Flex4RES
Flexible Nordic Energy Systems

DTU

State of the art in the States: Applying an analytic framework for flexibility in US district energy systems

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4th International Conference on Smart Energy Systems and 4th Generation District Heating

13 November 2018

DARTMOUTH

norden
Nordic Energy Research

Agenda

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PART I
- Defining flexibility

PART II
- Defining a taxonomy for barriers

PART III
- Applying a taxonomy for barriers

PART IV
- Concluding remarks

PART I

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DEFINING FLEXIBILITY

Motivation

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Flexible district energy exists. But not all over.

“If something exists, then it must be possible”

- Boulding’s first law

Finding out why: Barriers for integration of variable renewable energy with DE systems

DISTRICT ENERGY = DISTRICT HEATING + COOLING + (ELEC.)

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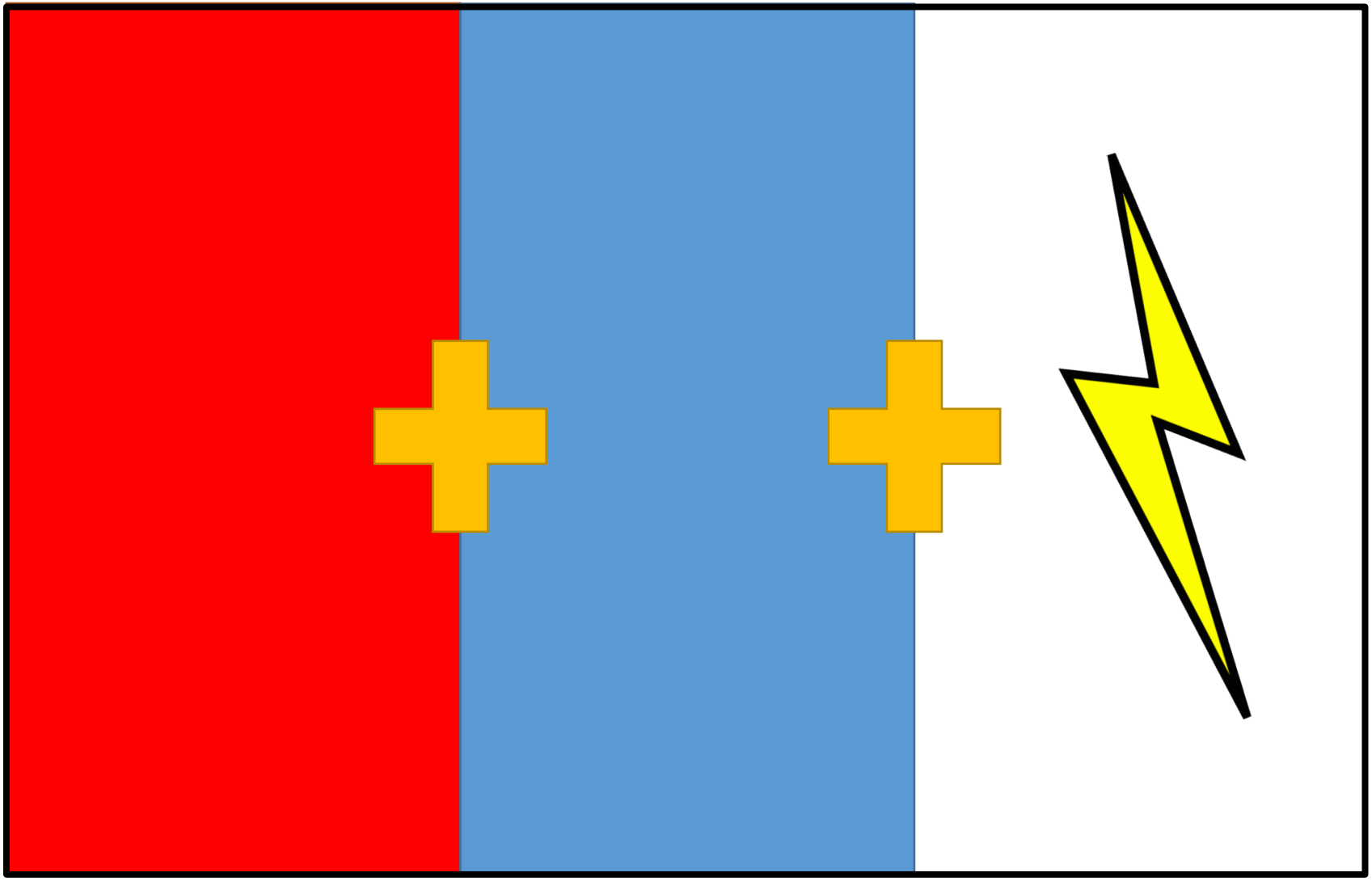

PRACTICE: DE can operate on market

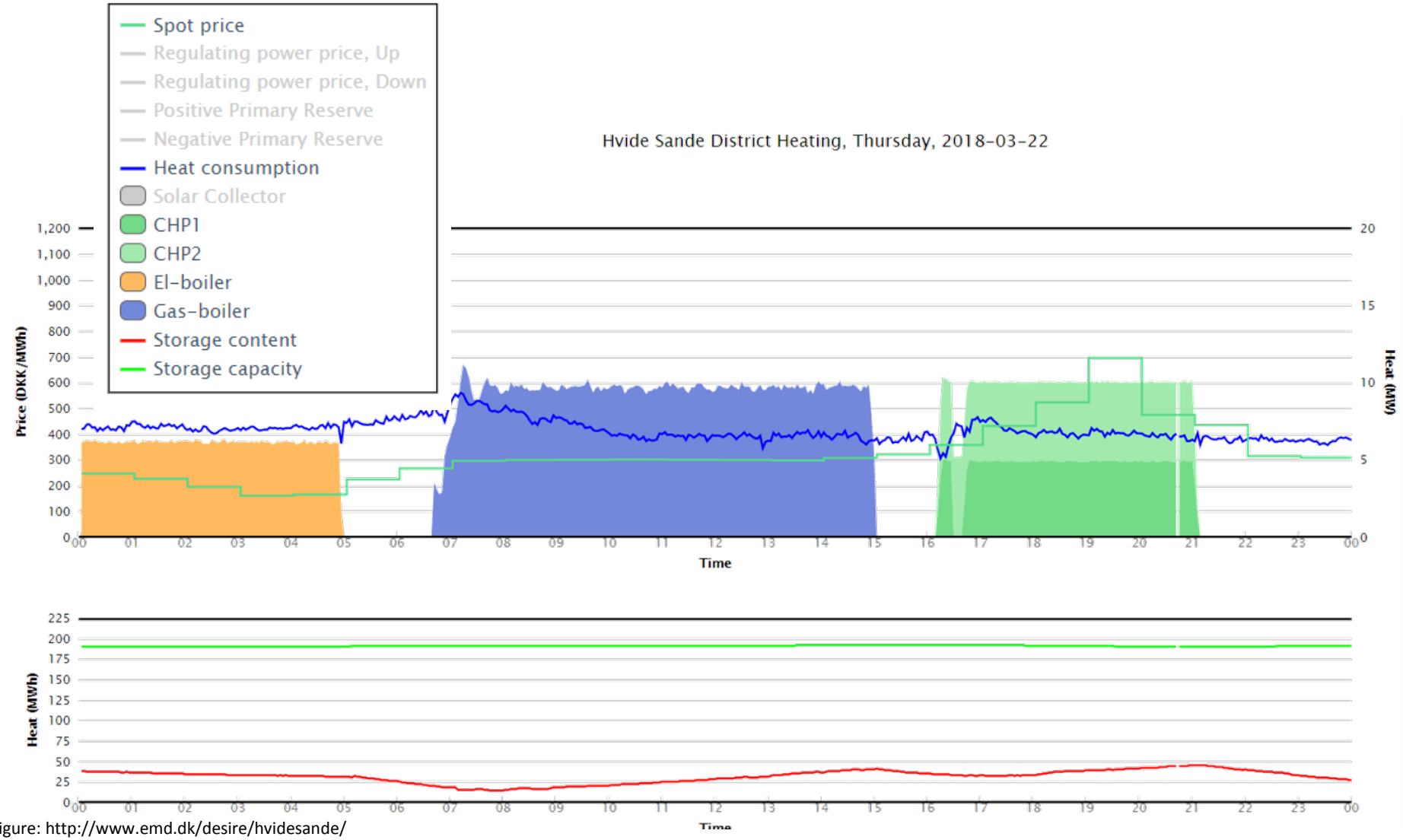

Figure: http://www.emd.dk/desire/hvidesande/

PRACTICE: DE can integrate renewables

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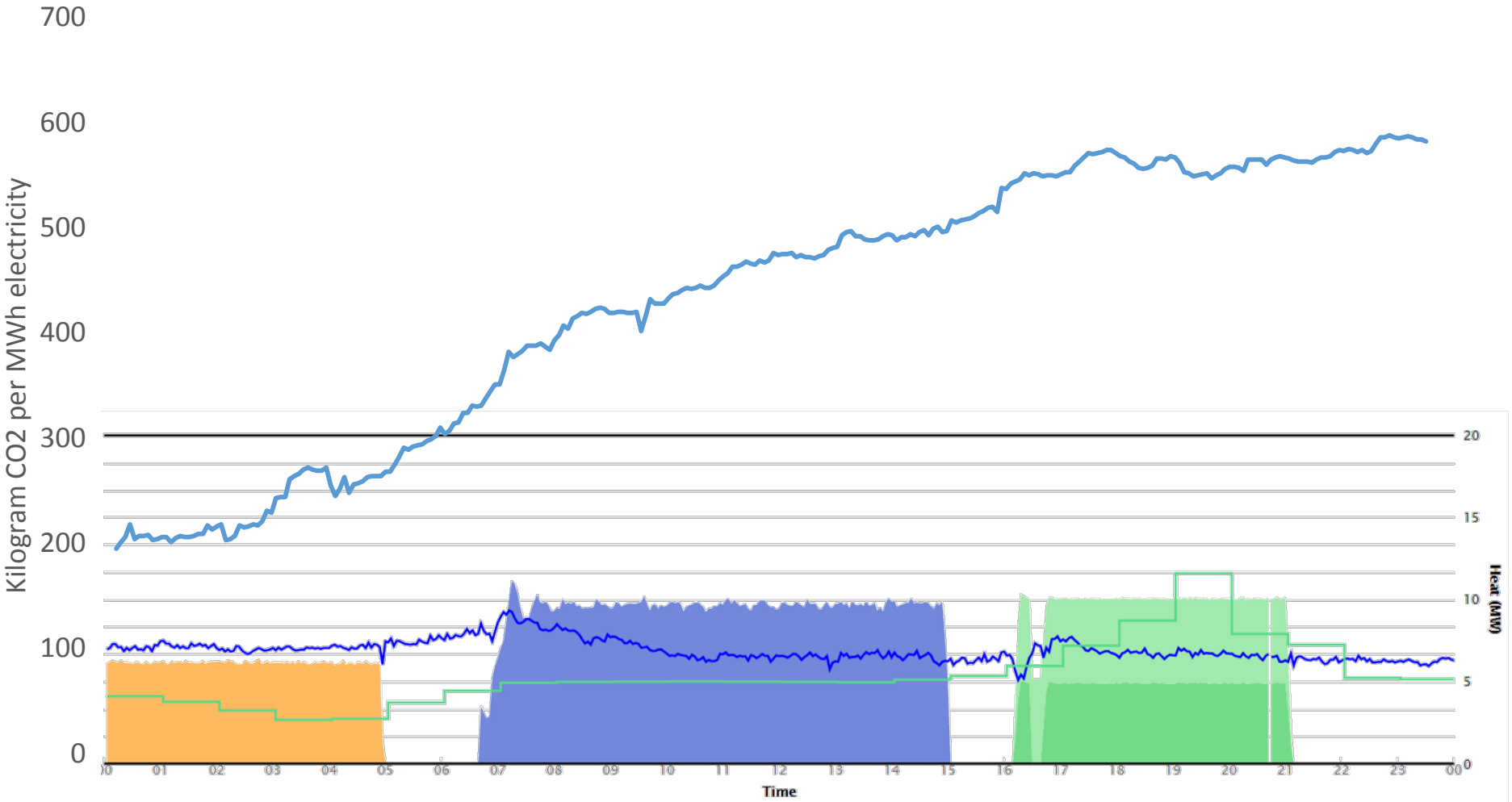

Figures: http://www.emd.dk/desire/hvidesande/ and https://www.energidataservice.dk

PART II

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DEFINING A TAXONOMY FOR BARRIERS

Barrier characteristics

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Technologies
Heat-only boiler
Heat pump
Electric boiler
CHP
Heat storage

Barrier categories

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Barrier category	Barrier sub-category	References
Economic	Financing and technology risk Investment subsidies	[1-15,17-22]

Combined: Taxonomy

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Barrier category	Barrier sub-category	Barrier name	Under which conditions is it a barrier?	Which technologies are affected?	Where in the project life cycle is the impact?	Which decision-level does the barrier stem from?
Economic						
Operational signalling						
Permitting						
Technological						
Physical						
Bounded rationality						
Commitment						

PART III

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APPLYING THE TAXONOMY FOR BARRIERS ON US DE SYSTEMS

Heat delivery (2014) and deployment

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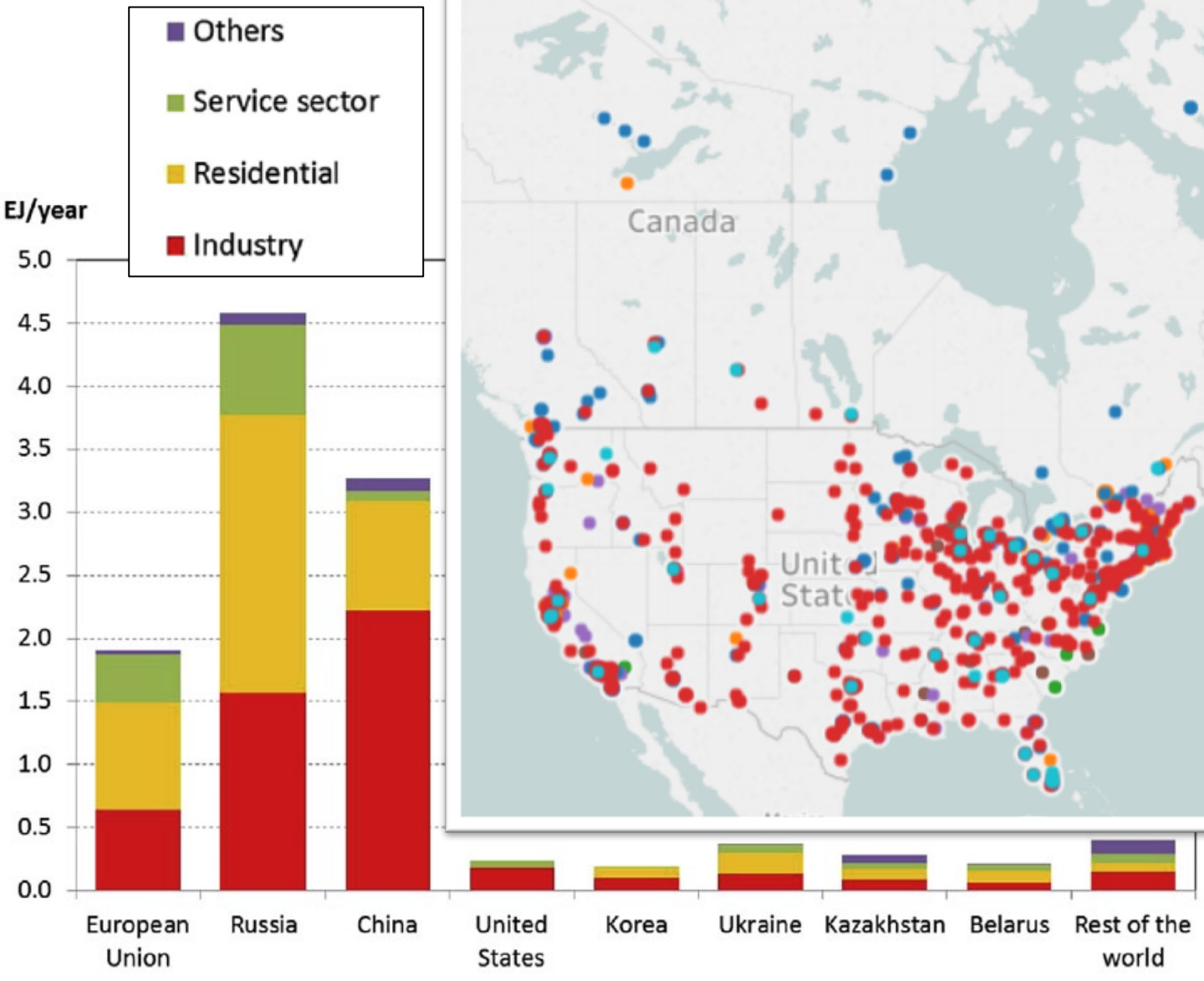

https://www.districtenergy.org/resources/resources/system-maps

S. Werner, International review of district heating and cooling, Energy. 137 (2017) 617–631. doi:10.1016/j.energy.2017.04.045.

District energy in the Northeast

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Ivy
- Dartmouth College
- University of Pennsylvania
- Harvard University
- Yale University
- Columbia University
- Princeton University

Other unis
- U Massachusetts
- University of Vermont
- MIT
- University of Pittsburgh

Experts
- E. Haub School of Law
- IDEA
- eco(n)law - Baird Brown
- Renewable Thermal Alliance

ISO/RTO
- ISO New England
- PJM Interconnection

10 universities – 100+ years DE systems
- Green policies

4 experts

2 ISO/RTO

BARRIERS IDENTIFIED IN 10 US UNIVERSITY DE SYSTEMS

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Conditions in the DE-electricity interface	Sub-category	Barrier name	Technology type	Project life cycle	Level of origin
Operational signalling	*Electricity grid tariffs and utility rates*	Signals limited by utility rate structure	CHP and P2H	Operation phase	Regional
-	-	Prices too low to incentivise flexibility	All	Operation phase	Regional
-	*Energy markets*	Access to markets important	CHP and P2H	Operation phase	Regional
Economy	*Financing and technology risk*	Limited ability to self-finance due to lack of understanding from rating agencies	All	Investment and financing phase	Service and technology providers
-	-	Limited funds	All	Investment and financing phase	In plant/on premises
Permitting	*Other regulatory conditions*	Transition from attractive to less attractive regulatory regime	CHP and P2H	Operation phase	National
Technology	*Cost and technological maturity*	Hot water conversion limited by cost	Thermal storage	Tendering phase	Service and technology providers
Physical	*Land availability*	Limited land available for thermal storage	Thermal storage	Planning phase	In plant/on premises
Stakeholder bounded rationality	*Institutional bounded rationality*	Hot water conversion constrained by limited information	Thermal storage	Feasibility study phase/Scoping phase	In plant/on premises
-	-	Limited understanding of benefits of flexibility	All	Operation phase	In plant/on premises
Stakeholder commitment	*Institutional commitment*	Buying indulgences instead of local action	All	Operation phase	In plant/on premises
-	-	Humans in the electricity consumption/production loop for security	CHP and P2H	Operation phase	In plant/on premises
-	-	Humans in the loop for optimal operation	CHP and P2H	Operation phase	In plant/on premises
-	*Individual commitment*	Lacking sense of need	CHP and P2H	Operation phase	In plant/on premises

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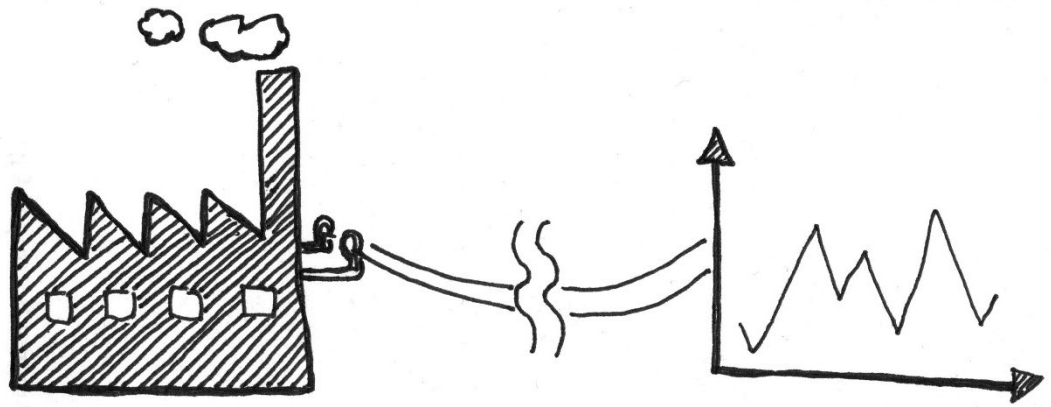

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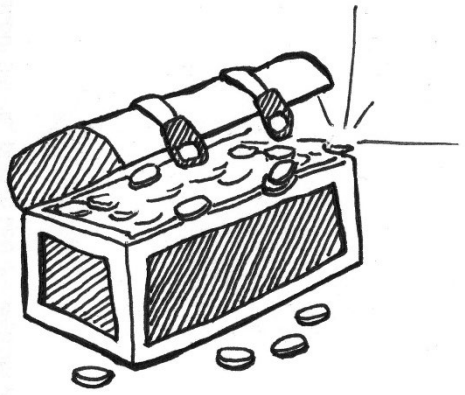

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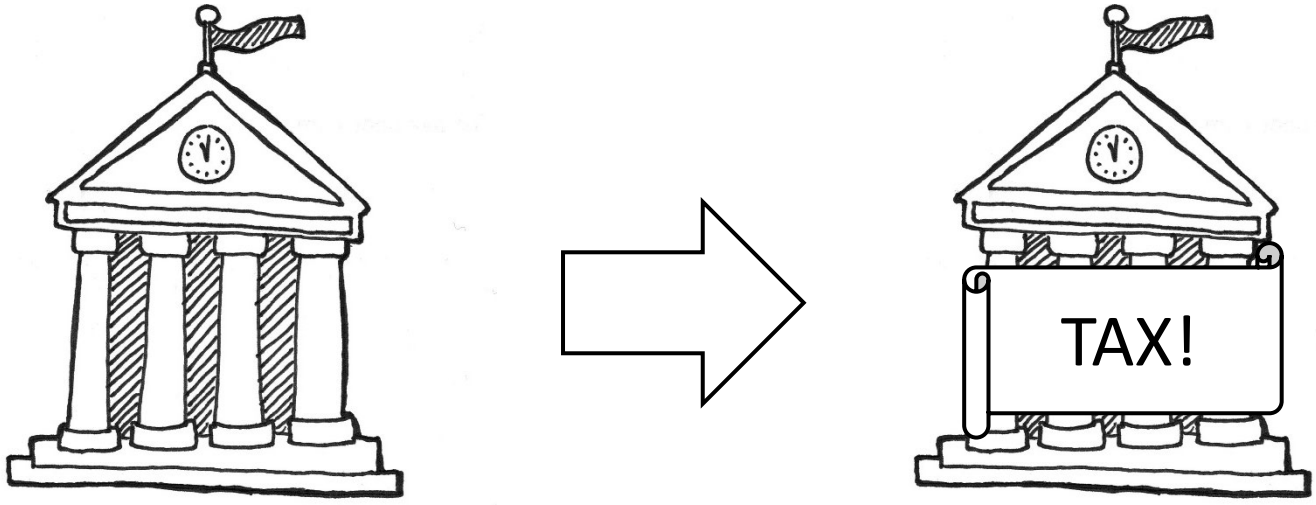

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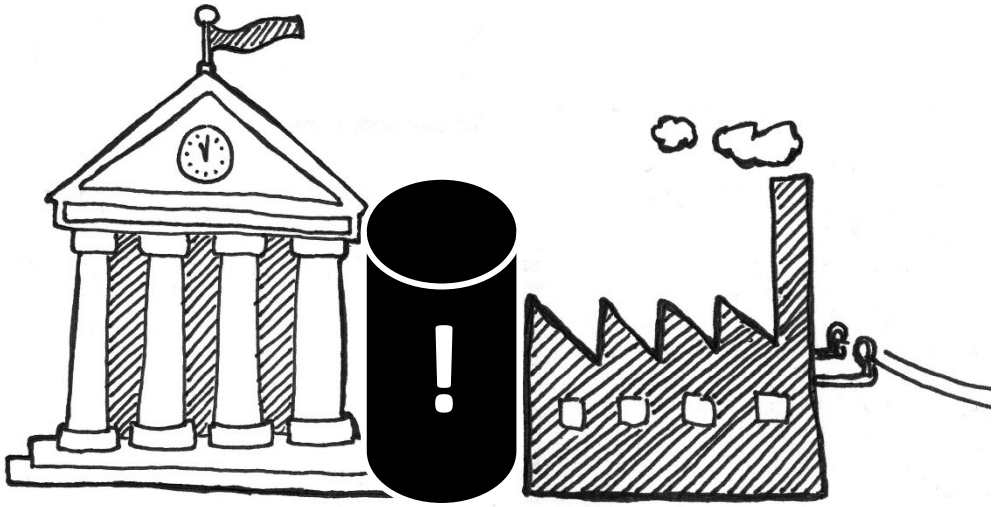

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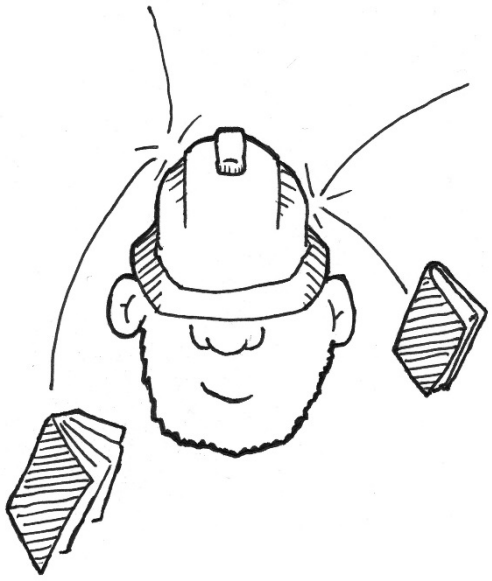

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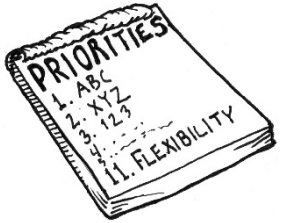

PART IV

CONCLUDING REMARKS

Testing the taxonomy on US DE

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Robust taxonomy: Caught most; few new

…but never finished

Getting more flexible US DE

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Plants' priorities: Safe, cheap, green

Give them

- Signals and incentives – markets/tariffs
- Water – thermal storages important
- Information – costs, opportunities, technologies

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www.Flex4RES.org

References – taxonomy structure

[1] J. Steinbach, E. Popovski, T. Fleiter, E. Chassein, I. Bedoya, Policy recommendations to decarbonise European heating and cooling systems, 2017.

[2] S. Leete, J. Xu, D. Wheeler, Investment barriers and incentives for marine renewable energy in the UK: An analysis of investor preferences, Energy Policy. 60 (2013) 866–875. doi:10.1016/j.enpol.2013.05.011.

[3] C. Bergaentzle, K. Skytte, E.R. Soysal, L. Boscan, O.J. Olsen, Regulatory barriers for activating flexibility in the Nordic-Baltic electricity market, Int. Conf. Eur. Energy Mark. EEM. (2017). doi:10.1109/EEM.2017.7981948.

[4] M.A. Brown, D.M.S. Building, B.K. Sovacool, Barriers to the diffusion of climate-friendly technologies, Int. J. Transf. Commer. 10 (2011) 43–62. doi:10.1504/IJTTC.2011.038453.

[5] International Renewable Energy Agency, Renewable Energy in District Heating and Cooling: A sector roadmap for REmap, Abu Dhabi, 2017.

[6] F. Hvelplund, P.A. Østergaard, N.I. Meyer, Incentives and barriers for wind power expansion and system integration in Denmark, Energy Policy. 107 (2017) 573–584. doi:10.1016/j.enpol.2017.05.009.

[7] F. Mosannenzadeh, M.R. Di Nucci, D. Vettorato, Identifying and prioritizing barriers to implementation of smart energy city projects in Europe: An empirical approach, Energy Policy. 105 (2017) 191–201. doi:10.1016/j.enpol.2017.02.007.

[8] I.J. Pérez-Arriaga, Regulation of the Power Sector, 1st ed., Springer-Verlag London, 2013. doi:10.1007/978-1-4471-5034-3.

[9] IEA, The power of transformation, IEA, Paris, 2014. doi:10.1007/BF01532548.

[10] S. Luthra, S. Kumar, R. Kharb, M.F. Ansari, S.L. Shimmi, Adoption of smart grid technologies: An analysis of interactions among barriers, Renew. Sustain. Energy Rev. 33 (2014) 554–565. doi:10.1016/j.rser.2014.02.030.

[11] C. Blumstein, B. Krieg, L. Schipper, C. York, Overcoming social and institutional barriers to energy conservation, Energy. 5 (1980) 355–371. doi:10.1016/0360-5442(80)90036-5.

[12] J.P. Painuly, Barriers to renewable energy penetration: A framework for analysis, Renew. Energy. 24 (2001) 73–89. doi:10.1016/S0960-1481(00)00186-5.

[13] S. Reddy, J.P. Painuly, Diffusion of renewable energy technologies-barriers and stakeholders' perspectives, Renew. Energy. 29 (2004) 1431–1447. doi:10.1016/j.renene.2003.12.003.

[14] J.S. González, R. Lacal-Arántegui, A review of regulatory framework for wind energy in European Union countries: Current state and expected developments, Renew. Sustain. Energy Rev. 56 (2016) 588–602. doi:10.1016/j.rser.2015.11.091.

[15] E. Cagno, E. Worrell, A. Trianni, G. Pugliese, A novel approach for barriers to industrial energy efficiency, Renew. Sustain. Energy Rev. 19 (2013) 290–308. doi:10.1016/j.rser.2012.11.007.

[16] M. Soshinskaya, W.H.J. Crijns-Graus, J.M. Guerrero, J.C. Vasquez, Microgrids: Experiences, barriers and success factors, Renew. Sustain. Energy Rev. 40 (2014) 659–672. doi:10.1016/j.rser.2014.07.198.

[17] U. Collier, Renewable heat policies Delivering clean heat solutions for the energy transition, IEA Publ. (2018). www.iea.org/t&c/.

[18] E. Sandberg, D.M. Sneum, E. Tromborg, Framework conditions for Nordic district heating similarities and differences, and why Norway sticks out, Energy. 149 (2018) 105–119. doi:10.1016/j.energy.2018.01.148.

[19] C. Meath, M. Linnenluecke, A. Griffiths, Barriers and motivators to the adoption of energy savings measures for small- and medium-sized enterprises (SMEs): The case of the ClimateSmart Business Cluster program, J. Clean. Prod. 112 (2016) 3597–3604. doi:10.1016/j.jclepro.2015.08.085.

[20] M. Olsthoorn, J. Schleich, M. Klobasa, Barriers to electricity load shift in companies: A survey-based exploration of the end-user perspective, Energy Policy. 76 (2015) 32–42. doi:10.1016/j.enpol.2014.11.015.

[21] N. Good, K.A. Ellis, P. Mancarella, Review and classification of barriers and enablers of demand response in the smart grid, Renew. Sustain. Energy Rev. 72 (2017) 57–72. doi:10.1016/j.rser.2017.01.043.

[22] S. Sorrell, E. O'Malley, J. Schleich, S. Scott, The economics of energy efficiency, 1st ed., Edward Elgar Publishing Limited, Cheltenham, 2004.

[23] E. Cagno, E. Worrell, A. Trianni, G. Pugliese, A novel approach for barriers to industrial energy efficiency, Renew. Sustain. Energy Rev. 19 (2013) 290–308. doi:10.1016/j.rser.2012.11.007.

[24] W.H. Golove, J.H. Eto, Market Barriers to Energy Efficiency : A Critical Reappraisal of the Rationale for Public Policies to Promote Energy Efficiency, Energy Environ. 26 (1996) 66. doi:10.1177/0042098011427189.

[25] R. Gonzales, Wind Integration for New York ' s Energy Markets New York in Perspective, (2011) 1–18.

THEORY: How can DE integrate renewables/operate on market?

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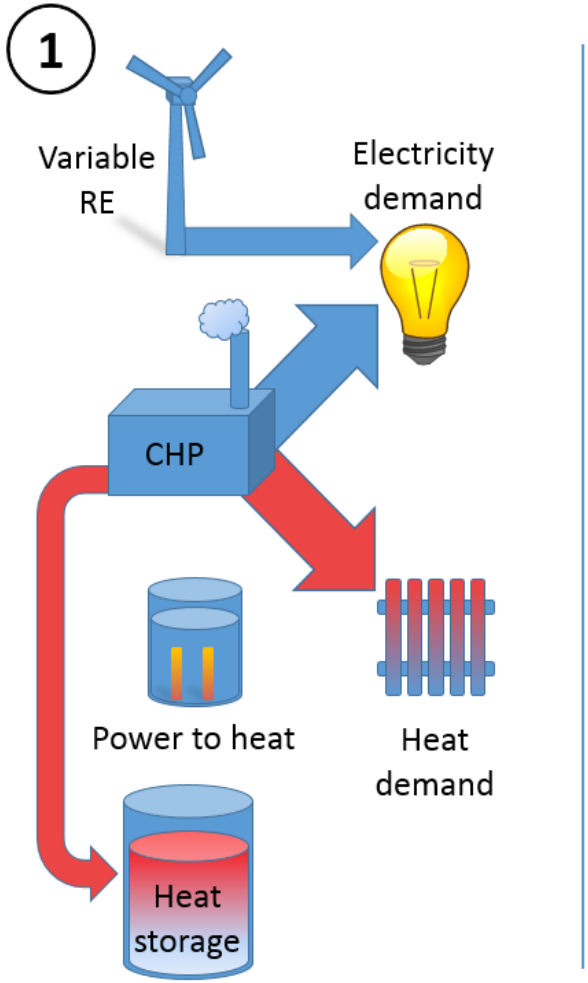
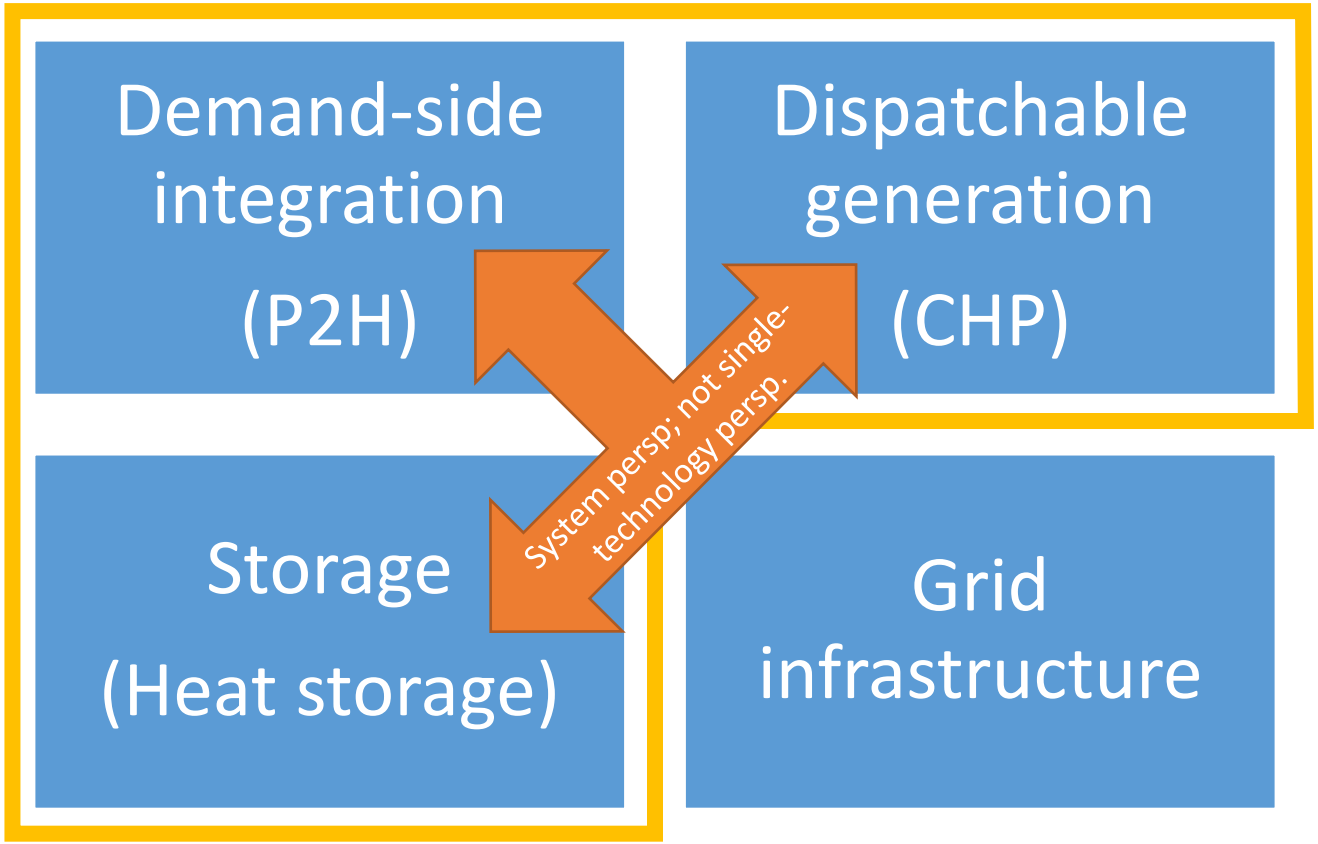


Figure: http://www.nordicenergy.org/wp-content/uploads/2016/10/Flex4RES-WP2-DH-report.pdf

DE does not fit in traditional flexibility definition



As defined in IEA. The power of transformation. Paris: IEA; 2014. doi:10.1007/BF01532548.

EXTRA: Why capacity tariffs can be bad for flexibility

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Example: 10 MW electric boiler, which pays to dispatch when electricity spot price is 7 EUR/MWh

Capacity charge: 12 000 EUR/MW/month

12 000 EUR x 10 MW = 120 000 EUR

10 MW x 3 hours = 30 MWh

120 000 EUR/30 MWh = 4 000 EUR/MWh

Completely infeasible to operate!

For comparison

Standard house 18 MWh/year = 72 000 EUR/year

Results: CHP + electric boiler depends on subsidies

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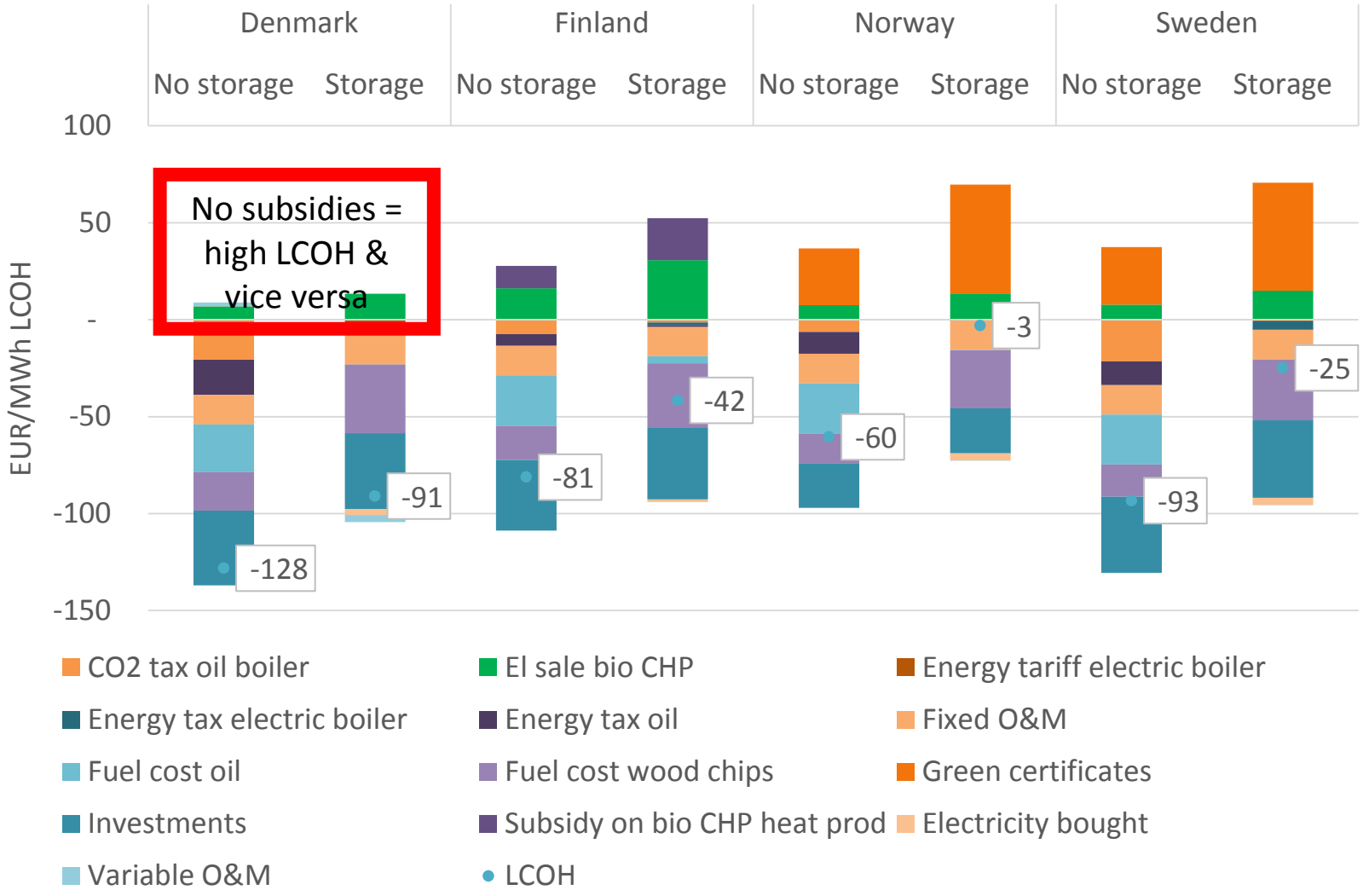

Results: Danish framework hampers investment in flexibility

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LCOH: Production cost of heat, before revenue from consumers

Technology setup	Grid tariff type	Storage	DK
Wood chip CHP + wood boiler			-97
Wood chip CHP + wood boiler			-108
Wood chip CHP + EB	Capacity charge		-91
Wood chip CHP + EB			-128
Wood chip CHP + EB	Energy charge		-91
Wood chip CHP + EB			-128
Wood chip boiler			-73
Wood chip boiler			-86
Wood chip boiler + EB	Capacity charge		-99
Wood chip boiler + EB			-104
Wood chip boiler + EB	Energy charge		-99
Wood chip boiler + EB			-104

DH plants – which are flexible?

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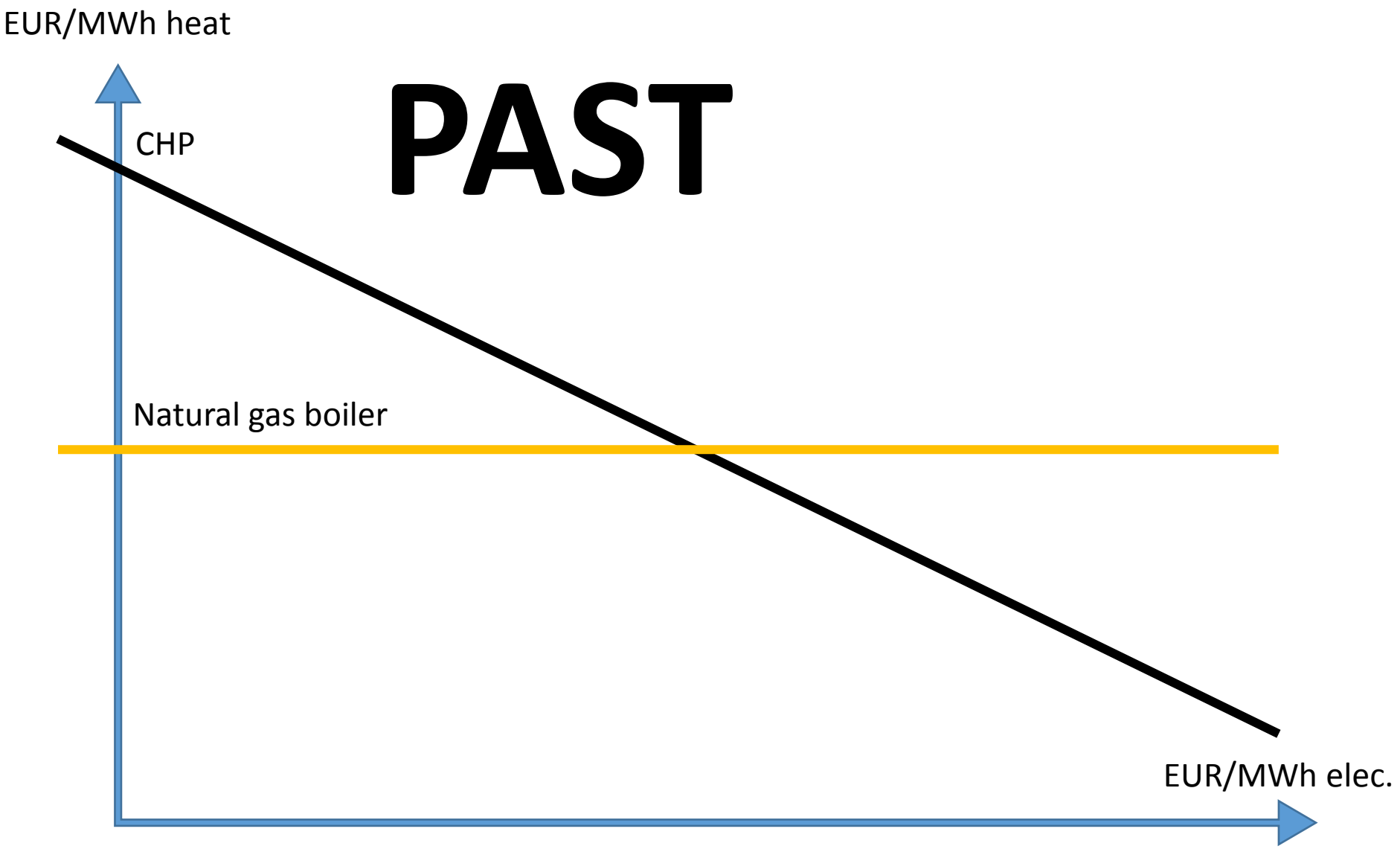

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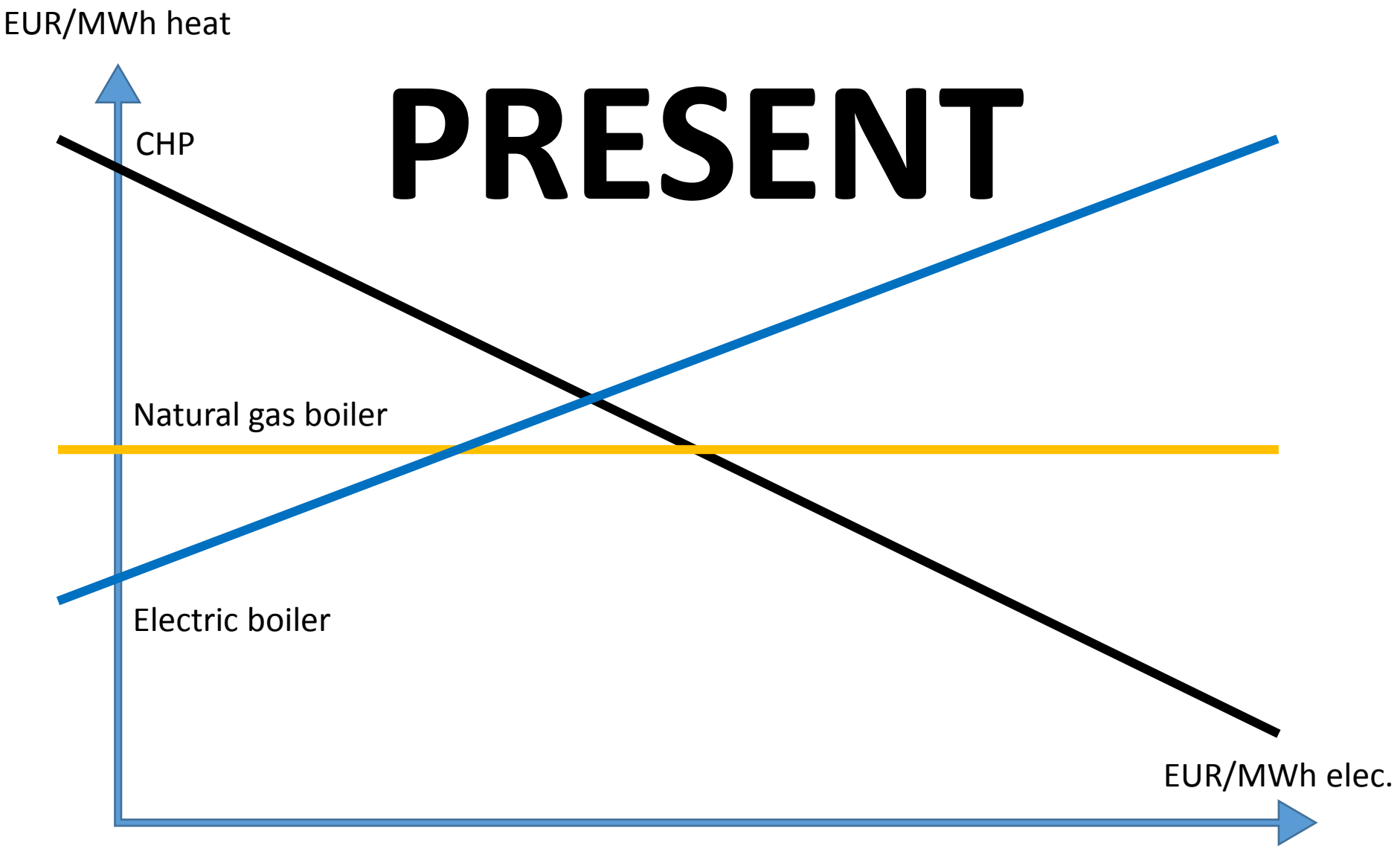

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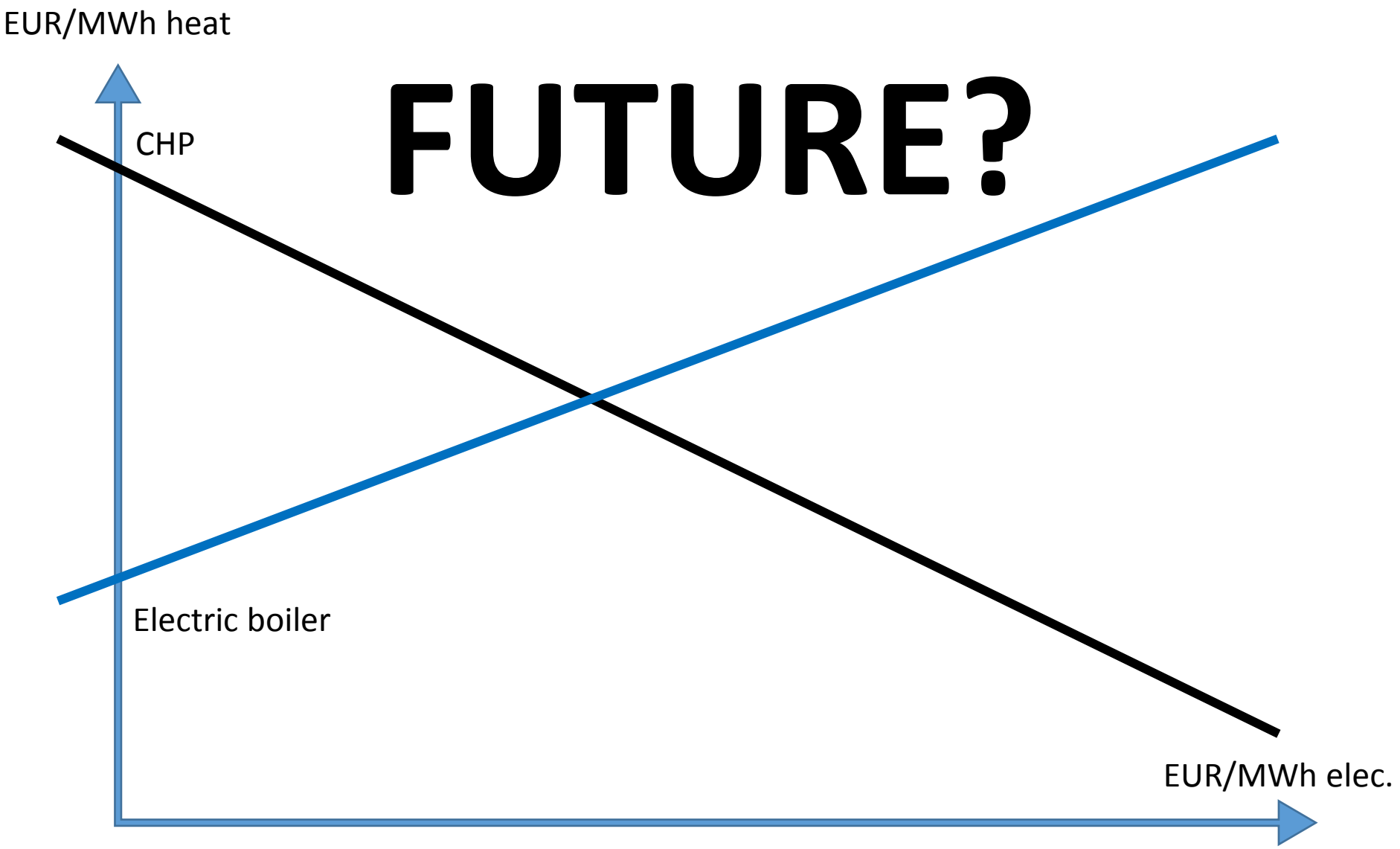

DH plants – which are flexible?

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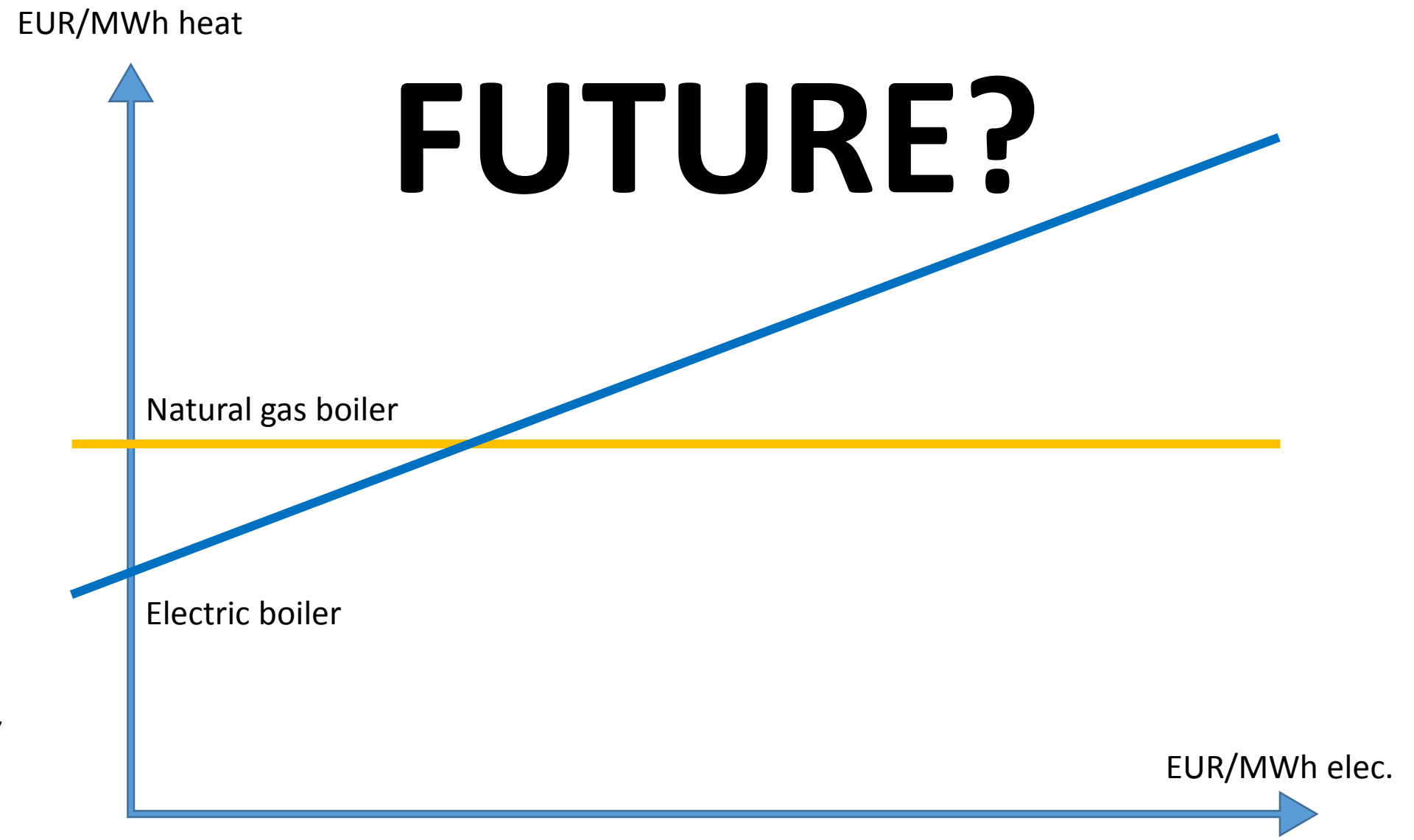

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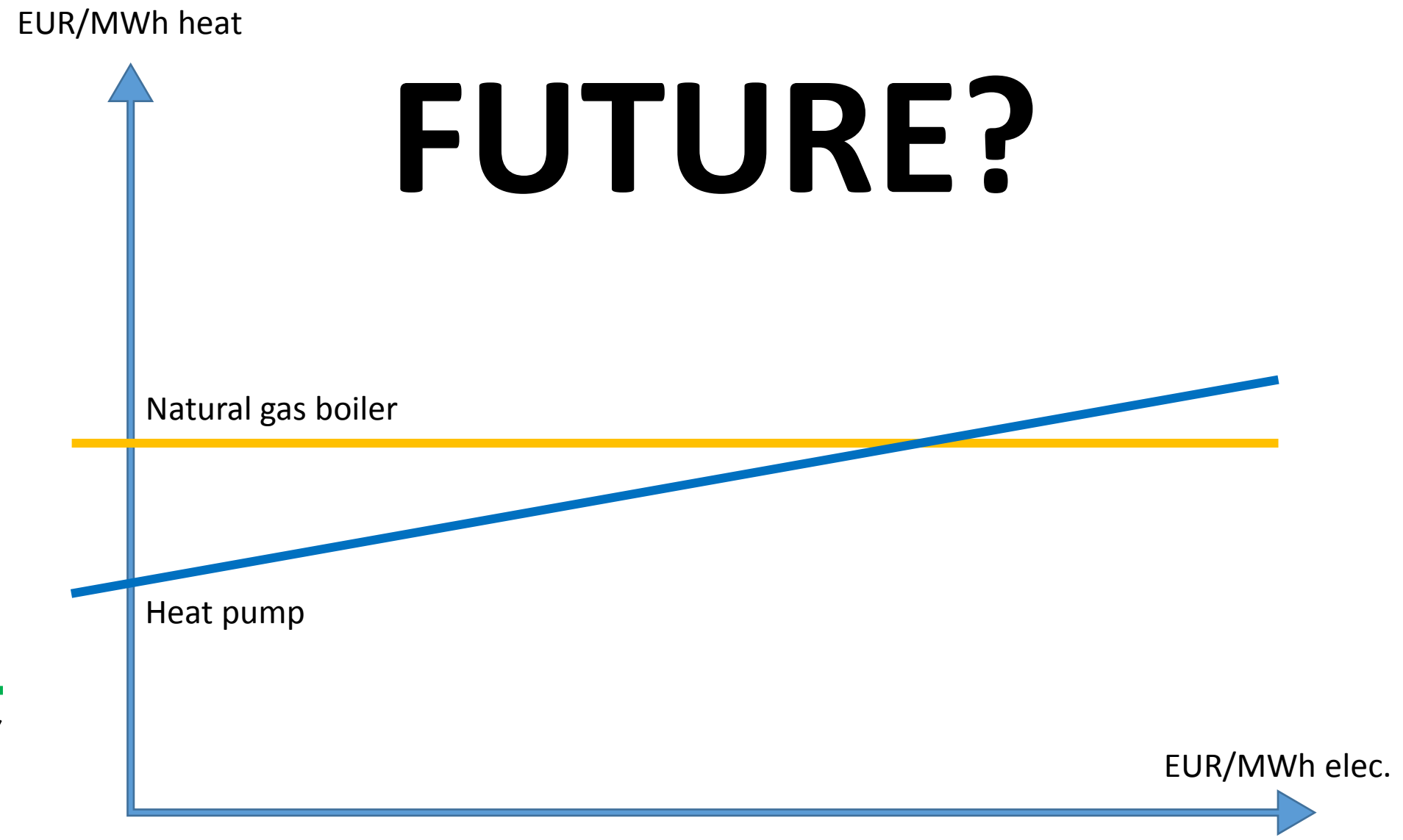

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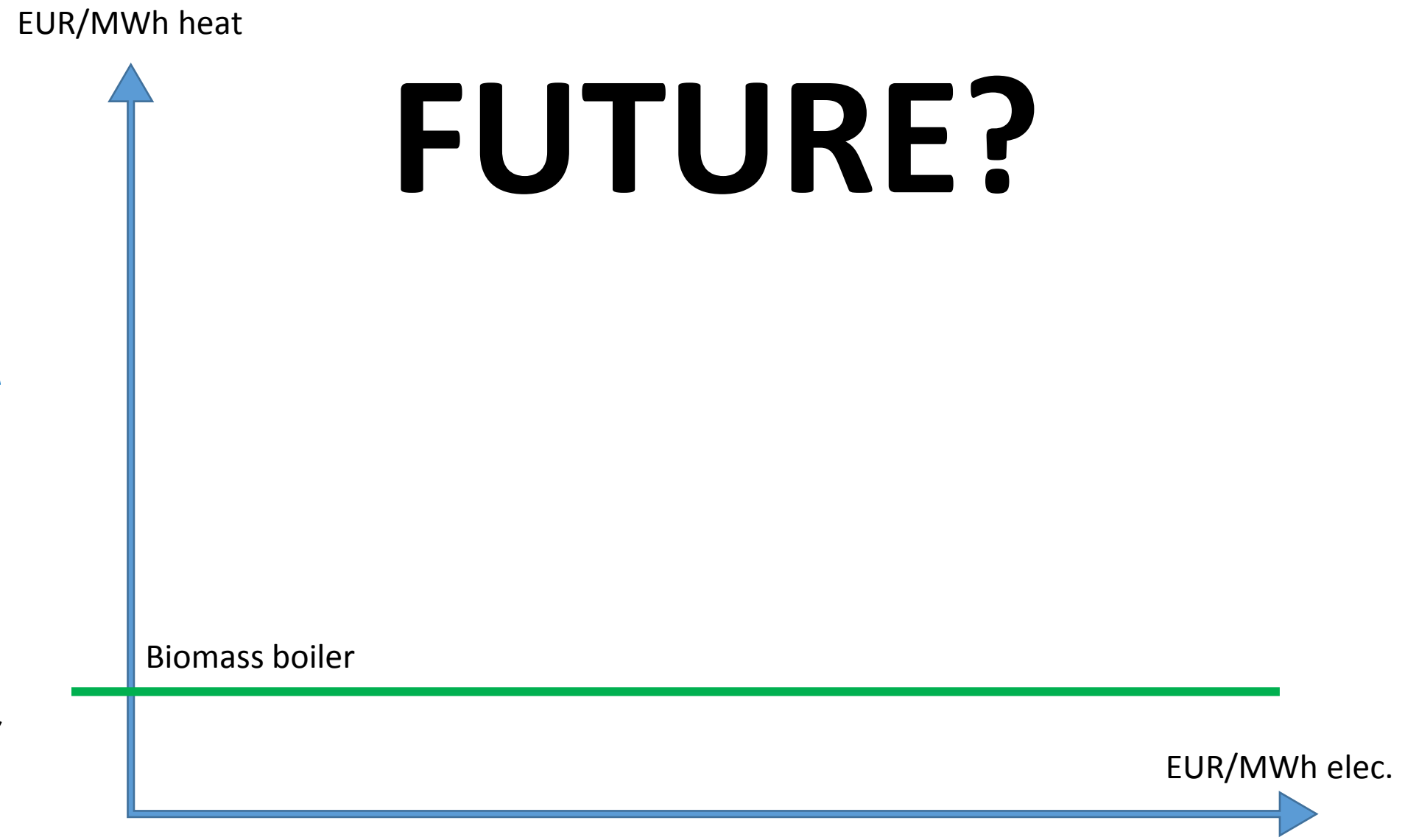

Environmental dispatch

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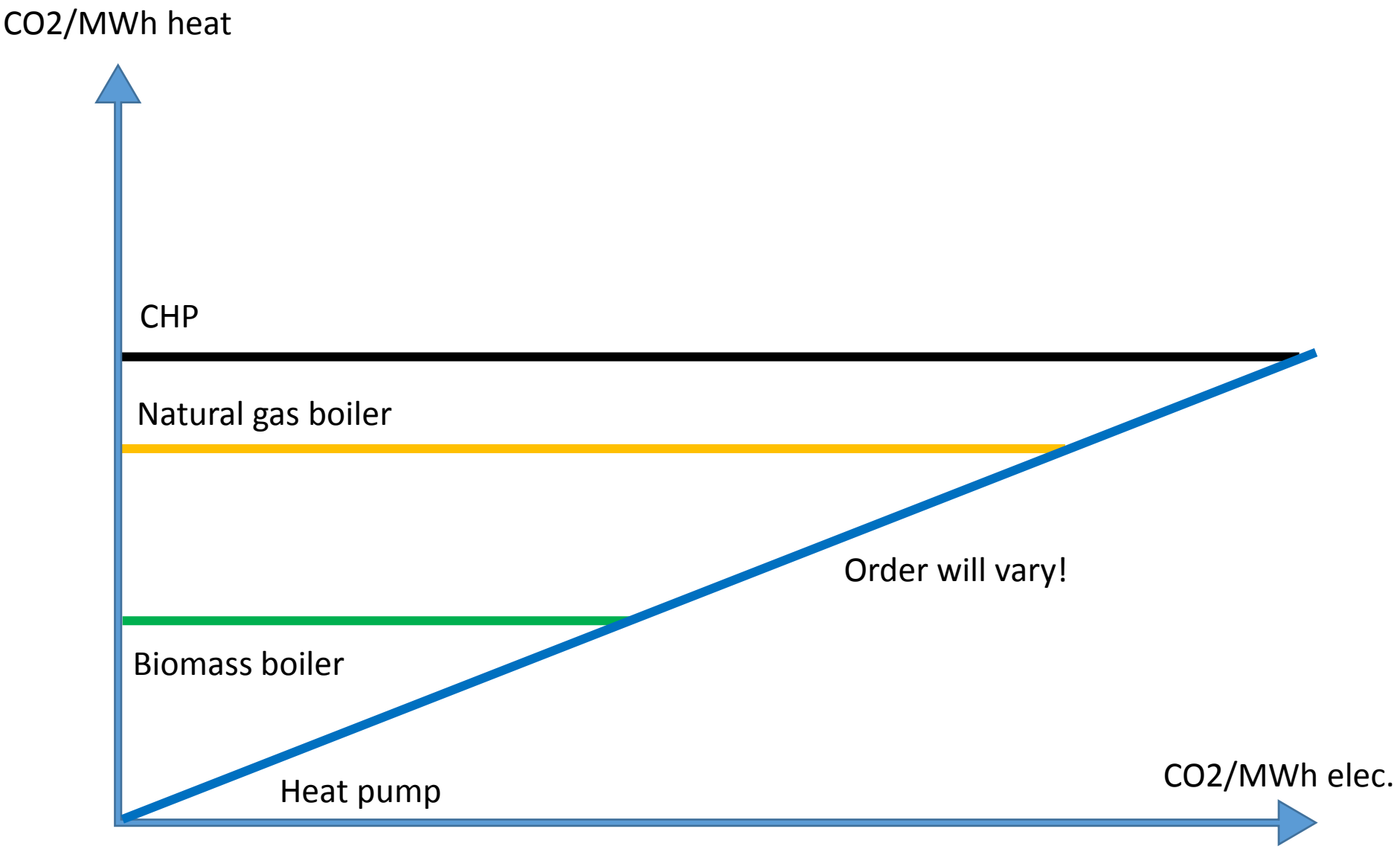

THEORY: What is a flexible DE system?

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