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Industrial Demand Side Management

Effiziente Möglichkeiten der Netzstabilisierung durch industrieller Verbraucher

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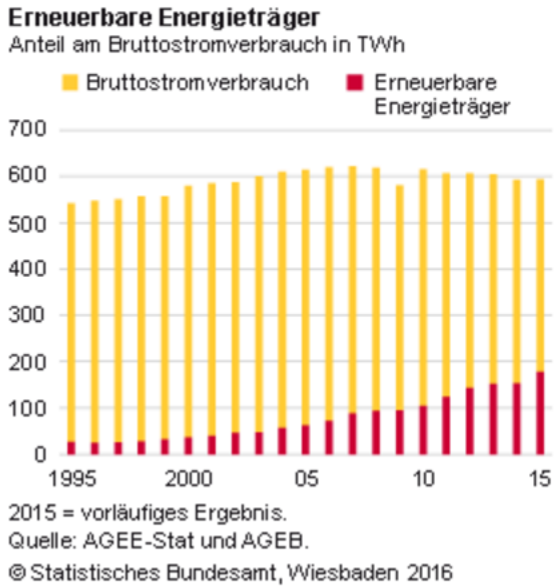
Seminar Energieinformatik WS1617
Betreuung: M.Sc. Nicole Ludwig - Institute for Applied Computer Science (IAI)

Motivation

- Energienetze:
  Eines der kompliziertesten und wichtigsten Gebilde unserer Zeit ?!?
- Zusätzlich:
  Zunehmender Wandel
- Höher, weiter, besser?
  - Kosten
  - Klima
  - Bürger



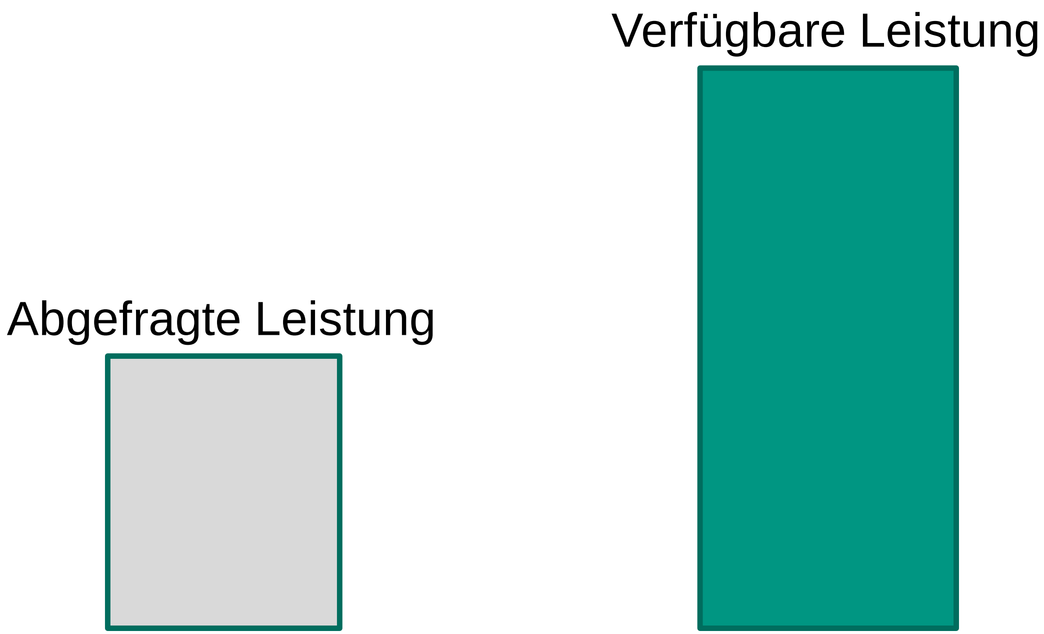
-> Besser einen smarten Ansatz

Motivation

- Vielfältige Gründe für unvorhersehbare Schwankungen [19]
  - => Vielfältige Lösungsansätze gesucht
  - => Flexibilität schaffen

Motivation

- Schon heute Erzeugung am Limit
- 20.01.2016
  80 GW Last bei 200 GW installierter Leistung



Motivation

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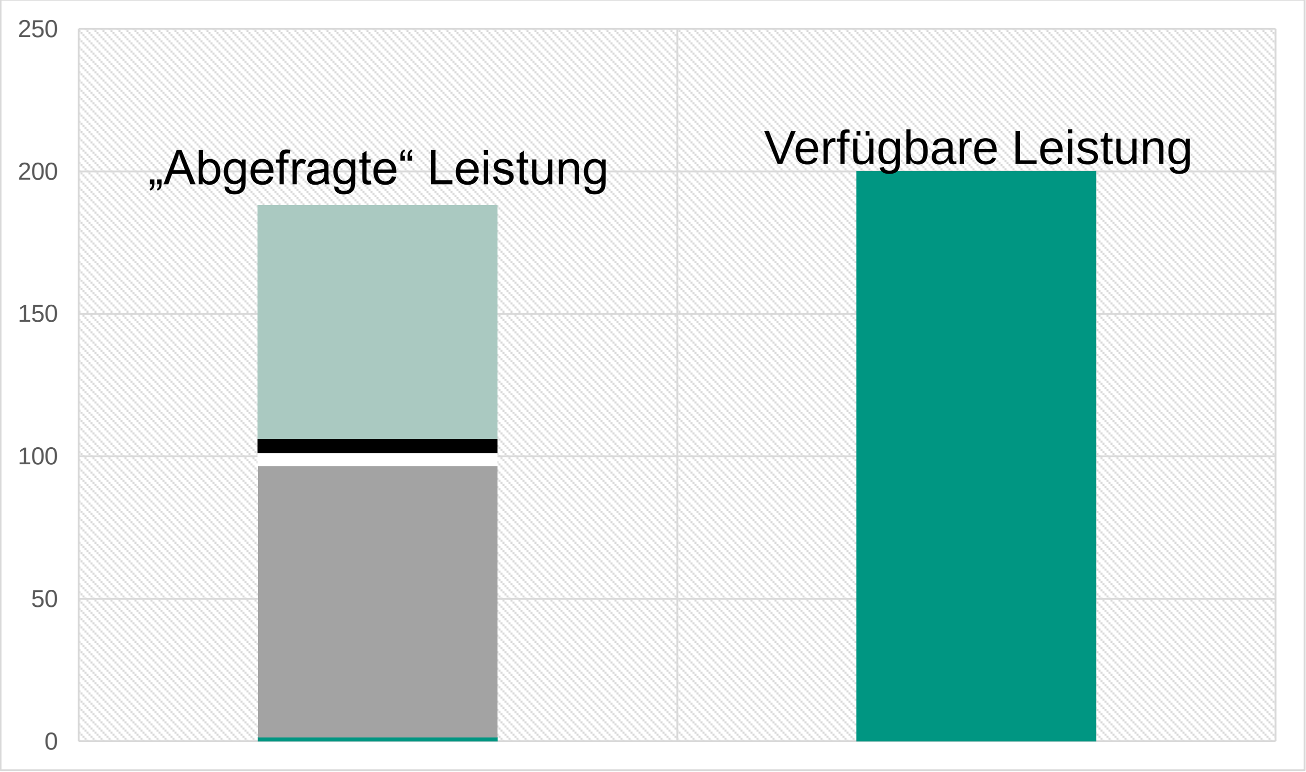

[31]

Motivation

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- Vielfältige Gründe für unvorhersehbare Schwankungen [19]
    - => Vielfältige Lösungsansätze gesucht
    - => Flexibilität schaffen

"*Demand side activities should be active elements and the first choice in all energy policy decisions designed to create more reliable and more sustainable energy systems*" *(IEA)*

Motivation

Energy Efficiency | Energy Controllers | Spinning Reserve

Demand Response | Demand Shifting | Time of Use

Real-Time-Pricing | Critical Peak Pricing | Virtual Storage Power Plant

Exklusiv für Großverbraucher?

Motivation

Energy Efficiency

Energy Controllers

Spinning Reserve

Demand Response

Demand Shifting

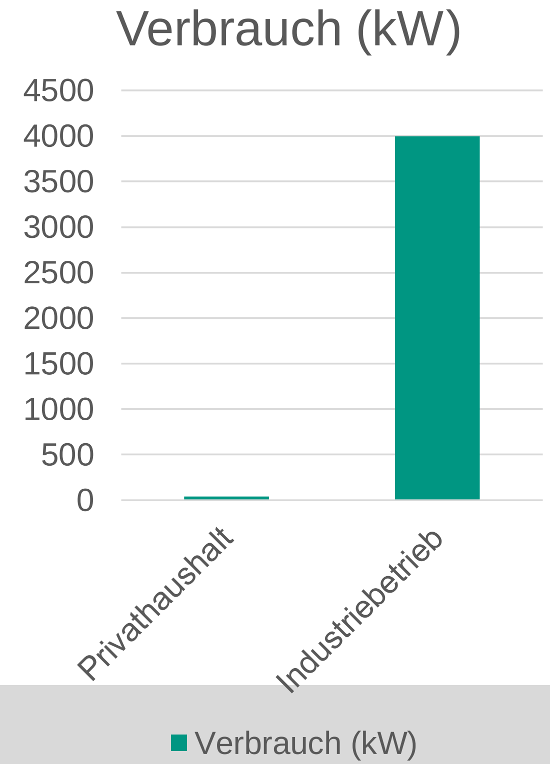
Time of Use

Real-Time-Pricing

Critical Peak Pricing

Virtual Storage Power Plant

Exklusiv für Großverbraucher?



Gliederung

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- Warum Demand Side Management?
  - Anpassung aufgrund EE
  - Vergleich zu anderen Lösungsstrategien
- IDSM – Maßnahmen und Ziele

  Case Study
  - Energy Efficiency, Energy Controllers, Demand Response, Demand Shifting
- Wo funktioniert IDSM?
  - Geeignete Industriesektoren
  - Anpassungen und Auswirkungen
- Zukünftige Ansätze und Forschung
  - Verantwortlichkeiten, Ziele

Warum Industrial Demand Side Management

- Früher: Durch die Verbraucher festgesetzter Bedarf. Nach diesem wurden die Kraftwerke gefahren
- Heute: Vorgegebene schwankende und unsicherere Stromproduktion

- Intelligente Lösungen auf der Seite der Nachfrager

Warum Industrial Demand Side Management

- Möglichkeiten zum Umgang mit Lastspitzen
  - Installation von Energiespeichern
    - Batterien
    - Pumpspeicherkraftwerke
  - Installation von zusätzlicher Kraftwerksleistung
    - Schnell fahrbare Kraftwerke

Warum Industrial Demand Side Management

- Ökonomische Vorteile
- Erhöhte Netzstabilität
- Verbesserung der Marktverhältnisse
- Gesamtvorteil Energieerzeugung
- Senkung der Emmissionen

Warum Industrial Demand Side Management

- Ökonomische Vorteile
- Erhöhte Netzstabilität
- Verbesserung der Marktverhältnisse
- Gesamtvorteil Energieerzeugung
- Senkung der Emmissionen

- Initiale Kosten
- Fixkosten
- Variable Kosten
- ITC
- Unsicherheiten

Was ist ISDM

- Einteilung in
  - Preisbasiert / Anreizbasiert
  - Wirtschaftliche Zwecke / Umwelt Zwecke / Netzentlastung [18]
  - Kurzfristig / langfristig [25]

Was ist ISDM

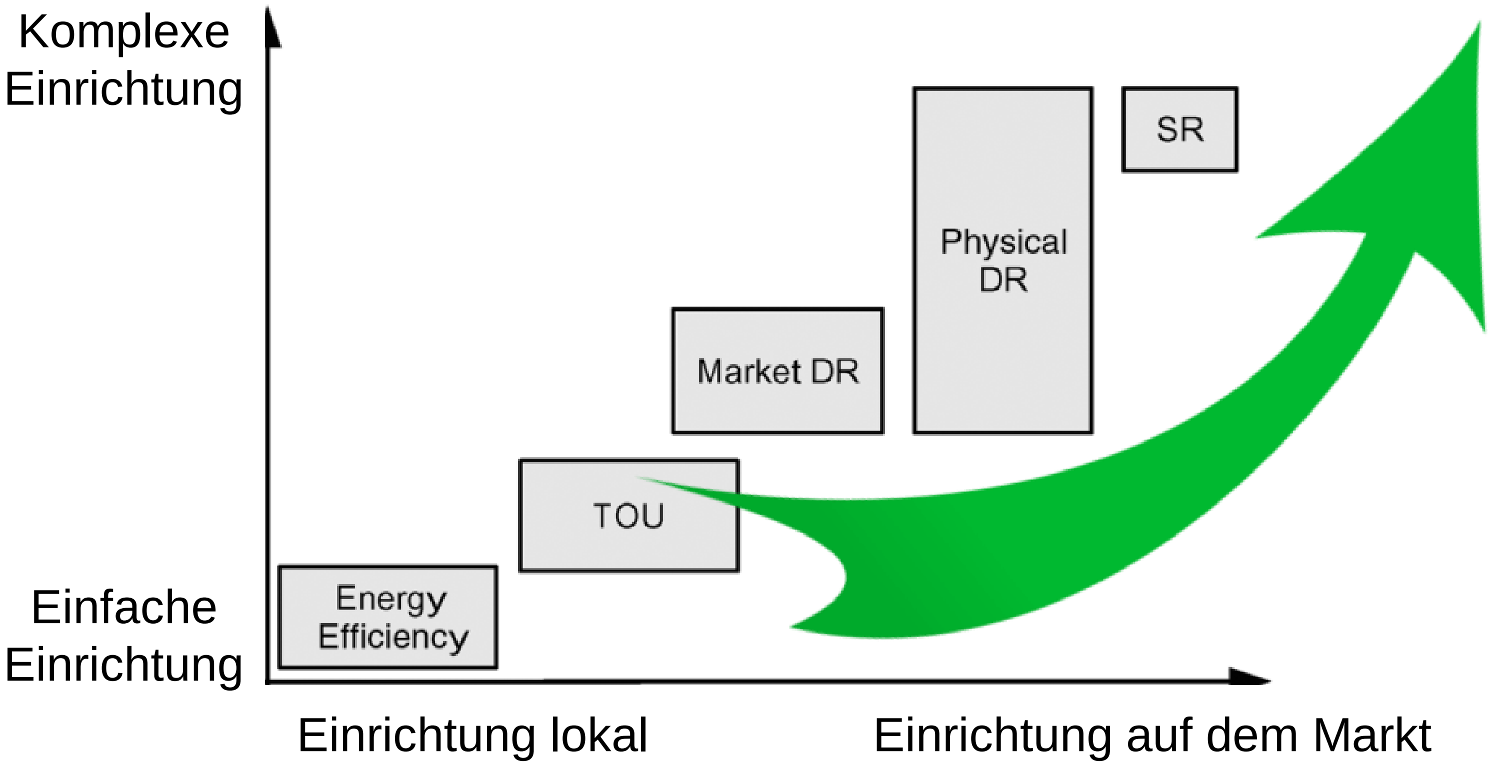


Fig. 1. Categories of DSM.

[20]

ISDM – Energy Effiency

- Dauerhafte Anpassung der Verbraucher (Lüftung, Isolierung)
- Sofortige und dauerhafte Änderung des Verbrauchsprofils

Fig. 1. Curtailing load without changing load pattern.

[20]

ISDM – Energy Effiency

- Energy Information System
  - Baseline vs. peak load
    - Hoher standby Verbrauch
  - Zeitlicher Vergleich
    - KW 25 vs KW 26
  - Benchmarks
    - Vergleich zwischen unterschiedlichen Gleichen

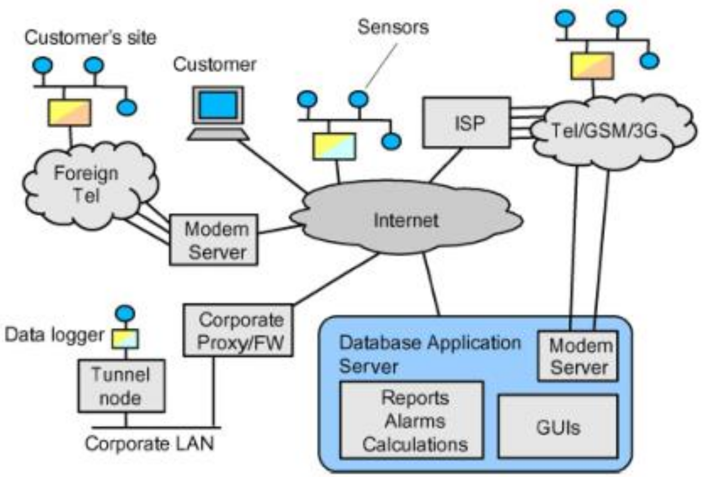


Fig. 4. A web-based energy information system, based on [11].

[20]

ISDM – Energy Controllers

- Automatische Abschaltung von Endgeräten bei Spitzenverbrauch
- Nutzung von festgelegten Prioritäten

[20]

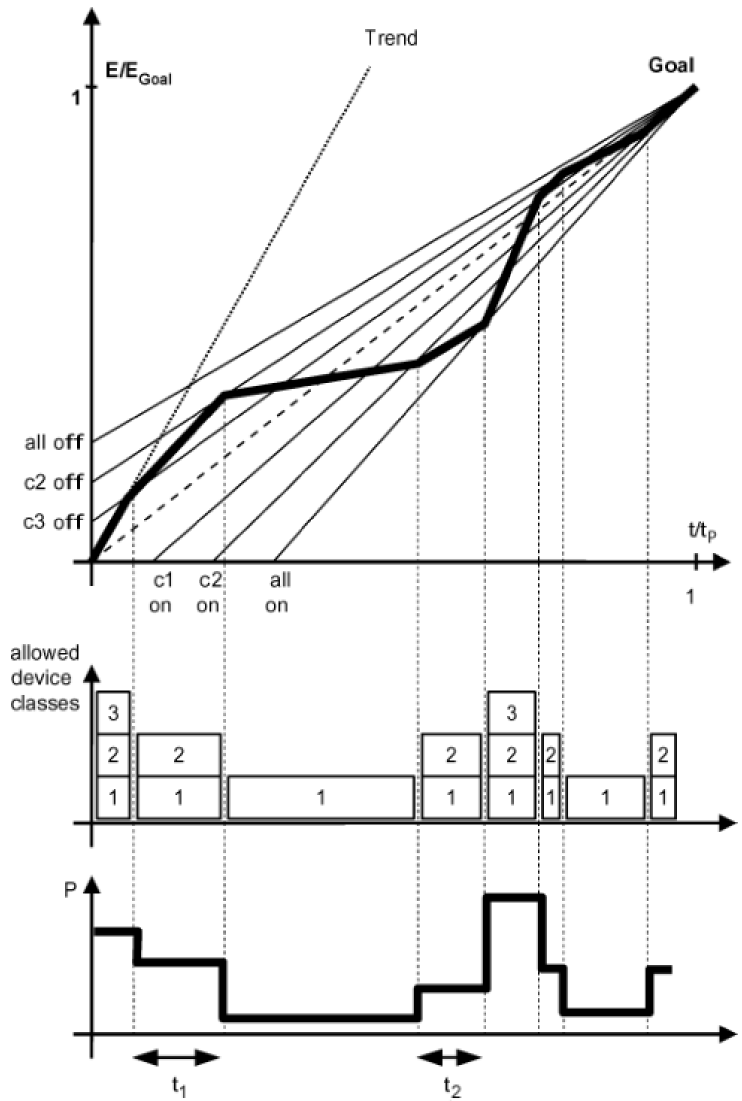


Fig. 6. Selection of priorities in a maximum demand monitor.

Was ist ISDM

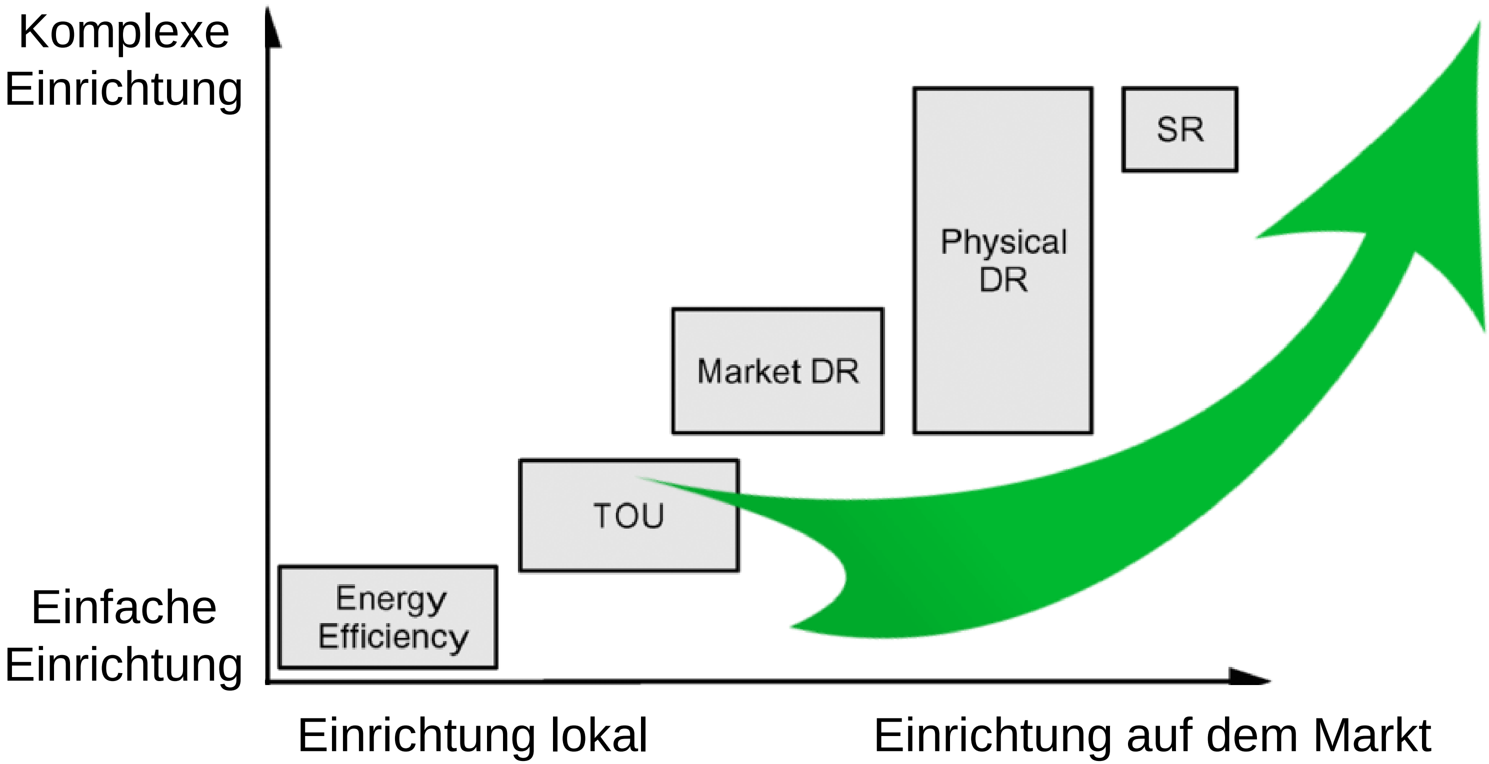


Fig. 1. Categories of DSM.

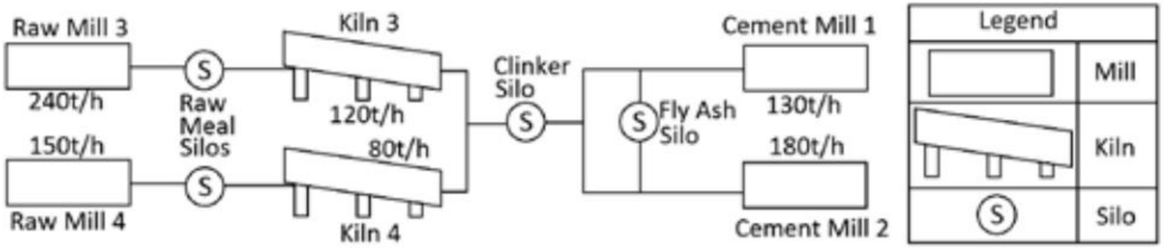
[20]

ISDM – Preis

- Direkte Veränderung der Stromkosten im laufenden Stromtarif

Lidbetter, Liebenberg 2013 [22]

- Szenario: 1 Zementwerk in Südafrika mit Time-of-Use Tarif
  - 3 Verbrauchszeiten * 2 Jahreszeitentarife
  - Keine Reduzierung der Verbrauchsmenge möglich



  - Walzen können Betrieb schell ändern -> Smarter Einsatz

Lidbetter, Liebenberg 2013 [22]

- Von der Theorie zur Praxis
  - Herleiten einer Auslastungskurve
  - Simulation des Silo Füllstandes

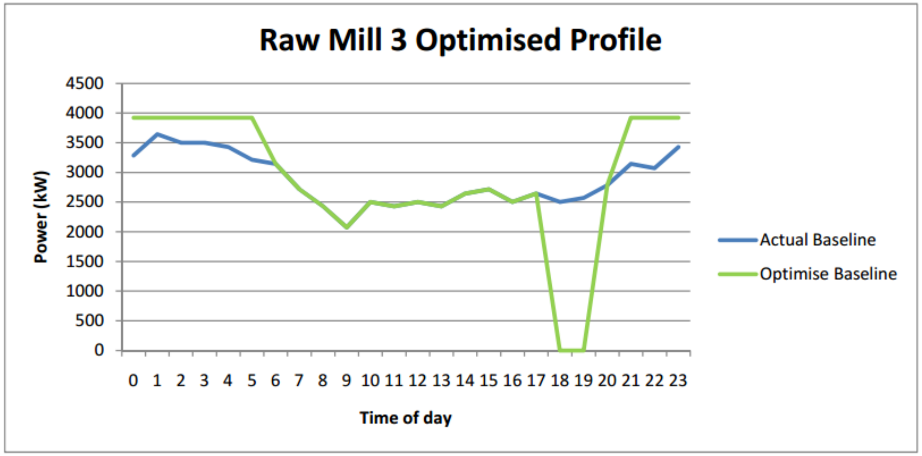


Figure 3.11a - Raw mill 3 optimised profile

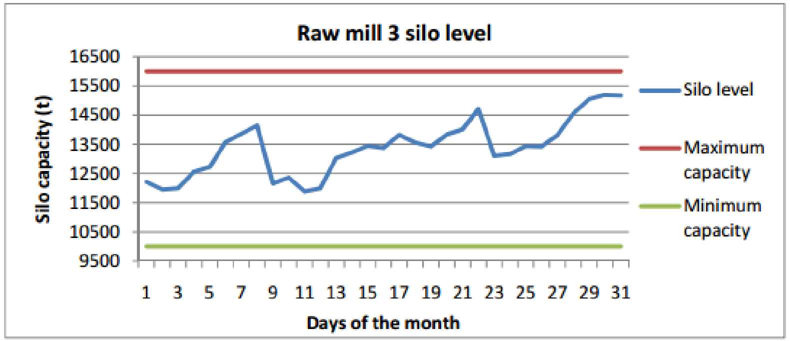


Figure 3.7- Change in raw meal silo level

Lidbetter, Liebenberg 2013 [22]

- Von der Theorie zur Praxis
  - Optimierter Betrieb des Zermahlers

	Savings per weekday		Savings per Saturday	
	Winter	Summer	Winter	Summer
RM3	R5 919	R1 066	R577	R361

Days in 2010	66	195	13	39

	Yearly savings	Original yearly cost
RM3	R620 033	R6 670 640

Table 2: Savings gained by the load-shifting scheme with averaged tariffs.

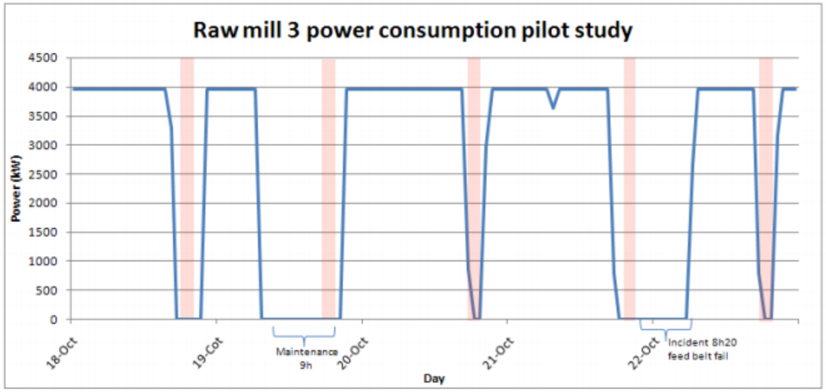


Figure 4.8 - RM3 power consumption pilot study

9,3% Ersparnis

Lidbetter, Liebenberg 2013 [22]

- Von der Theorie zur Praxis
  - Live-Betrieb des Zermahlers nach dem optimierten Plan
  - Ausfälle / Betriebsereignisse machen die 100% Umsetzung unmöglich
  - Kostenvergleich wird ebenfalls beeinflusst -> 2% savings
  - Peak-Shaving erfolgreich
    4 MW Peak-Shave

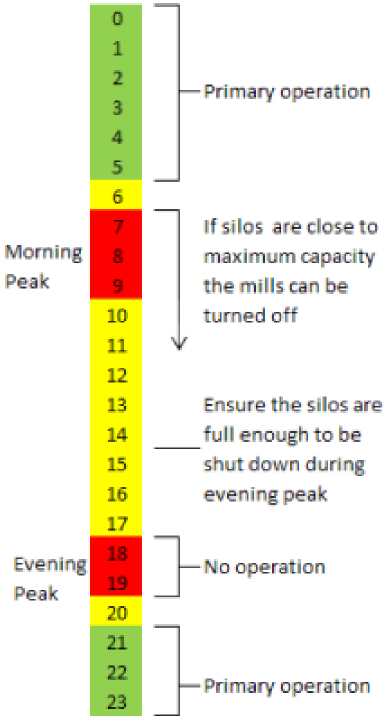


Figure 4.1 - Load-shifting parameters

Was ist ISDM

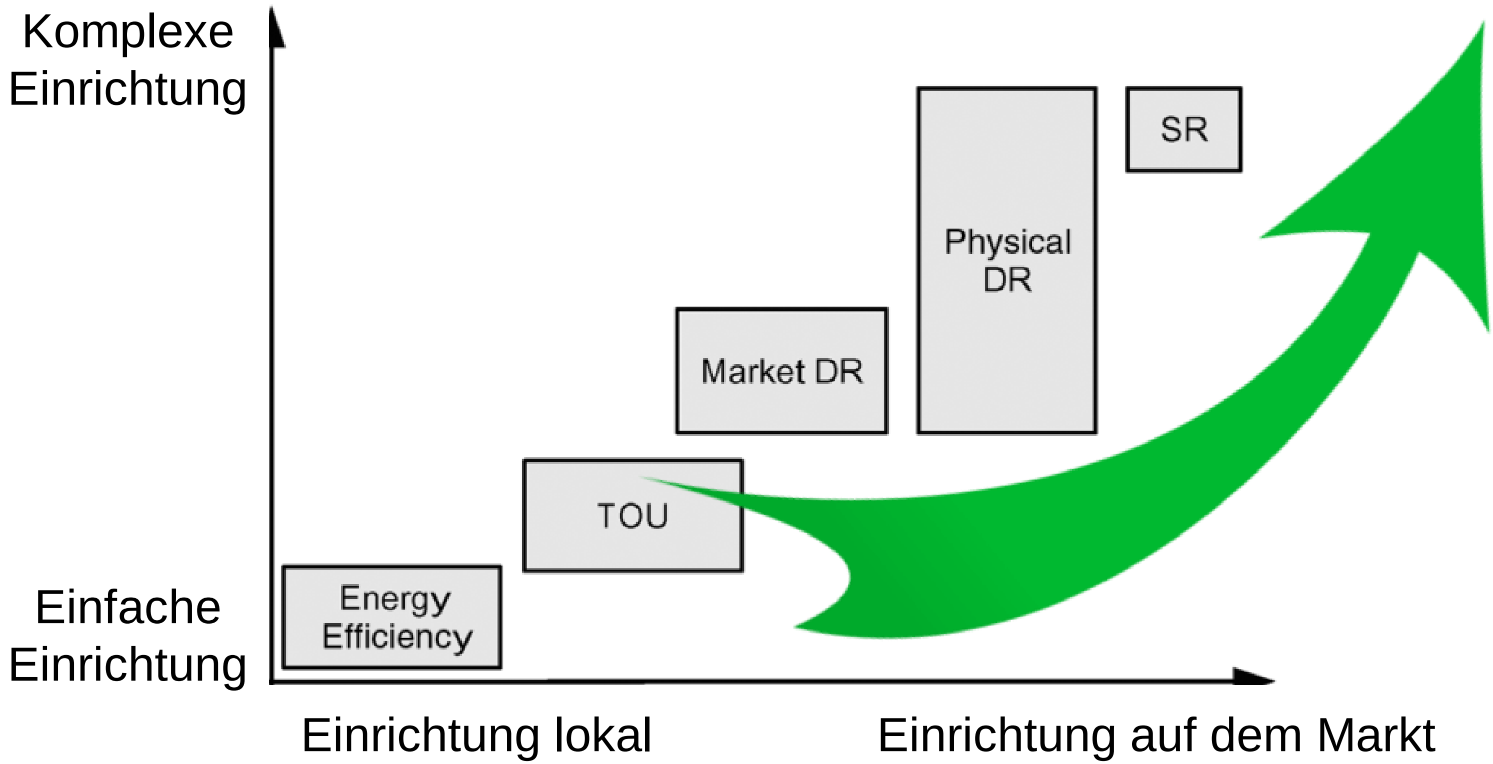


Fig. 1. Categories of DSM.

[20]

Finn, Fitzpatrick 2013 [2]

- Gesetzliche Rahmenbedingungen
  - EU
    - Obergrenze Emmissionen
  - Irland
    - Garantierte Einspeisung von Wind
    - Maximalquote für EE (50% Last)
    - Einige Programme bereits aktiv (Load-Shedding)

    - Abhängigkeit vom Außenhandel (91% Import für FE)

Finn, Fitzpatrick 2013 [2]

- Strommarkt Irland
  - Day-Ahead
  - 48 Intervalle (30 Min) pro Tag
  - Sammeln der Angebote und Kalkulation eines Preises

  - Preisvorhersage 16:00
  - Preisbestimmung 4 Tage später

Finn, Fitzpatrick 2013 [2]

- Studie in Irland
  - -> Anteil der Windenergie steigern
  - -> Kosten senken

  - Flexibilität im Verbrauch

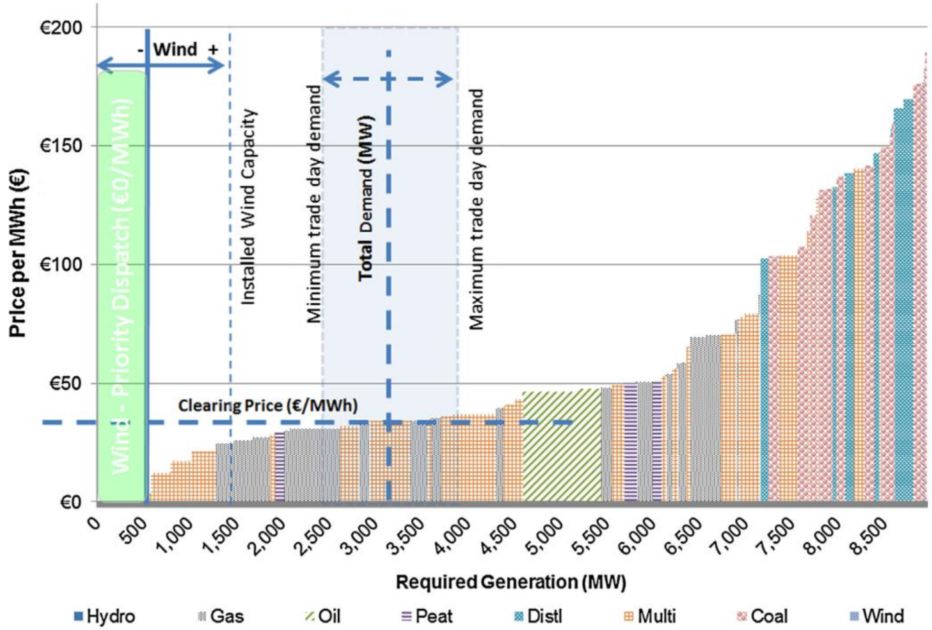


Fig. 2. Competitive bidding process illustrating clearing price, market spot demand and priority dispatch of wind.

Finn, Fitzpatrick 2013 [2]

- Marktteilnehmer
  - 2 Großabnehmer am Mittelspannungsnetz
    - Kühlwarenlager
    - Produktionsfirma
  - Veränderung der Anreize während der Studie
    - Saisonale Einflüsse
    - E-Mail Service in den letzten 3 Monaten

Preisvorteil ⇔ EE-Anteil

Finn, Fitzpatrick 2013 [2]

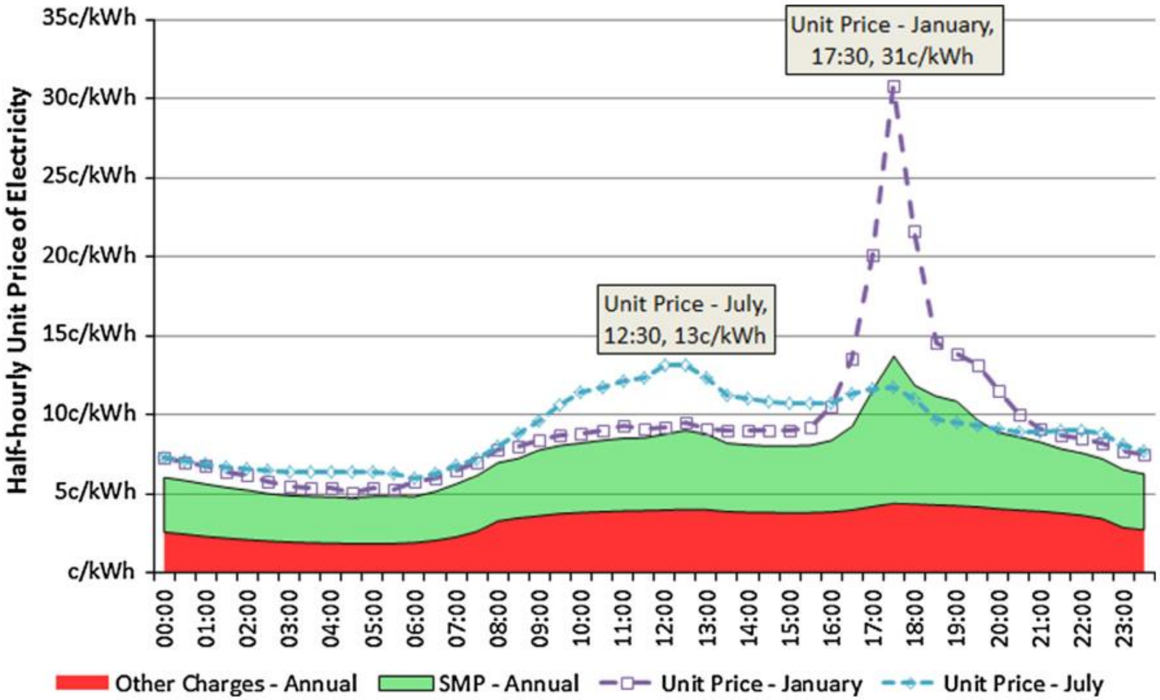


Fig. 3. Annual average half-hourly unit price of electricity separated into SMP and other charges compared to average half hourly prices for January (winter) and July (Summer).

Finn, Fitzpatrick 2013 [2]

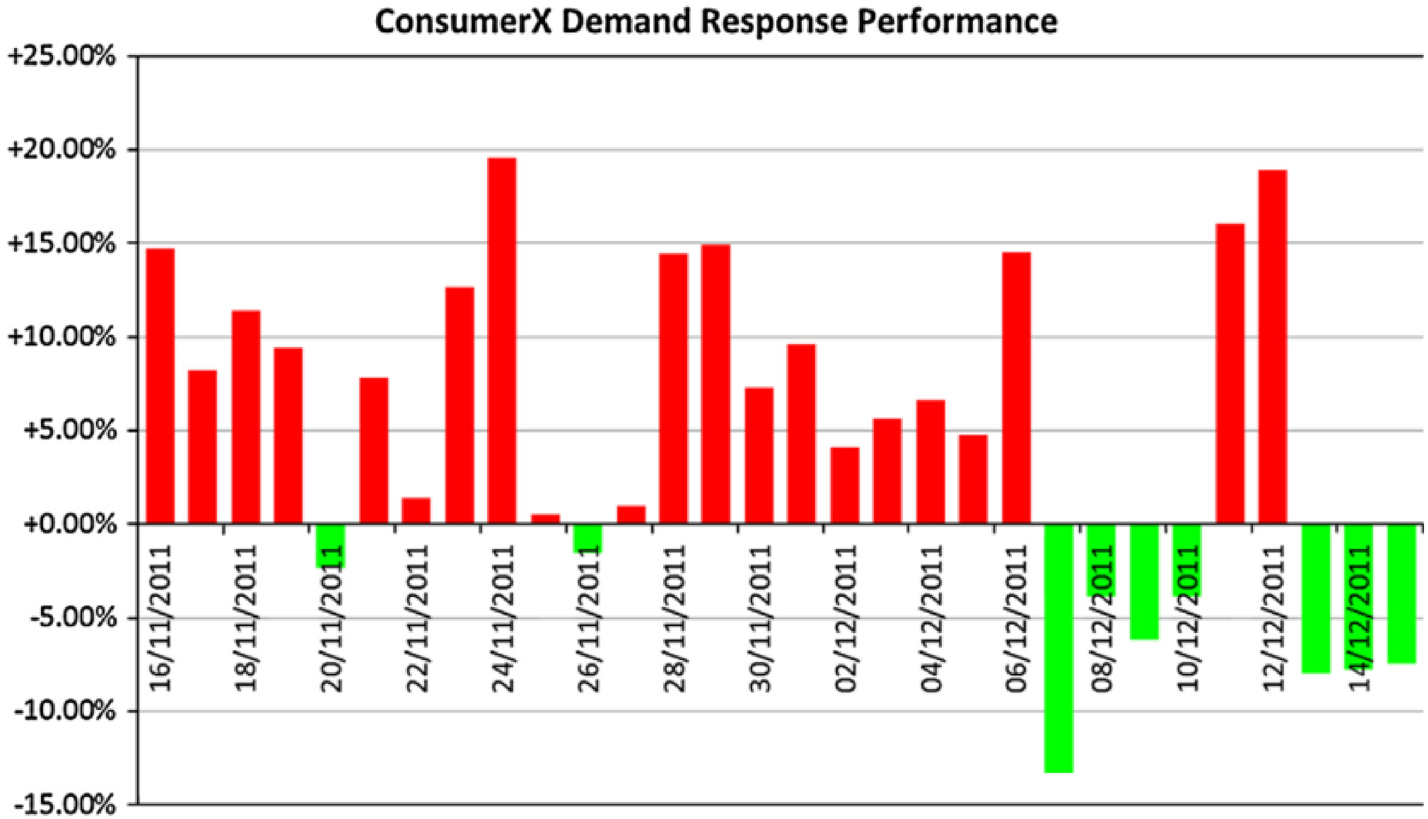


Fig. 10. Demand response performance during the previous 30 days.

Finn, Fitzpatrick 2013 [2]

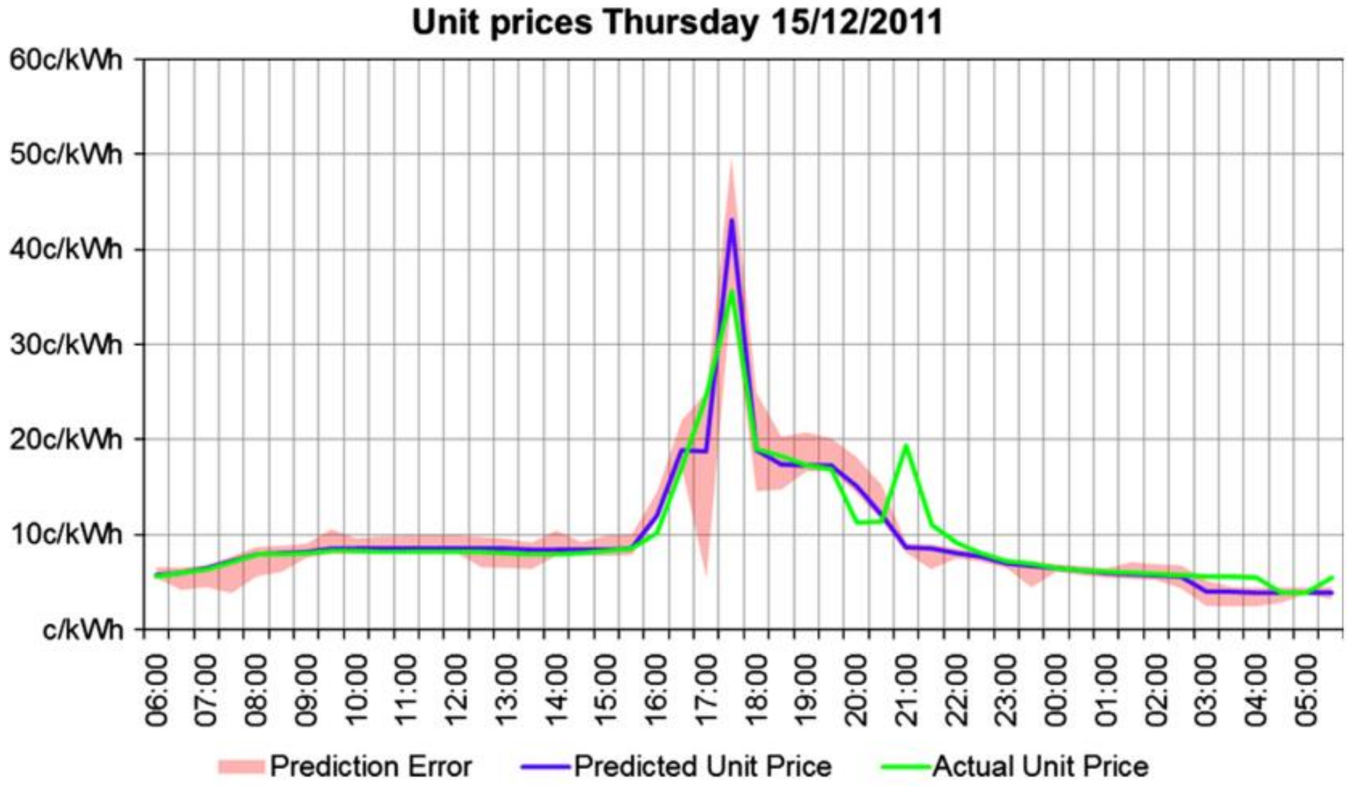


Fig. 6. Actual unit prices compared to predicted unit prices from 4 days previously.

Finn, Fitzpatrick 2013 [2]

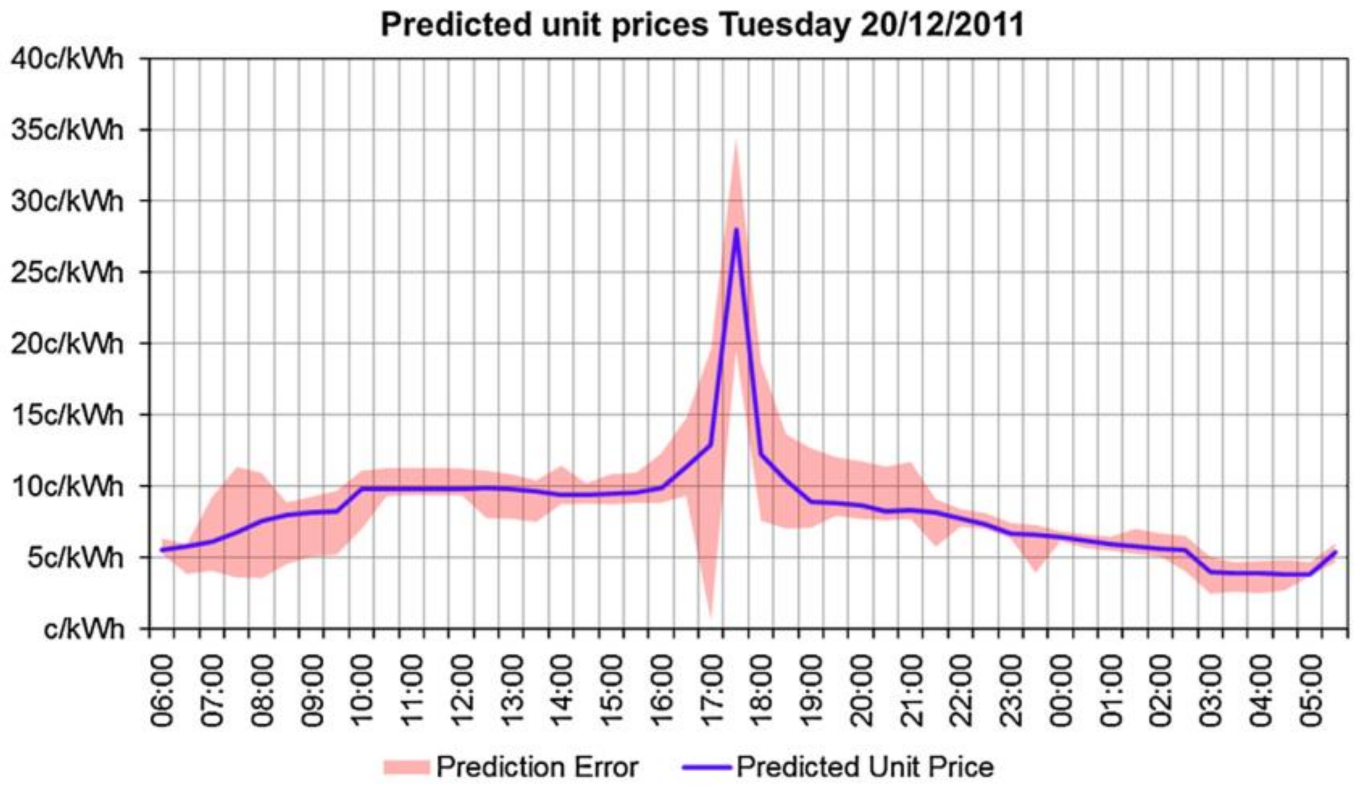


Fig. 5. Day-ahead unit price predictions including a prediction error analysis.

Finn, Fitzpatrick 2013 [2]

$$Performance_{Price} = \frac{Avg\_Price_{Unit\_Demand}}{Avg\_Price_{Consumer\_Demand}} * 100$$

$$Avg\_Price_{Consumer\_Demand} = \frac{\sum_{i=1}^{48} Demand_{Consumer}(i) * Price(i)}{\sum_{i=1}^{48} Demand_{Consumer}(i)}$$

$$Avg\_Price_{Unit\_Demand} = \frac{\sum_{i=1}^{48} Price(i)}{48}$$

Finn, Fitzpatrick 2013 [2]

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$$Performance_{Wind} = \frac{Wind_{Consmer}}{Wind_{National}} * 100$$

$$Wind_{Consumer} = \frac{\sum_{i=1}^{48} Demand_{Consumer}(i) * \frac{Generation_{Wind}(i)}{Demand_{National\ (i)}}}{\sum_{i=1}^{48} Demand_{Consumer}(i)} * 100$$

$$Wind_{National} = \sum_{i=1}^{48} \frac{Generation_{Wind}(i)}{Demand_{National}(i)} * 100$$

Finn, Fitzpatrick 2013 [2]

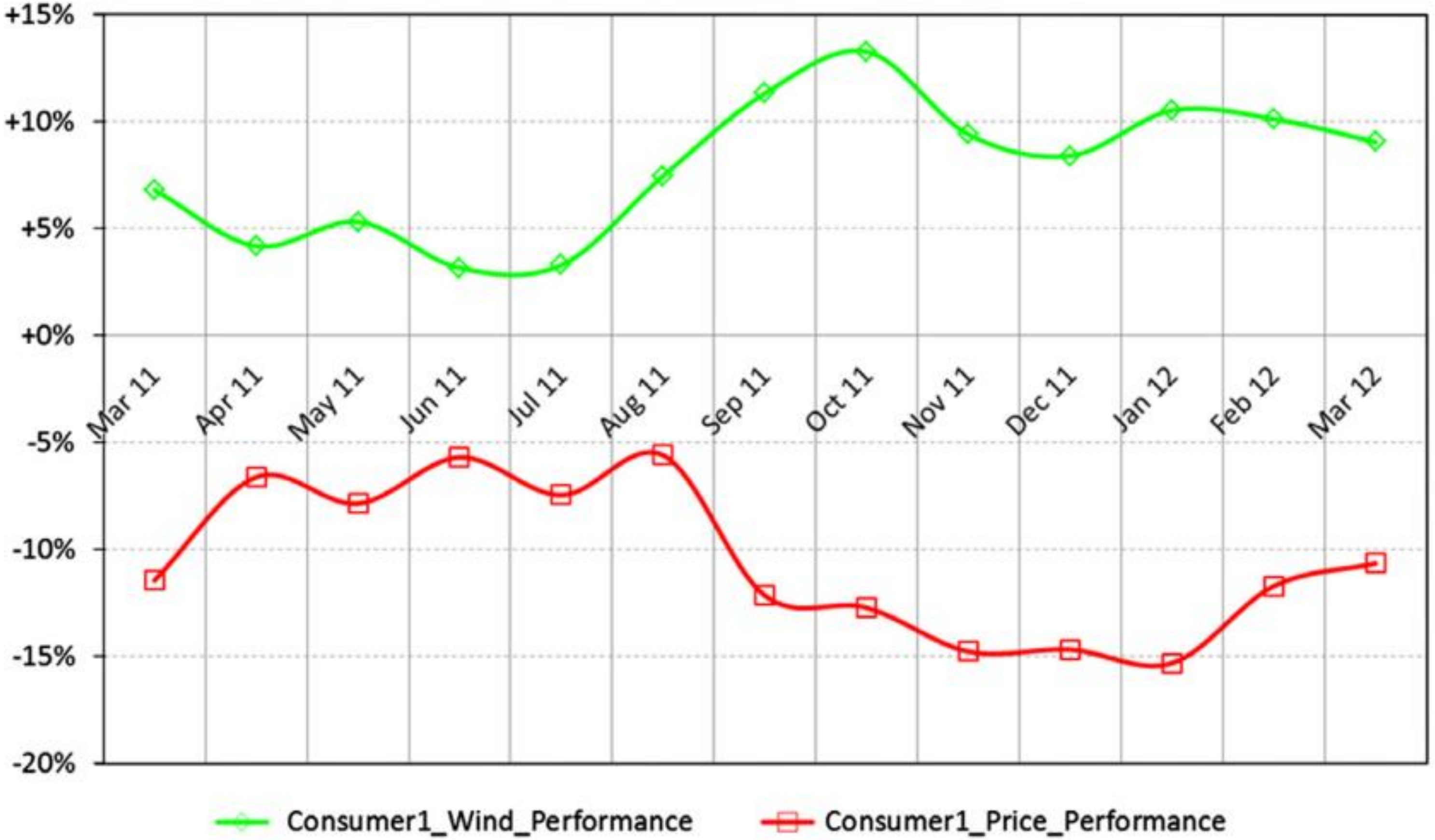

Fig. 12. Consumer1's monthly wind performance and price performance during the observation period.

Finn, Fitzpatrick 2013 [2]

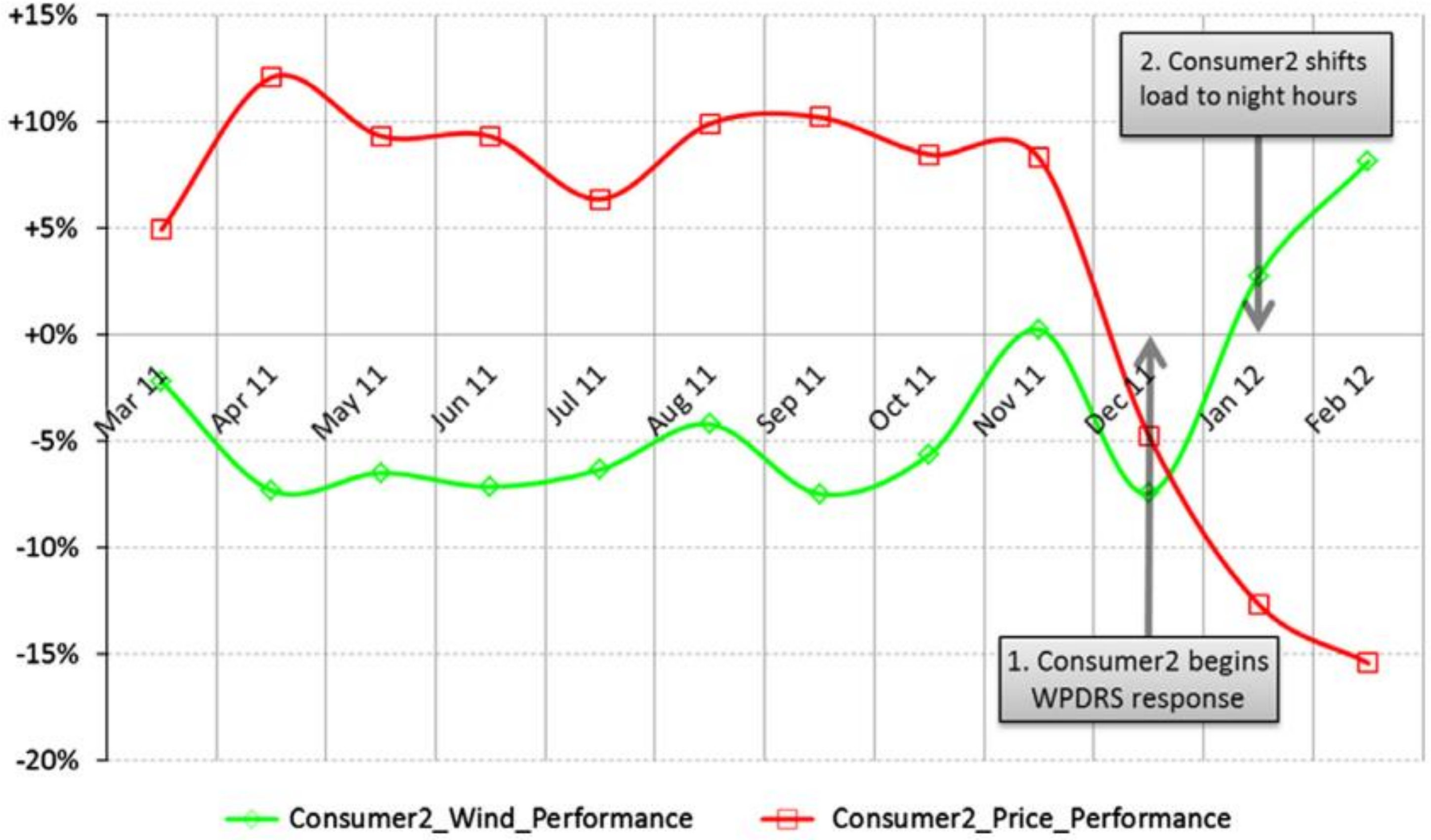

Fig. 13. Consumer2's monthly wind performance and price performance during the observation period.

Finn, Fitzpatrick 2013 [2]

0 P. Finn, C. Fitzpatrick / Applied Energy 113 (2014) 11–21

Fig. 14. Average wind performance mapped to various levels of price performance for Consumers 1 and 2 including a linear estimation of the two trends combined.

Preiseinsparungen bringen direkte Mehreinspeisung von EE

Was ist ISDM

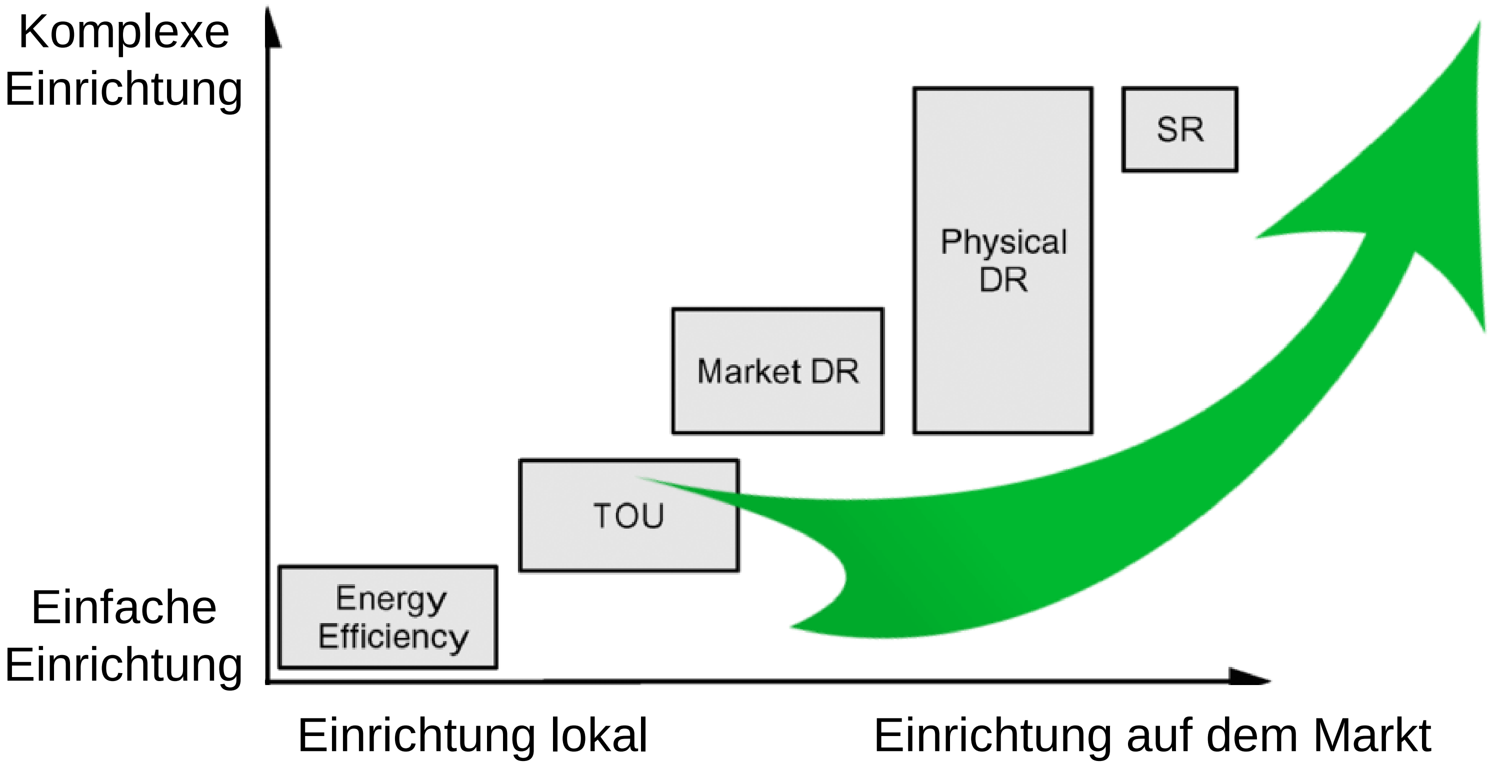

Fig. 1. Categories of DSM.

[20]

ISDM – Demand Response

- Einbindung von Industrie als Tertiärreserve
- Industriesektoren gesucht und gefunden
- Analyse der Prozesse nach technischen und ökonomischen Aspekten

Paulus, Borggrefe 2011 [01]

- Industrieanalyse

M. Paulus, F. Borggrefe / Applied Energy 88 (2011) 432–441

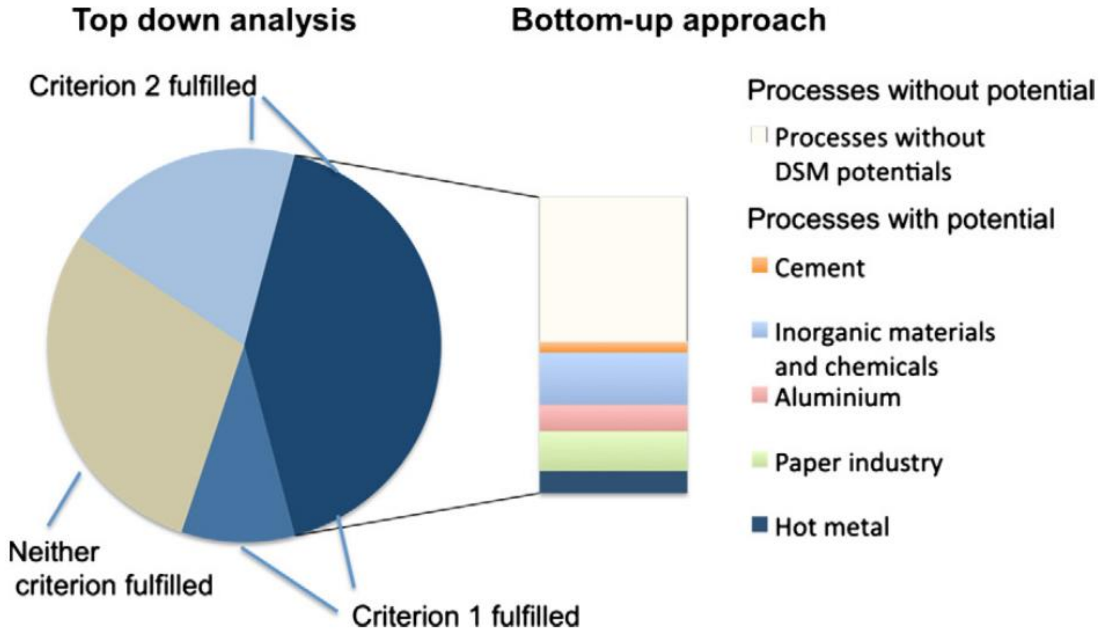

Fig. 1. Top-down analysis of DSM potential in balancing markets in Germany (own analysis).

Paulus, Borggrefe 2011 [01]

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- Technische und wirtschaftliche Analyse

Table 1
Overview and scope of the investigated industrial processes (own analysis).

Industrial product	Process	Capacity [MW]	Classification
Chloride	Chloralkali electrolysis	660	Load shifting/ shedding
Aluminum	Aluminum electrolysis	227	Load shedding
Cement	Cement milling	314	Load shifting/ shedding
Wood pulp	Mechanical refining	312	Load shifting
Steel	Melting in electric arc furnace	1097	Load shedding

[01]

Table 2
Technical parameters of the investigated industrial processes (own analysis).

Process	Technical potential [TW h/a]	Storage volume [MW h]	Restrictions	Energy intensity [MW h/t]	Pre-qualified for tertiary reserve[a] [MW]
Chloralkali electrolysis	14.6	1320	Utilization, storage size, process risk	2.85	660
Aluminum electrolysis	9.7	n/a	Utilization, process risk	15	227
Cement milling	2.2	3014	Supply chain dependencies, utilization	0.1	0
Mechanical refining	2.2	468	Medium storage size	1.5	0
Melting in electric arc furnace	7.2	n/a	Utilization, cool-down, energy intensity	0.53	550

[a] The information on pre-qualified capacity of industrial processes stems from personal interviews with the providers of ancillary services in Germany and, the four TSOs RWE, E.ON, EnBW and Vattenfall. Those interviews were conducted during 2007 and 2008 for the ongoing *dena2 grid study* [20].

Paulus, Borggrefe 2011 [01]

- Technische und wirtschaftliche Analyse

Table 3
Economic parameters of the investigated industrial processes (own analysis).

Processes	Investment costs [€/kW]	Variable costs [€/MW h]	Fixed costs [€/kW a]
Chloralkali electrolysis	<1	>100	~0
Aluminum electrolysis	<1	500–1500	~0
Cement mills	15–18	400–1000	~0
Wood pulp production	12–15	<10	~0
Electric arc furnace	<1	>2000	~0

[01]

→ DIME Simulation

Paulus, Borggrefe 2011 [01]

- Ergebnisse
  - Alle betrachteten DR Kapazitäten werden innerhalb von 13 Jahren eingebunden
  - DR der Industrie verdrängt Gasturbinen

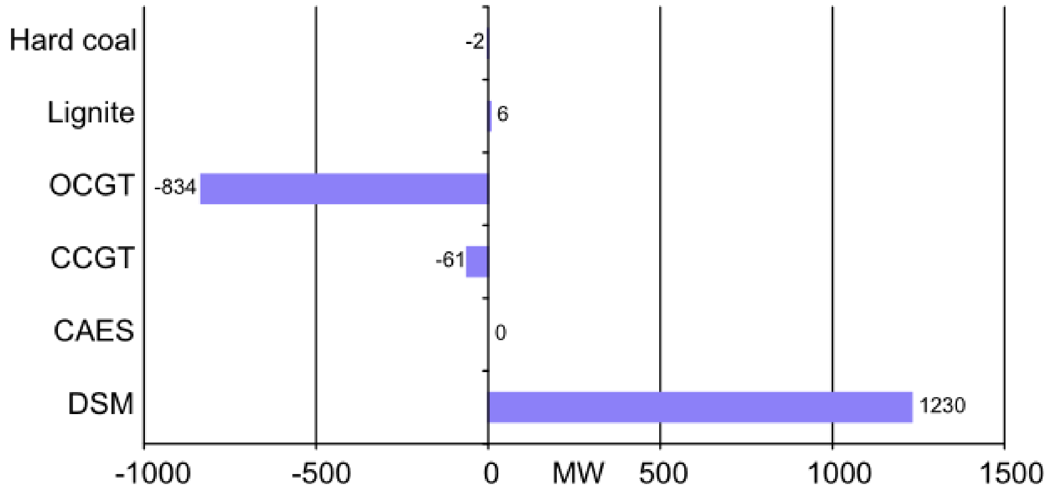

Fig. 3. Cumulated difference in net power plant commissions between 2007 and 2020 (own analysis).

[01]

Paulus, Borggrefe 2011 [01]

- Ergebnisse
  - Alle betrachteten DR Kapazitäten werden innerhalb von 13 Jahren eingebunden
  - DR der Industrie verdrängt Gasturbinen

M. Paulus, F. Borggrefe/Applied Energy 88 (2011) 432–441

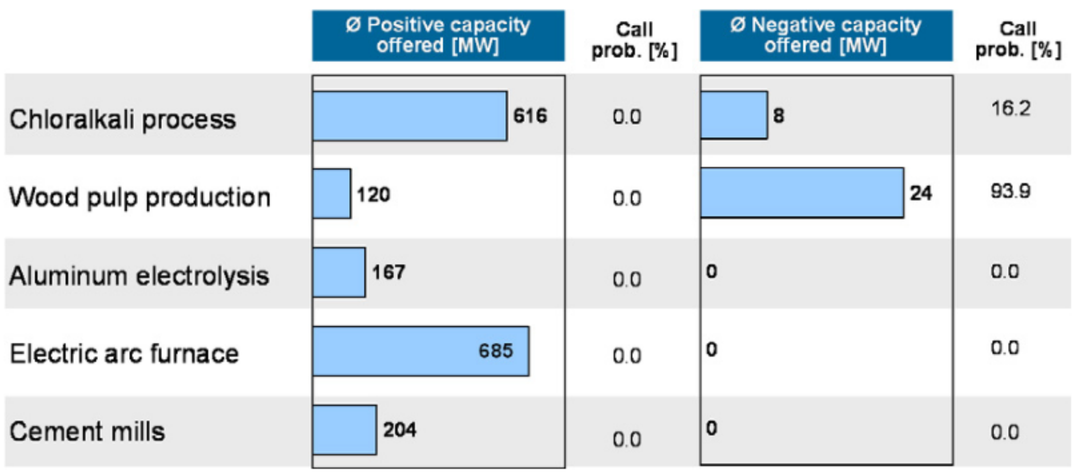

Fig. 4. Reserve capacity supplied by energy-intensive processes in Germany in 2020 (own analysis).

[01]

Paulus, Borggrefe 2011 [01]

- Ergebnisse
  - Alle betrachteten DR Kapazitäten werden innerhalb von 13 Jahren eingebunden
  - DR der Industrie verdrängt Gasturbinen
  - Load-Shift besser geeignet als Load-Shed
  - Hohes technisches Potential, in der Praxis geringer
  - „Taktieren“ der Industrien bereits im Modell
  - 2007-2020: 0.5 Mrd € gespart

Fig. 1. Curtailing load without changing load pattern.

Fig. 2. Load shifting.

- Kennzahlen eines geeigneten Industrieprozesses
  - Niedrige Auslastung der Produktionsanlagen
  - Schnelles Hoch-/Runterfahren der Prozesse
  - Qualitätsneutrales „Fahren“ der Prozesse
  - Lager-/Speichermöglichkeiten
  - Wenig menschlicher Arbeitseinsatz

- Höchste Einsparpotentiale bei
  - Starken Preisschwankungen
  - „Gamification“ / Information

Aktueller Stand

- China: 2800 MW verbundene Kapazität
  500 MW unter direct load control
- Florida Power and Light’s on Call Direct Load Control Program

- Forschung braucht hohe Akzeptanz bei mehreren Beteiligten
- Inhomogener, Europäischer Energiemarkt
- Fragliche Verdrängung der bisherigen Peak-Erzeugung
- Wer ist für die Forderung verantwortlich

Ansätze und Forschung - ITC

- Idee nicht neu, aber Möglichkeiten sind neu
- Kommunikationswege
  - Für intelligente System
  - Für faire Systeme
- Darstellung verlässlicher Last Szenarien

Ansätze und Forschung - ITC

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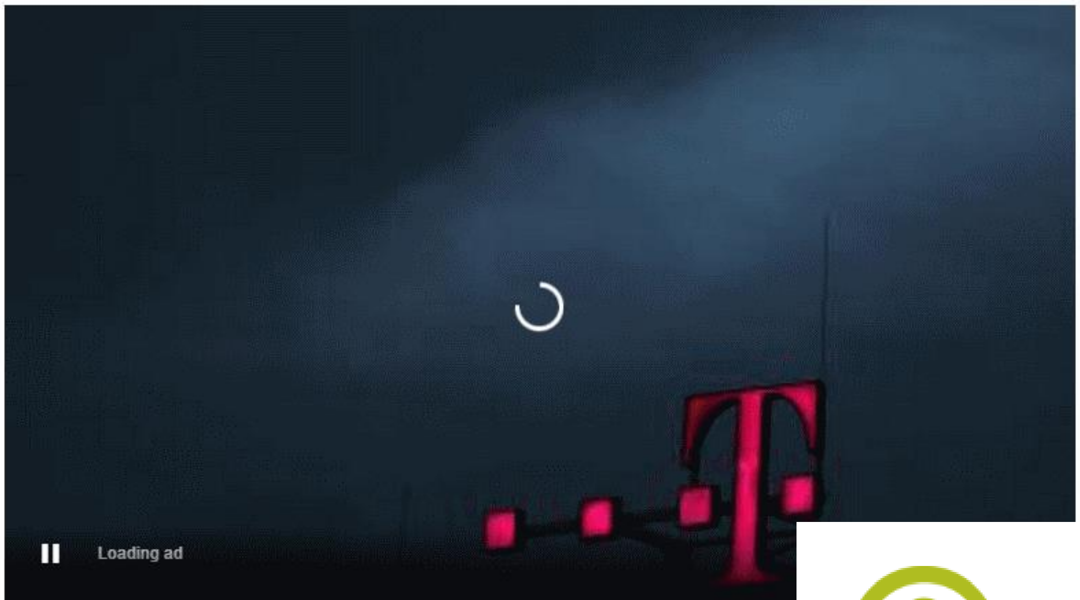
WEBWELT & TECHNIK INTERNET, TELEFONIE, FERNSEHEN

900.000 Router ausgefallen - Telekom prüft Hacker-Angriff

Stand: 28.11.2016 | Lesedauer: 4 Minuten



Die bundesweite Störung bei der Telekom dauert offenbar an. Auf Facebook macht das Unternehmen seinen Kunden wenig Hoffnung. Betroffen ist das Mobilfunknetz, sowie die Internet- und Fernsehdienste.

Quelle: Die Welt

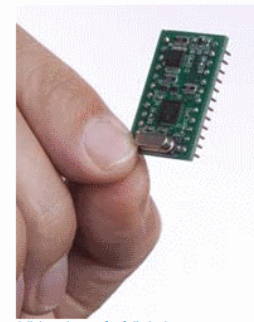
Grid Friendly Appliance™ Controller

Battelle Number(s): 12782-E, 13538-B
Patent(s) Issued
Available for licensing in all fields

Summary

The Grid Friendly Appliance controller developed at PNNL senses grid conditions by monitoring the frequency of the system and provides automatic demand response in times of disruption.

Within the North American power grid a disturbance of 60-Hz frequency is an indicator of



(click on image for full size)

A coin-sized integrated circuit developed by researchers at Pacific Northwest National Laboratory may help solve the nation's overworked electricity grid. Called The Grid Friendly™ Appliance Controller, the circuit board would turn normal household appliances into ones that would better regulate energy usage and help prevent local and national blackouts.

openADR ALLIANCE

Ansätze und Forschung - ITC

- Interoperabilität
- Stabilität / verlässlichkeit der Algorithmen

- Sicherheit
(Confidentiality / Integrity / Authenticity)
- Digital identity
(Signatures)

- Informationstechnik ⬄ Effiziente Nutzung EE [29]

Energy Management is not complicated

it‘s just difficult

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- [2] Finn, Fitzpatrick
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- [27] Kim, Shcherbakova
  Common failures of demand response
- [28] Albadi, El-Saadany
  A summary of demand response in electricity markets

Quellen

- [29] Marija, Xie
  Efficient Coordination of Wind Power and Price-Responsive Demand-Part I: Theoretical Foundations
- [30] Ilic, Xie
  Efficient Coordination of Wind Power and Price-Responsive Demand—Part II: Case Studies
- [31] DÜNB
  Bericht der deutschen Übertragungsnetzbetreiber nach Leistungsbilanz 2013

Backup – DSM im privaten Umfeld

Karlsruher Institut für Technologie

- Hohe Investitionskosten pro kWh Load Reduction
- Tempo tariff Frankreich Link
- Stromkosten anteilig am Haushaltseinkommen bis 2.8%. Bei 30% Kostensenkung ergeben sich 0,84% geringer Haushaltsausgaben
- Cave: Gleiche Beträge für KFZ Unterhalt

Backup Paulus, Borggrefe 2011

- Dispatch and Investment Model for Electricity Markets in Europe (DIME)

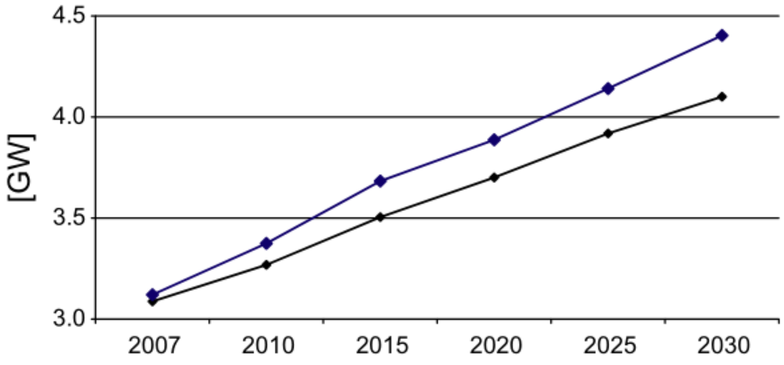


Fig. 2. Demand for positive (black) and negative (blue) tertiary reserve capacity in Germany until 2030 (own analysis). (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

[01]

Backup Paulus, Borggrefe 2011

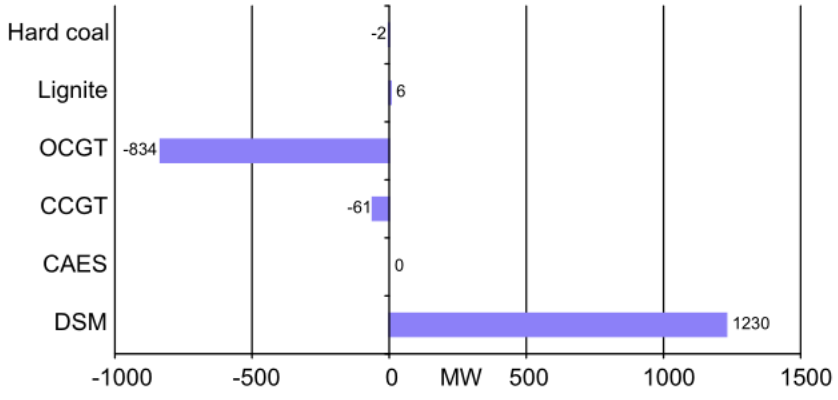


Fig. 3. Cumulated difference in net power plant commissions between 2007 and 2020 (own analysis).

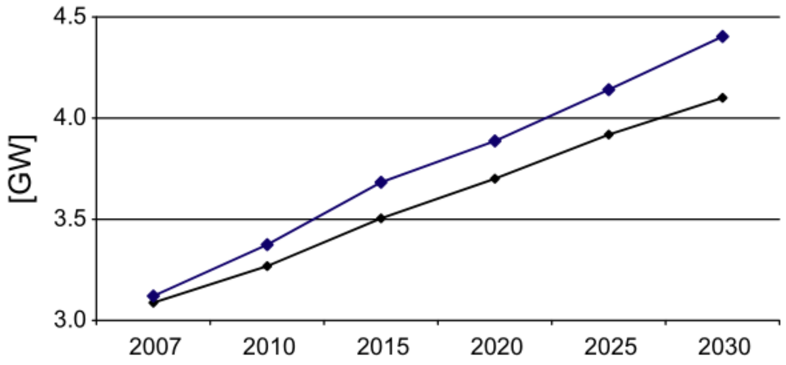


Fig. 2. Demand for positive (black) and negative (blue) tertiary reserve capacity in Germany until 2030 (own analysis). (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

[01]

Backup Paulus, Borggrefe 2011

The assumptions for the probability distributions of the forecast error and the stochastic noise of the electricity load were taken from [5,17]. The standard deviation for the forecast error lies in the range of 2–2.5% of annual peak electricity load. The standard deviation for the stochastic noise of electricity load lies in the range of 90–150 MW independent of actual load. The wind forecast error is modelled through a beta distribution based on empirical data. The detailed sample set and calibration of the beta distribution is described in [5]. The probability distribution of unplanned non-disposable power plant outages is modelled by a two-step Markov-Process. The probabilities for outages are convoluted for every single power plant block in Germany. It is assumed that power plant outages are independent events (for a detailed description see [16,17]). The probabilities for power plant outages are based on empirical data for power plant outages in Germany from 1995 to 2005. It can be found in [21].

10

The empirical distribution of wind forecast errors in Germany is negatively skewed. This is because positive short term increases of the wind feed-in have historically been more difficult to predict than short term wind calms (see also [5,16,17]).

Backup Finn, Fitzpatrick 2013 [2]

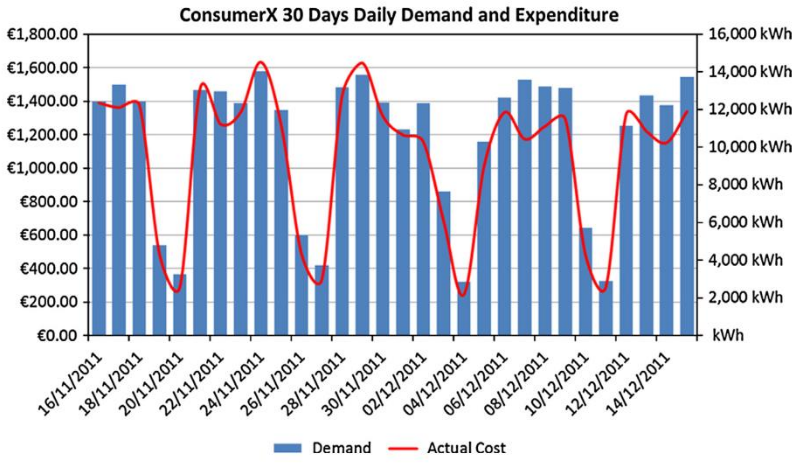


Fig. 8. Daily electricity consumption and cost for the previous 30 days.

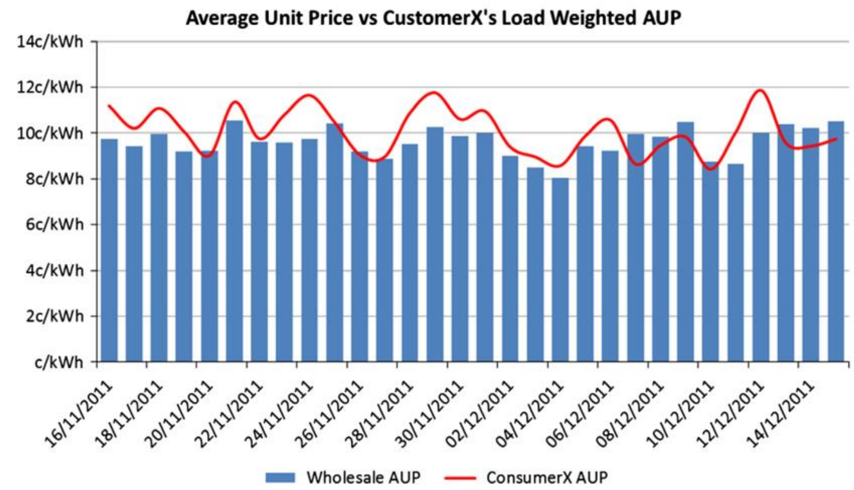
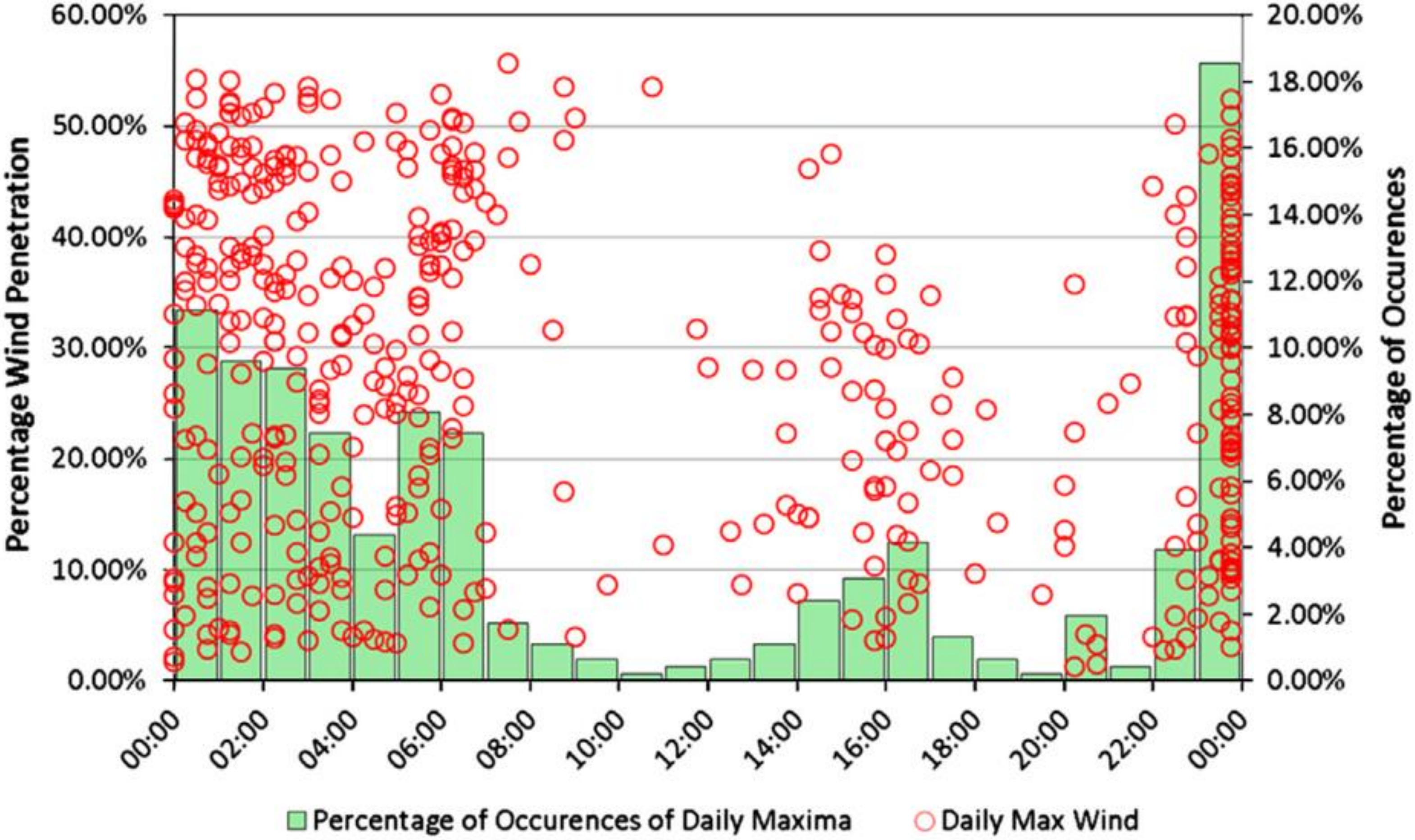


Fig. 9. Daily average unit price of electricity for a unit load compared to the consumer's load weighted average unit price during the previous 30 days.

Backup Finn, Fitzpatrick 2013 [2]



Backup Warum Industrial Demand Side Management

Karlsruher Institut für Technologie

- Vorteile / Ersparnisse
  - Niedrigere Strompreise
  - Effizientere Netznutzung
  - Versorgungssicherheit
  - Bessere Marktstruktur
  - Weniger Emmissionen
  - [18]
- Nachteile / Kosten
  - Initiale Kosten
  - Laufende Fix- und variable Kosten
    - Hardware
    - Software
  - Schulung / Marketing

Backup DSM – Virtual Storage Power Plant

- Zusammenschluss mehrerer Verbraucher zu einem Virtual Storage Power Plant
- Bspw. Garantierte Abnahme der Energie beim Hochfahren eines Kraftwerks