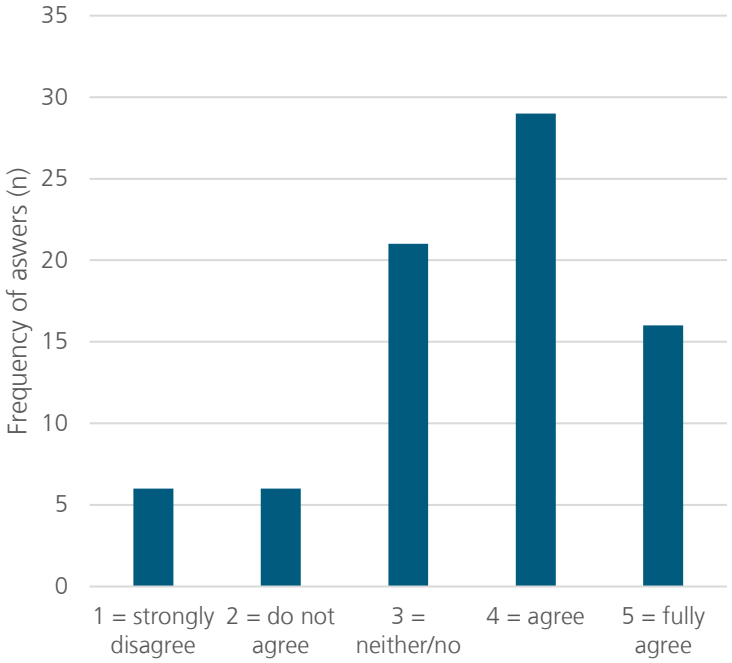
- **The order situation is crucial and so is personnel planning in the plant. This cannot be adjusted too spontaneously.**
- **24/7 production**
- **Ideally, an expensive production plant should run around the clock from Sunday night to Friday evening.**
- **You can't simply not produce when there is no electricity or no cheap electricity. You would then need overcapacities to be able to produce when there is supply. Who pays me for this overcapacity when I'm not producing?**
- **All-day operation** / three-shift operation anyway;
- no operating permit for night work (hammer mill)
- **Interlinked processes with hot transfers**
- **Working time regulations / laws**
- **High production pressure.** Flexibility is possible in the form of a cold store and, in future, electric steam generation with corresponding buffer capacities.
- **Two-shift operation**
- **Too few employees**

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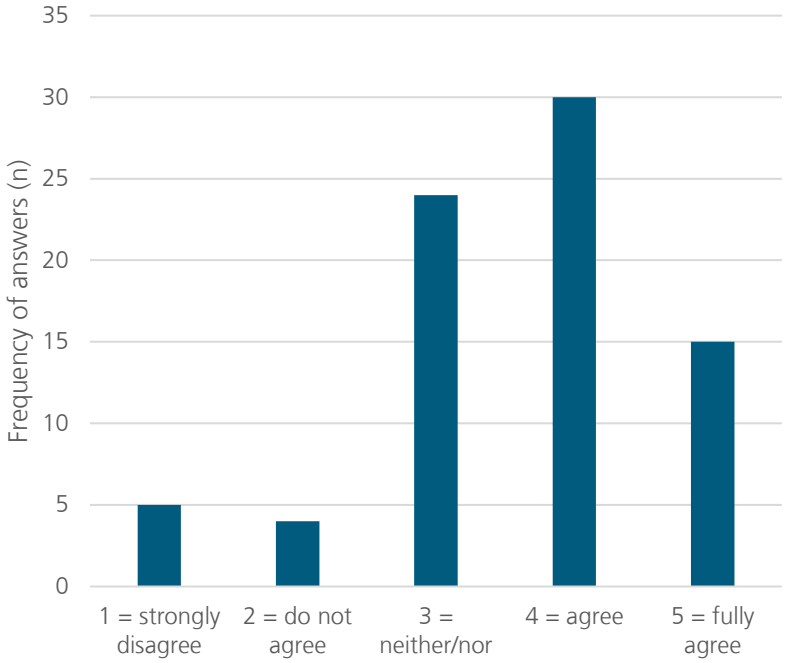
Nevertheless: Extrinsic motivation to act

External pull factors are on!

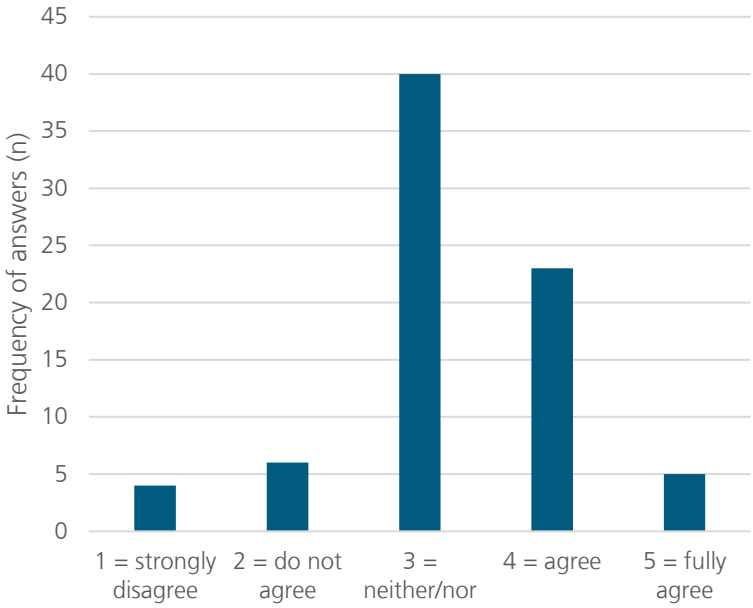
Society expects my company to switch to climate-neutral production.



Our customers expect my company to switch to climate-neutral production.



Other companies in our industry are showing great ambition to decarbonize their industrial processes.



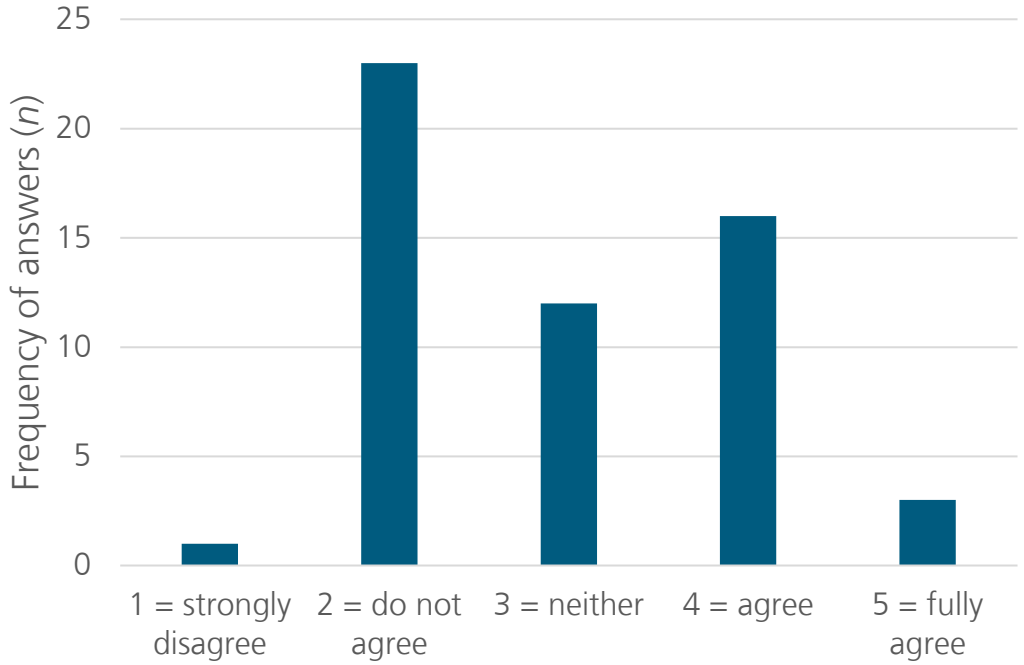
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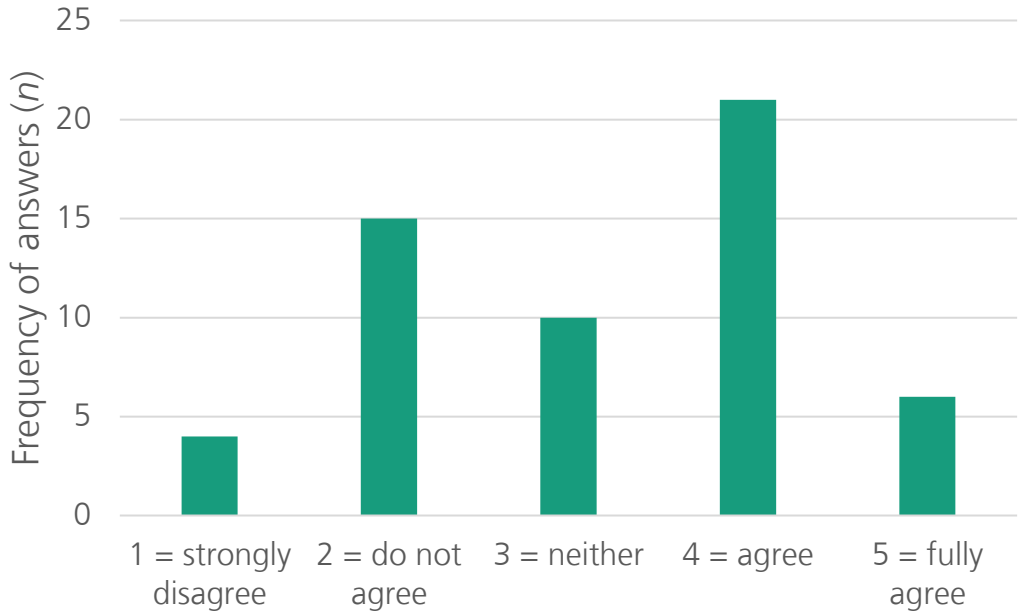
Early replacement of fossil technology

Many companies are willing to replace technology before end-of-life

My company strives to use the technologies/processes used until their respective end of life.



An early replacement of our fossil-fueled technologies/processes (before the end of their product life) is an option for my company.



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Conclusion

- Direct electrification and efficiency measures seem to be on the agenda of parts of energy-intensive industries
- Many companies have already invested in the decarbonization of their production processes –> mostly electrification and efficiency measures but might also indicate selection bias
- German energy-intensive industry faces many barriers, not only technical and financial but also organizational ones
- Overall, demand response currently not considered a relevant topic (might change in the future)
- SMEs require additional support for the transformation
- Planning security regarding availability H2 and green electricity, sufficient grid connection capacity, crucial

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Bibliography

Buhl H.U., Gabrek N., Gerdes J., Kaymakci C., Rauland K., Richter F., Sauer A., Schneider C., Schott P., Seifermann S., Tristán A., Wagner J., Wagon F., Weibelzahl M., Weissflog J., & Zachmann B. (2021). Industrial Flexibility Options and their Applications in a Future Energy System. Fraunhofer FIT, St Augustin. hiips://doi.org/10.24406/fit -n-639062

Eurelectric (2014). Flexibility and Aggregation: Requirements for their interaction in the market. Union of the Electricity Industry, Brussels. hiips://www.usef.energy/app/uploads/2016/12/EURELECTRIC -Flexibility-and-Aggregation-jan-2014.pdf

Fridgen, G., Keller, R., Thimmel, M., & Wederhake, L. (2017). Shifting load through space–the economics of spatial demand side management using distributed data centers. *Energy Policy 109*, 400-13.

Heffron, R., Körner, M.-F., Wagner, J., Weibelzahl, M., & Fridgen, G. (2020). Industrial demand-side flexibility: A key element of a just energy transition and industrial development. Applied Energy 269, 115026.

Kleinertz, B., Gruber, A., Veltengruber, F., Kolb, M., & von Roon, S. (2019). Flexibility potential of industrial thermal networks through hybridization. 11. Internationale Energiewirtschaftstagung an der TU Wien (IEWT).

Koenig, W. (2020). Energy efficiency in industrial organizations – A cultural-institutional framework of decision-making. *Energy Research & Social Science 67*, 101483.

Luderer, G., Bartels, F., Blesl, M., Burkhardt, A., Edenhofer, O., Fahl, U., Gillich, A., Herbst, A., Hufendiek, K., Kaiser, M., Kittel, L., Koller, F., Kost, C., Pietzcker, R., Rehfeldt, M., Schreyer, F., Seibert, D., & Sievers, L. (2022). Deutschland auf dem Weg aus der Gaskrise: Wie sich Klimaschutz und Energiesouveränität vereinen lassen. Kopernikus-Projekt Ariadne, Potsdam. hiips://doi.org/10.48485/pik.2022.004

Palensky, P., & Dietrich, D. (2011). Demand side management: demand response, intelligent energy systems, and smart loads. *IEEE IEEE Transactions on Industrial Informatics 7*(3), 381-8.

Scharnhorst, L., Sloot, D., Lehmann, N., Ardone, A., & Fichtner, W. (2024). Barriers to demand response in the commercial and industrial sectors – An empirical investigation. *Renewable and Sustainable Energy Reviews 190*, 114067. hiips://doi.org/10.1016/j.rser.2023.114067

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IND-E Project overview and acknowledgements

Decarbonization and electrification potential in German industry: data, players and models

Overall targets

- Electrification and flexibility potentials of German energy-intensive industry
- Identification of transformation pathways

Duration

- March 2021 – August 2024

Acknowledgements

- We would like to express our sincere gratitude to the entire project team fo their support in designing and disseminating the questionnaire survey. Furthermore, we thank the BMWK for providing the grant.

Gefördert durch:

Bundesministerium für Wirtschaft und Technologie

aufgrund eines Beschlusses des Deutschen Bundestages

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