Flex-Efficiency

A Concept for Integrating Efficiency and Flexibility By Industrial Consumers

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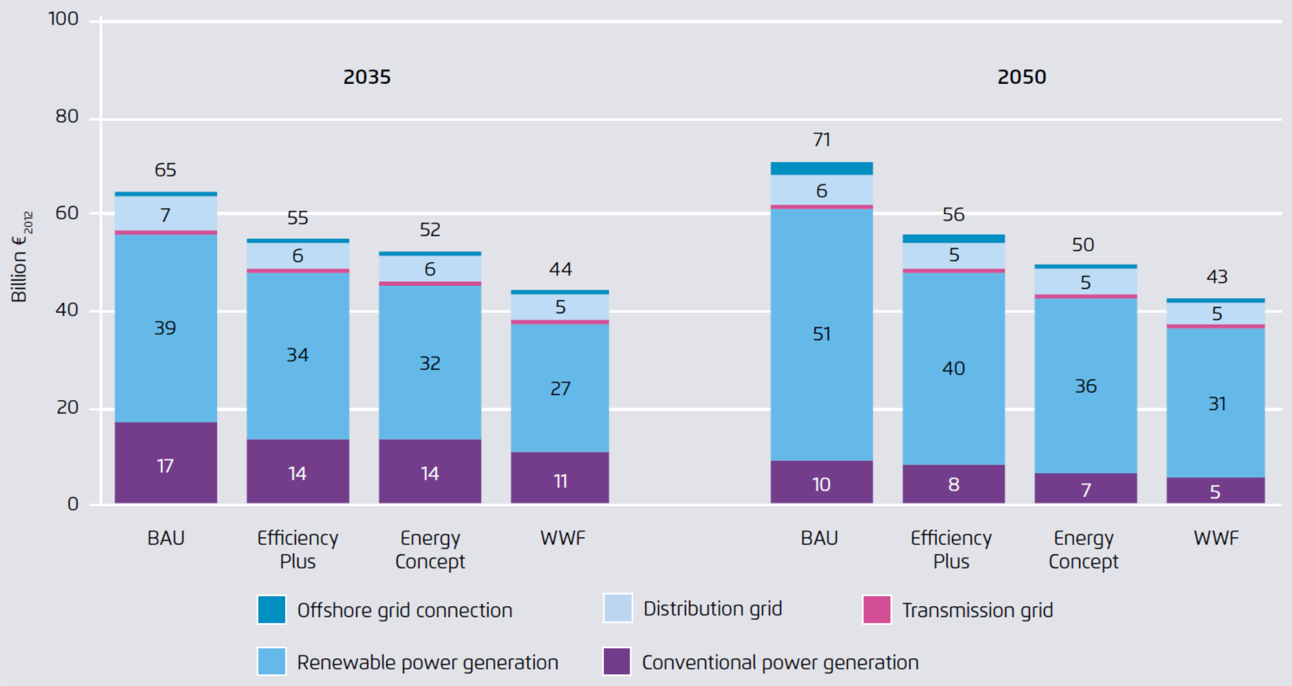
Energy efficiency – a crucial pillar of Germany's energy transition

Total costs of the power system



Prognos AG/IAEW (2014): Benefits of Energy Efficiency on the German Power Sector.

Increasing efficiency
Reduction of electricity consumption relative to 2008: - 10% in 2020; - 25 % in 2050

The more electricity that industries and private households save, the less power grids and power plants (both for conventional and renewable energy) are needed.

Higher efficiency will reduce the costs of the total system by up to 28 billion euros by 2050.

Every kilowatt hour not consumed saves between 11 and 15 euro cents.

There's considerable potential for more flexibility among energy consumers, especially among large industrial players

When renewables exceed 50 percent of the energy supply, the value of efficiency and flexibility will fluctuate depending on time of day and year. This has an effect on electricity markets and prices.

Increasingly, efficiency and flexibility become factors in company decision-making and the design of new production facilities and equipment.

Using demand-side-management, companies can fully utilise low wholesale prices when wind and PV feed-in levels are high.

Therefore, energy efficiency policies should emphasize the integration of efficiency and flexibility.

Combining efficiency and flexibility can lead to both synergies and antagonisms

We thus asked what the integration of efficiency and flexibility means for companies in practice:

→ What are the **technological and economic options** for optimisation at the company level?

→ What **general conditions and incentives** would be needed for company and investment decisions that are good for the national economy and that offer the power system efficiency and flexibility cost-effectively?

The analysis of flex-efficiency examines multiple levels

- **Production facility:** Does the technical implementation of efficiency and flexibility in a production facility lead to synergies or antagonisms?
- **Power system**: How are efficiency and flexibility optimized within the overall system?
- Efficiency and flexibility in **company practice**: two case studies – aluminium electrolysis at Trimet and pump systems.
- **Obstacles**: What obstacles stand in the way of finding the optimal combination of efficiency and flexibility?
- **Measures**: What measures are suited to reduce obstacles?
- **Implementation:** What can companies do today to exploit synergies?

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A variety of technologies exist to implement efficiency and flexibility at a production facility

Implementing efficiency and flexibility at a production facility

Efficiency
Process dimensioning
Using newest technologies
Improving insulation
Process coupling and adaption
Reducing flow resistance
Modulating times of use

Flexibility
Process adaption
Use of storage capacities such as: • Heat storage • Cold storage • Compressed air storage • Water storage • Natural gas storage • Material buffers

Efficiency and flexibility can interact in different ways

Investments in efficiency and/ or flexibility can lead to the following synergies and antagonisms:

a. Efficiency and flexibility both rise **(synergy)**

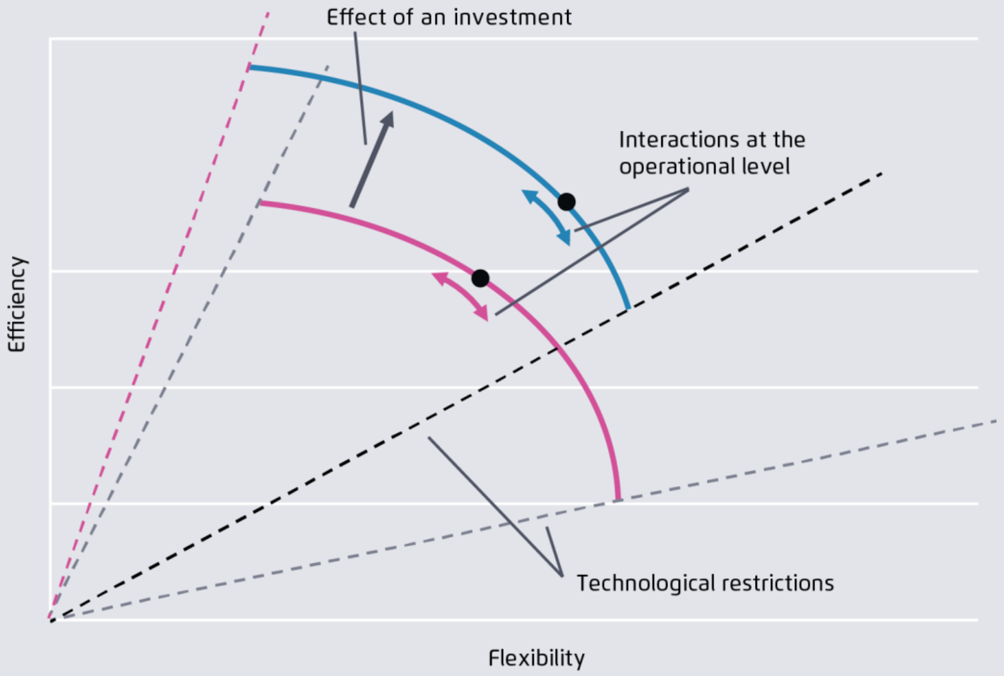
b. Efficiency increases but flexibility decreases **(antagonism)**

c. Flexibility increases but efficiency decreases **(antagonism)**

d. There is **no interaction** between increased efficiency and increased flexibility

Schematic diagram of interaction types

Schematic diagram of interactions at the operational and investment levels



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The two curves represent the possible combinations of efficiency and flexibility at the operational level and within the technological restrictions (dotted lines).

If additional investment decisions are considered, the degree of freedom increases.

The shift of the curve (from red to blue) indicates an increase of both efficiency and flexibility (interaction type a).

There exists nevertheless numerous technological arrangements in which investment decisions increase efficiency or flexibility at the cost of the other.

The schematic diagram can be used to categorise different technological measures

Synergies and antagonisms of some technologies and procedures

Technology / procedure	Operational vs. investment	Contributes to efficiency	Contributes to flexibility	Interaction? (Type)	Description of the interaction
Introducing and improving control and monitoring technologies	Investment	+	+	Synergy (Type A)	Process monitoring allows energy efficiency to be improved and shifts in demand to be better controlled
Improvement of storage capacity through insulation	Investment	+	+	Synergy (Type A)	Insulation reduces heat loss and increases storage and, with it, flexibility
Adopting more efficient procedures	Investment	+	+	Synergy (Type A)	Changing to a more flexible process can increase efficiency
Reducing overdimensioning in turbomachinery	Investment	+	-	Antagonism (Type B)	If overdimensioning is reduced and investments are made in new machines, flexibility declines but efficiency rises
Adjusting process intensity	Operational	-	+	Antagonism (Type C)	Intensity of process is varied and run at the optimal level
Operating turbomachinery at partial load at overdimensional production facilities	Operational	-	+	Antagonism (Type C)	As the effectiveness of turbomachinery declines at partial load, so does efficiency
Improving energy and material buffers in production processes	Investment	-	+	Antagonism (Type C)	Storage increases flexibility, but any storage losses will decrease efficiency
Heat recovery of waste heat	Investment	+	O	No interaction (Type D)	Heat recovery does not shape flexibility
Increasing efficiency of turbomachinery	Investment	+	O	No interaction (Type D)	Investments in similarly dimensioned but more efficient machinery increases efficiency but does not influence flexibility
Increasing efficiency of lighting	Investment	+	O	No interaction (Type D)	Improved light yield does not influence flexibility
Reducing flow losses in piping systems	Investment	+	O	No interaction (Type D)	Reducing flow loss does not influence flexibility

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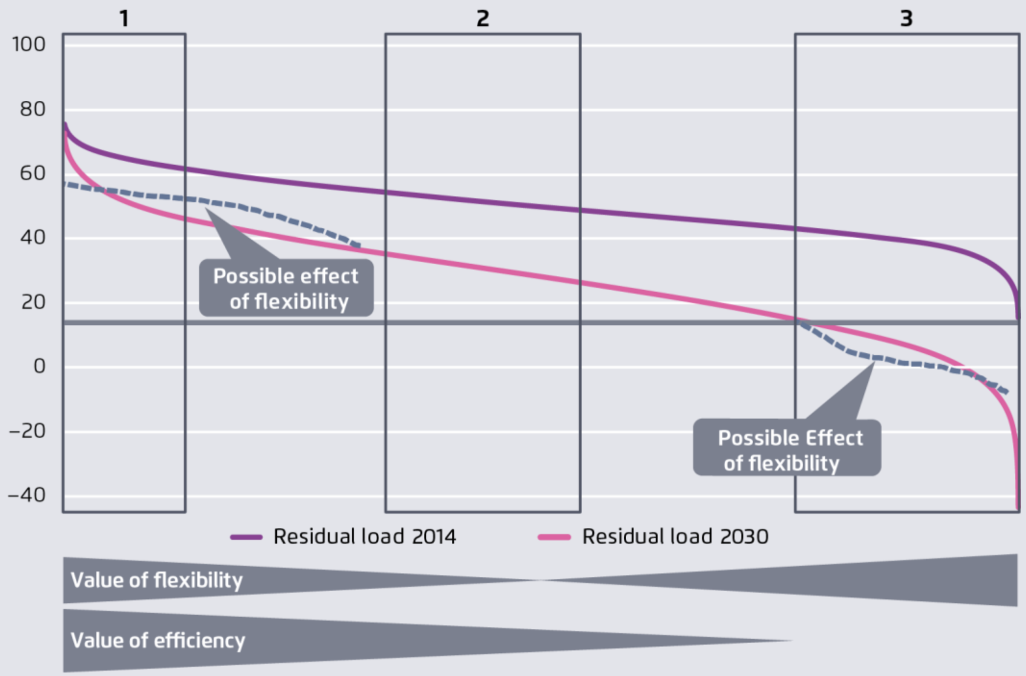
The value of efficiency and flexibility depends on residual load

Residual load duration curve/ sorted hourly residual load of one year



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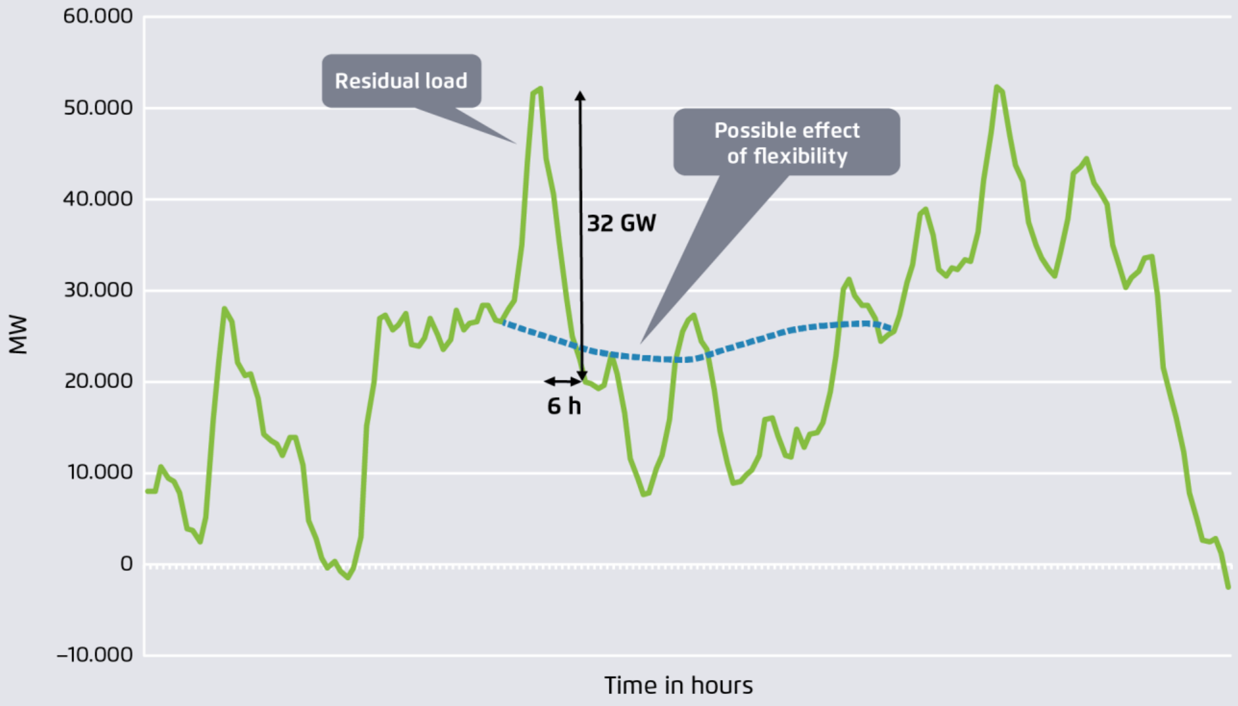
At the system level, flexibility can be use to avoid peaks and strong ramping of residual load

Gradient of modulated residual load in 2030 and possible effect of flexibility



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Conclusions so far

The challenge lies in

→ harmonizing operational and investment decisions about efficiency and flexibility with changing system requirements.

When efficiency and flexibility are deployed optimally from an economic standpoint

→ they keep the cost of the power system to a minimum in times when generation is volatile.

In doing so it is important

→ to solve tasks of operational allocation and about investment decisions.

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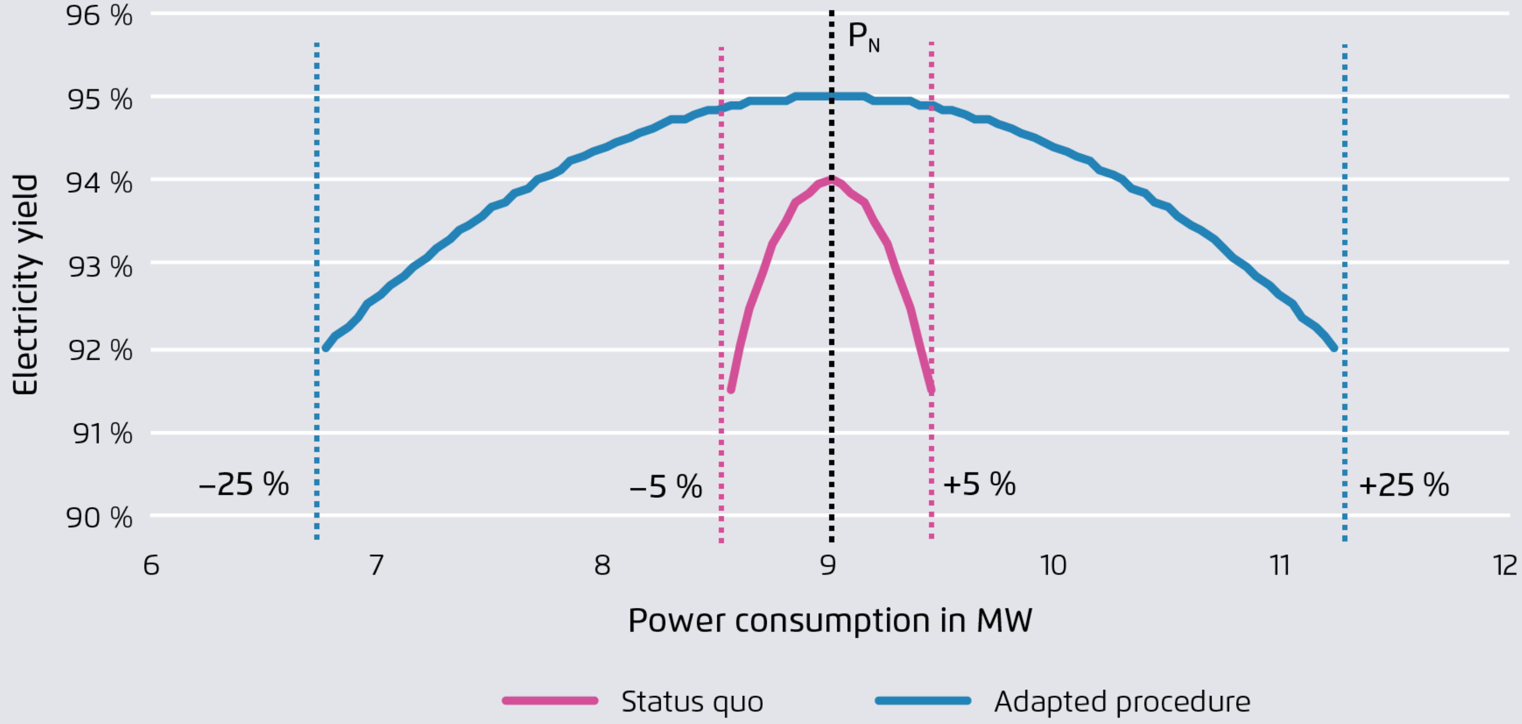
Trimet increases efficiency and flexibility through investment

Illustration of the interaction of efficiency and flexibility through the use of heat conductors in aluminium production in 12 of Trimet´s electrolysis ovens



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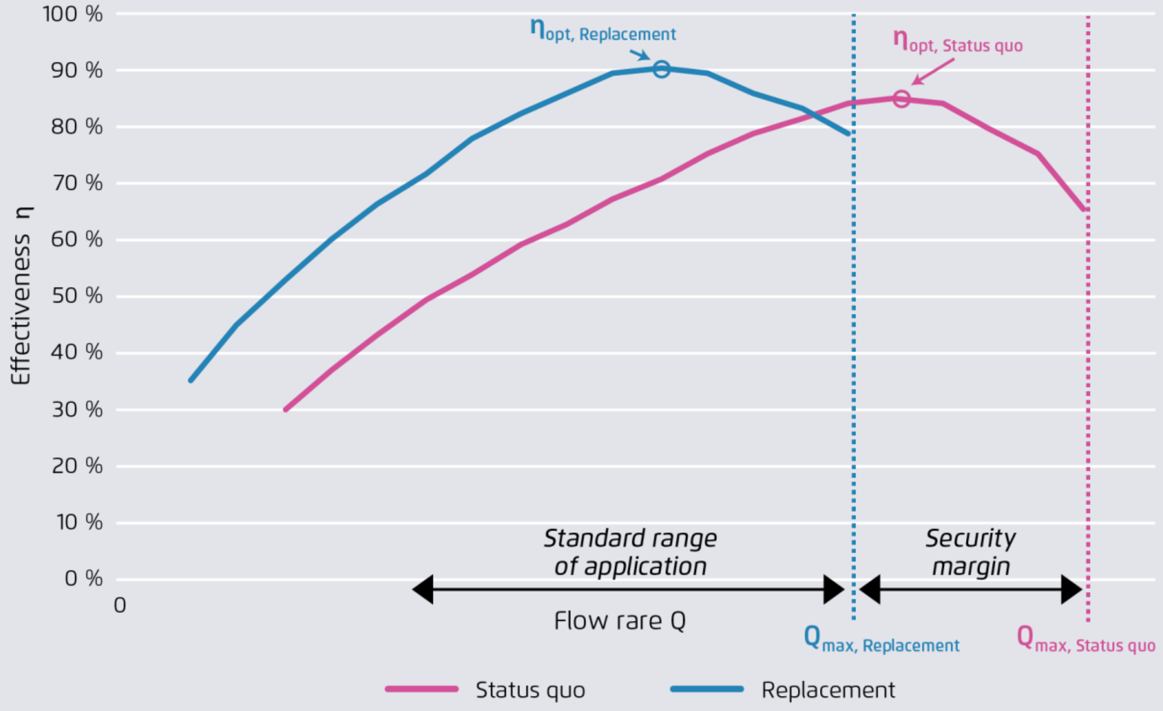
In the case of pump systems, antagonisms occur between efficiency and flexibility even when investments are made

Schematic illustration of the effects of replacing overdimensional pumps with smaller, more efficient pumps



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Conclusions so far

With the status quo (operational adjustment) the deployment of flexibility in production facilities and processes leads to deviations from the optimal operating point and to operations with lower efficiency:

→ *Either the electricity yield of the electrolysis is reduced when leaving the optimal operating point or the effectiveness of the pump system is reduced (antagonism).*

Investments can lead to both synergies and antagonisms between efficiency and flexibility:

→ *In the case of Trimet, efficiency and flexibility are increased. In the pump system example, efficiency increased while flexibility decreased.*

The challenge lies in harmonising the optimal relation from a power system perspective with the investors´ decisions:

→ *Trimet increased investment in expectation of increased demand for flexibility. Investors in cross-sectional technologies have fewer chances to leverage the system value of greater investment for more flexibility and efficiency on the operational level.*

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Ideally, price signals show the system requirements for flexibility and efficiency

Summary of price incentives for efficiency and flexibility from the wholesale electricity market

	Efficiency incentives	Flexibility incentives
Short-term (operational)	Level of spot and intraday prices	Volatility of spot and intraday prices Prices for flexibility products
Long-term (investment)	Forward prices, and possible in the future: efficiency markets	Expected volatility of wholesale prices in the long term Expected prices for flexibility products in the long term

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Numerous obstacles stand in the way of full effectiveness of price incentives

The effect of the price signal is limited

- → because the price signal from the wholesale market is only indirectly passed on to consumers
- → because deficits exists in the design of flexibility markets
- → because the structure of grid charges creates false incentives
- → because duties, surcharges, and other fees create additional false incentives

Further obstacles exist (market imperfections) that impede economically sensible investments in efficiency such as

- → lack of information and uncertainty about future developments
- → lack of technological and economic adjustments
- → investor/user dilemma (especially for efficiency in residential buildings)

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To eliminate obstacles, we must think about regulatory- and company-level measures

Regulatory measures	Company measures
→ Improve price signals → Improve design of flexibility markets → Review grid charges and other duties and surcharges → Reduce information gaps and uncertainties → Amend ISO 50001	→ Operational • Make interactions transparent • Carry out operational adjustments • Integrate flexibility elements in energy management systems → Investment • Account for interactions when designing production facilities and when making investment decisions

→ ***More research is needed to quantify interactions, overall system effects, regulatory measures, and practical solutions.***

Key Findings

1	**Efficiency and flexibility grow into a joint concept: flex-efficiency.** As the share of renewables in the energy supply increases, efficiency gains a time of use dimension. When the sun doesn’t shine or the wind doesn’t blow, wholesale electricity prices rise – and electrical efficiency becomes more valuable than in times when renewable energy are plentiful.
2	**Flex-efficiency is becoming a paradigm for the design and operation of industrial production facilities.** As the share of wind and solar energy increases, so do fluctuations of wholesale electricity prices. Today, plans for new industrial production facilities must incorporate both energy efficiency and flexibility if they are to benefit from times with low energy prices in the future.
3	**Flexibility markets and their products must be improved.** Market access, market structures, and the appropriate products (such as interruptible loads and demand-side management) are crucial if market price signals are to serve as incentives for the economically and system-optimised operation of production facilities or for attendant investments.
4	**Investments in flex-efficiency need a combination of market incentives and other incentives.** Market prices provide good incentives for the optimisation and operation of large energy-intense production processes. But they often fail in the face of “average” processes, storage systems, and cross-sectional technologies. Supplemental instruments are needed to raise their potential.

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