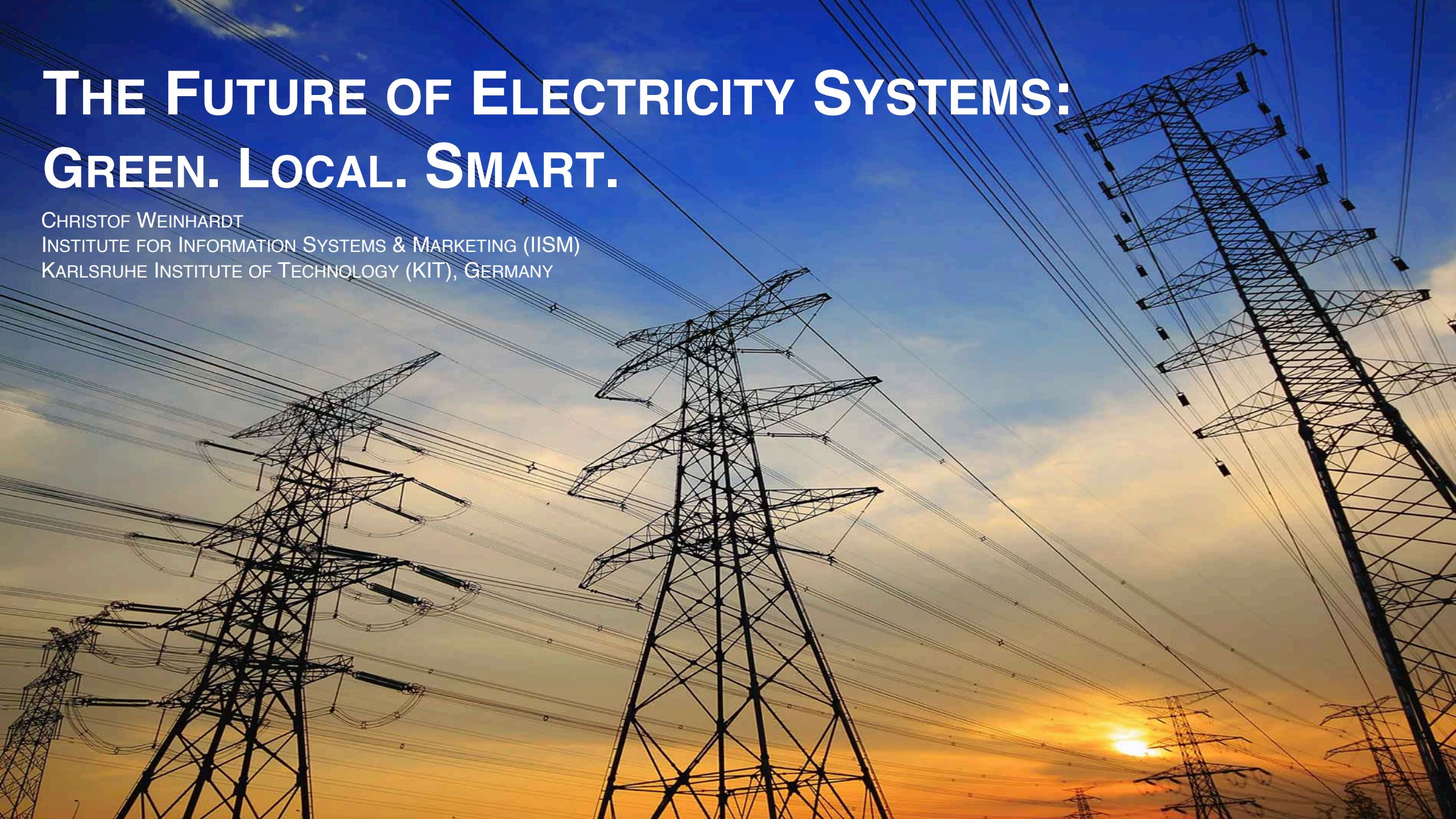
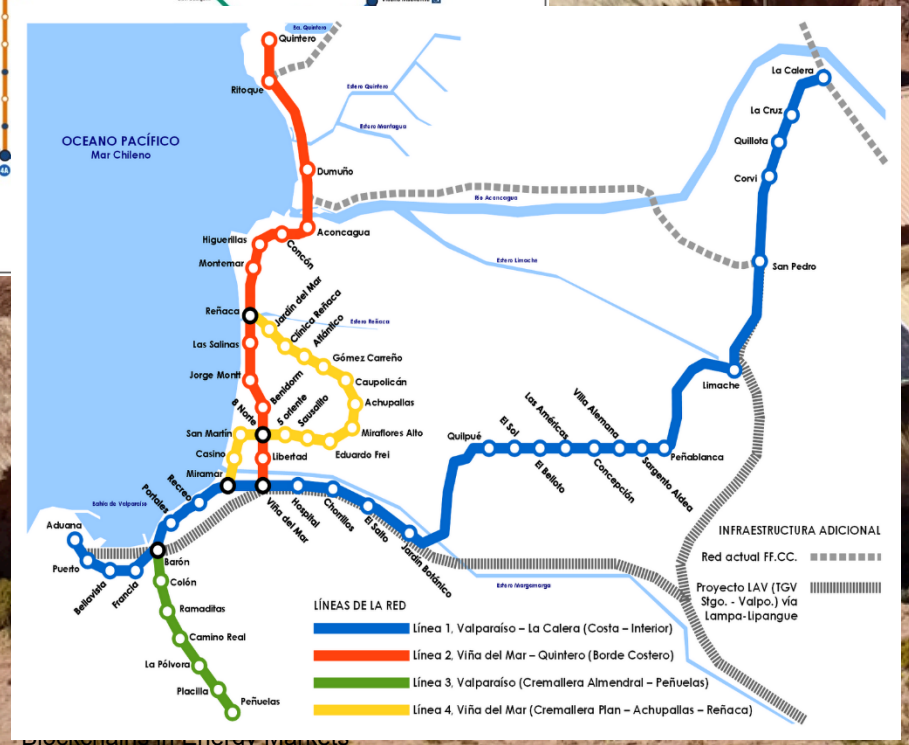


The Future of Electricity Systems: Green. Local. Smart.

Christof Weinhardt
Institute for Information Systems & Marketing (IISM)
Karlsruhe Institute of Technology (KIT), Germany



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Rheinstetten
Neuburgweier
Forchheim
Ettlingen West
Ettlingen Stadt
Waldbronn
Busenbach
Reichenbach
Spessart
Ettlingenweier
Bruchhausen
Malsch
Ober-weier
Schluttenbach
Schöllbronn
Sulzbach
Etzenrot
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Spielberg
Ittersbach
Pfaffenrot
Schielberg
Frauenalb
Marxzell
Freiolsheim
Moosbronn
Rotensol
Neusatz
Dobel
Bad Herrenalb
Bernbach
Gaggenau
Sulzbach
Ottenau
Bad Rotenfels
Oberweier
Winkel
Michelbach
Völkersbach
Waldprechtsweier
Rauental
Rastatt
Plittersdorf
Ottersdorf
Niederbühl
Winters-dorf
Förch
Kuppenheim
Bischweier
Sandweier
Oberndorf
Haueneberstein
Iffezheim
Hügelsheim
Muggensturm
Durmersheim
Bietigheim
Au am Rhein
Elchesheim-Illingen
Würmersheim
Mörsch
Steinmauern
Ötigheim
Plittersdorf
Otters-dorf
Lauterbourg
Scheibenhardt
Neulauterburg
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Maximiliansau
Im Rüsten
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Rohrbach
Herxheim
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Insheim
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Linkenheim
Leopoldshafen
Eggenstein
KIT Campus-Nord
Spöck
Friedrichstal
Stutensee
Staffort
Blankenloch
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Weingarten
Büchenau
Neuthard
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Neuthard
Karlsdorf
Forst
Ubstadt-Weiher
Bruchsal

Agenda

- Green
- Smart
- Local
- Flexible
- Collaborative
- Comprehensive

GREEN

1.1°C

RISE IN TEMPERATURE

1930

2002

2006

[NASA, 2017]

GREEN

42%

CO_2 EMISSIONS BY ENERGY PRODUCTION

[STATISTA, 2017]

GREEN

782 GW

WIND & PV

REQUIRE STRUCTURAL CHANGES

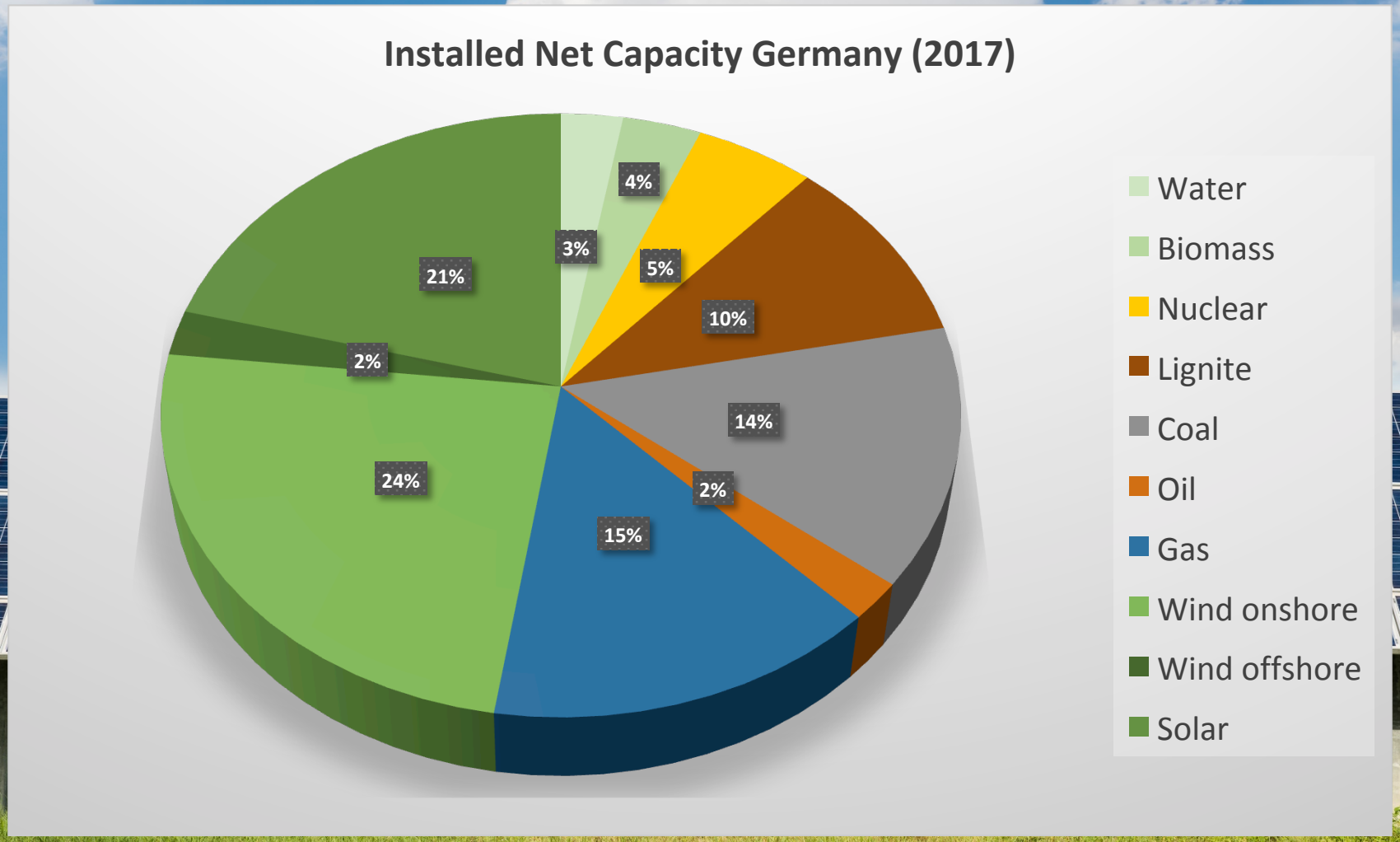
Green

97 GW Wind & PV

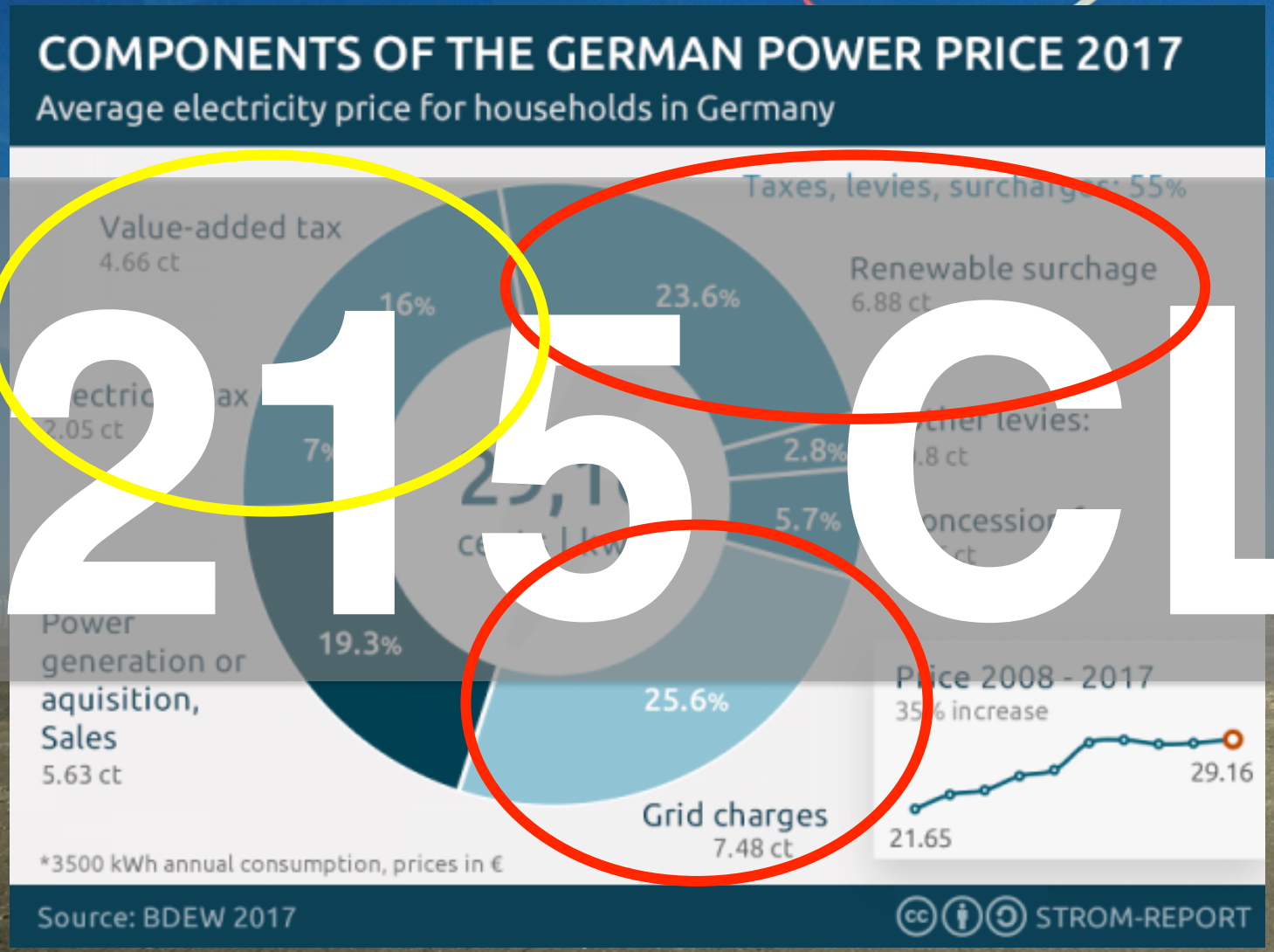
Onshore (49.5) – Offshore (4.9) – PV (42.5)

Germany

GREEN


Installed Net Capacity Germany (2017)
4%
3%
5%
10%
21%
2%
14%
24%
2%
15%
Water
Biomass
Nuclear
Lignite
Coal
Oil
Gas
Wind onshore
Wind offshore
Solar

GREEN

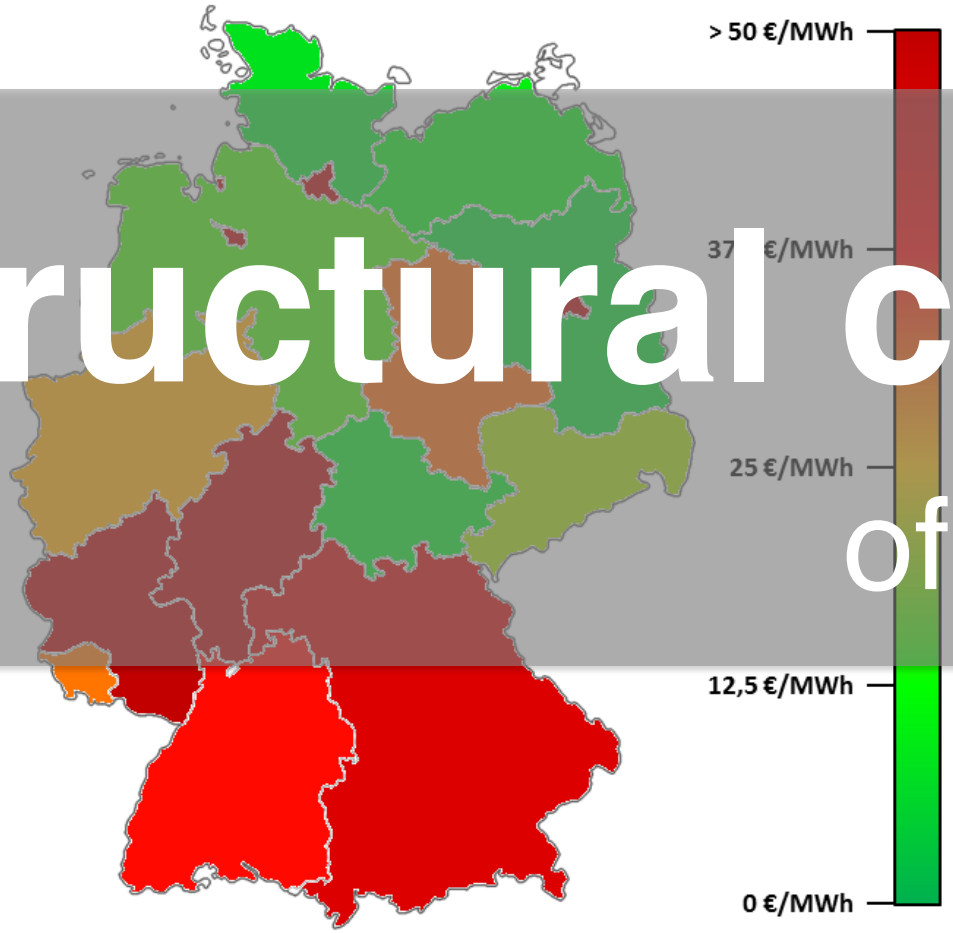


215 CLP

GREEN

Structural challenges

of renewable integration



EXCLUSIVE PREMIUM

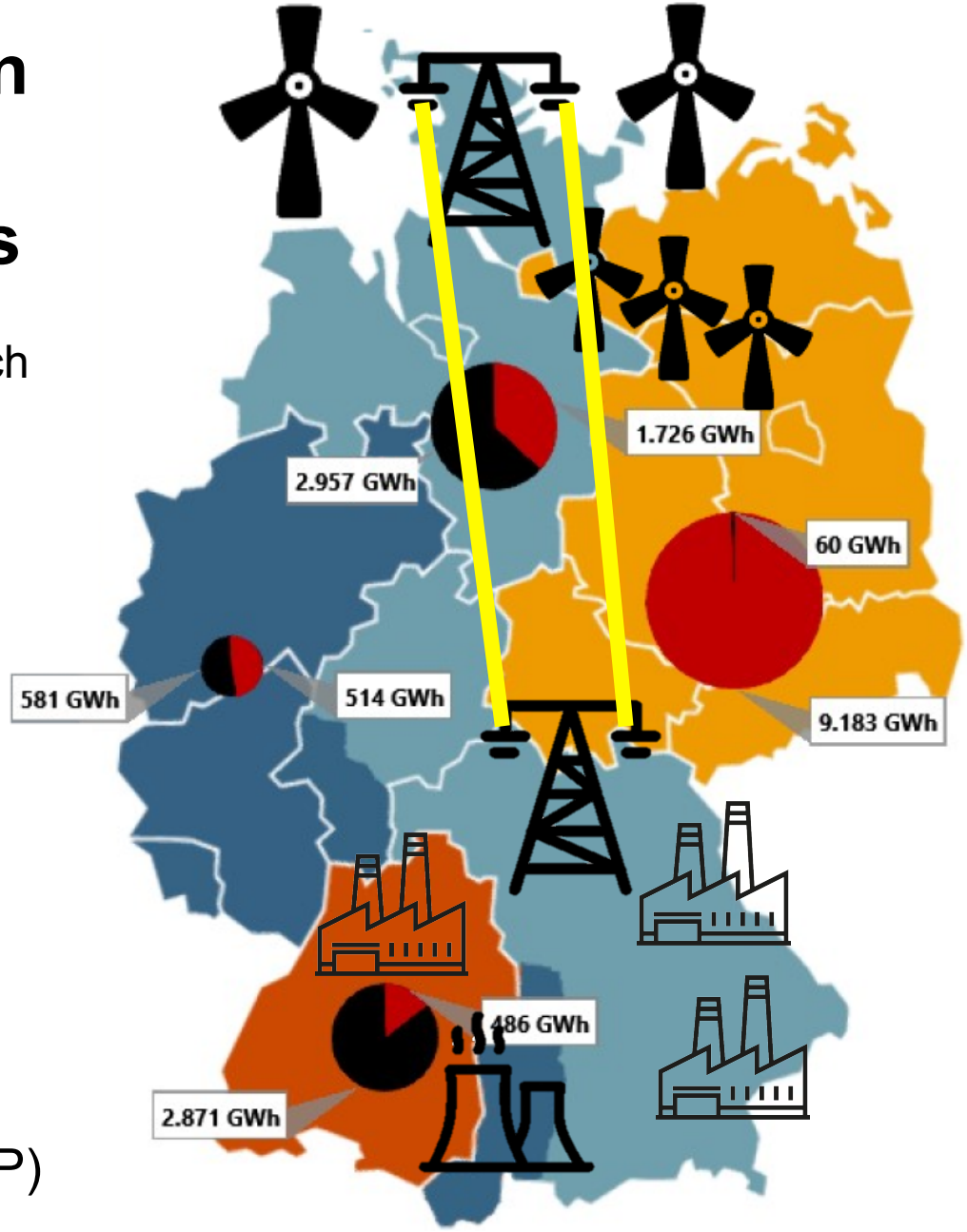
Exclusive: E.U. Commission Considers Splitting Germany Into Two Energy Price Zones

The European Commission is considering dividing the German electricity market into two price zones, Handelsblatt has learned. That would raise energy prices in southern Germany and lower them in the north.

(Staudt 2017)

Major Challenge in single-price electricity markets

Infrastructural/spatial mismatch between generation and consumption of electricity



- Redispatch Ramp Up
- Redispatch Ramp Down

current solution:

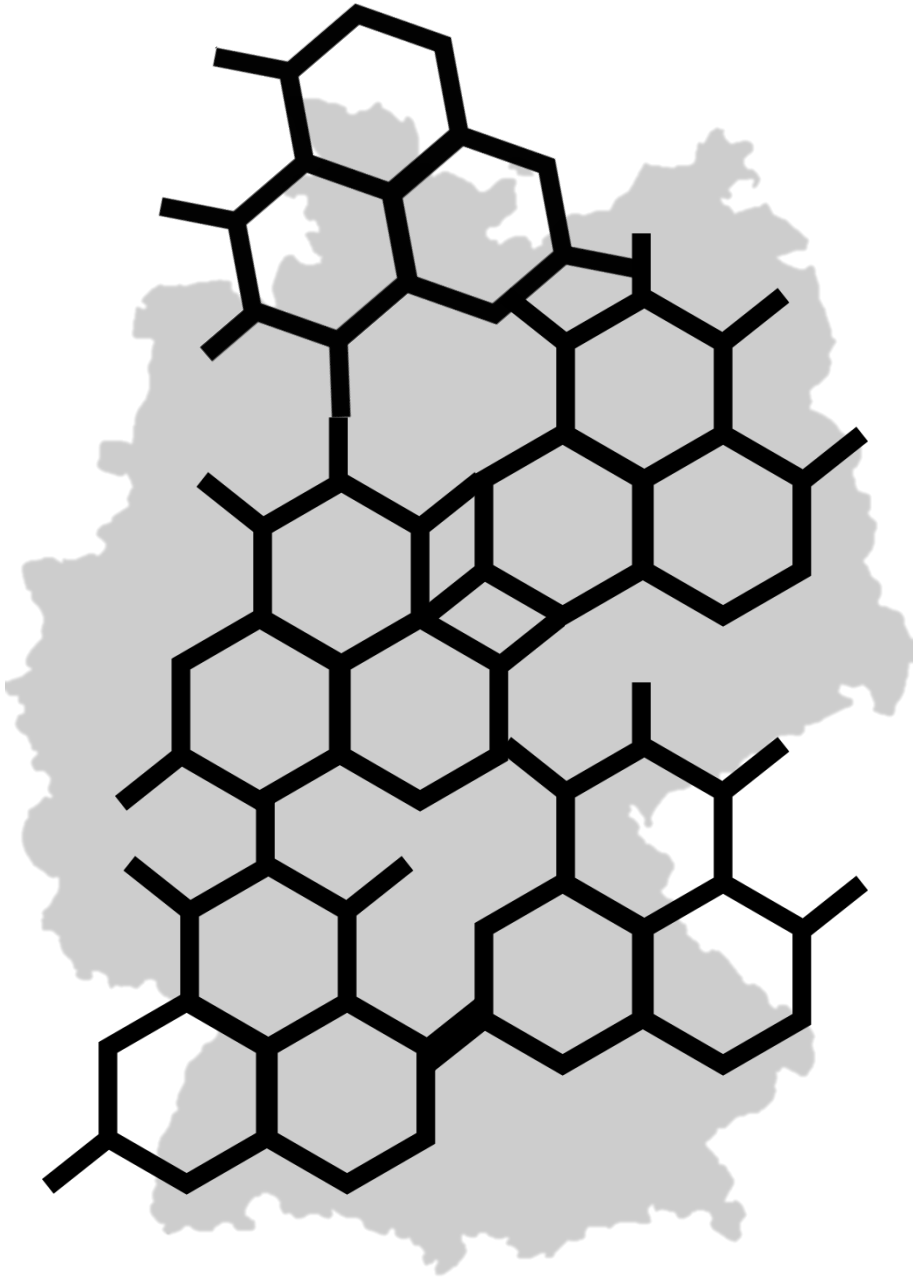
→**Redispatch**

(Cost in Germany 2015
1 billion € = 740 billion CLP)

LOCAL
Our vision

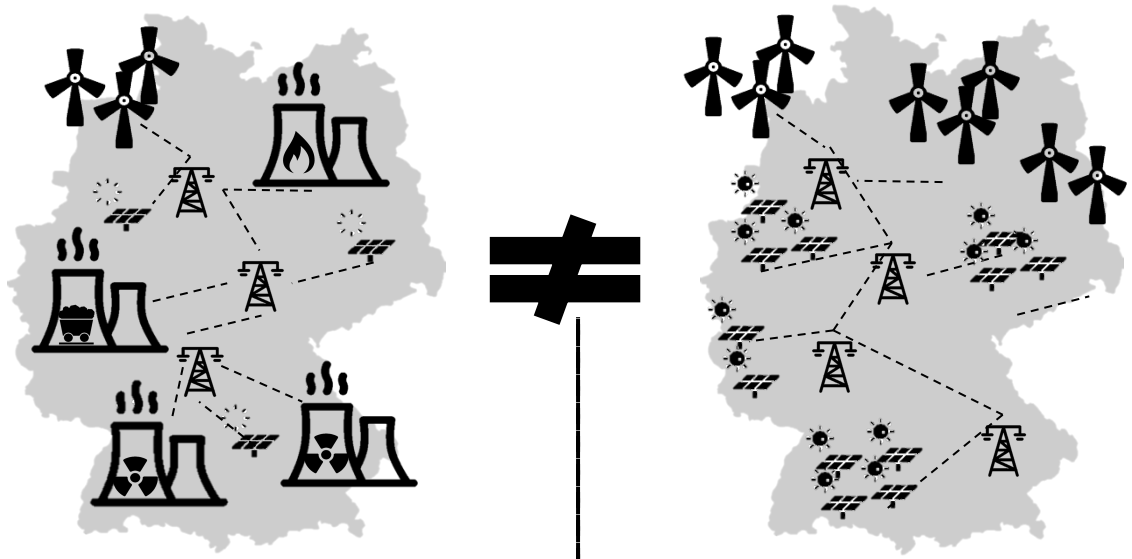
Karlsruhe Institute of Technology

Decentralized cellular structure for Local Markets

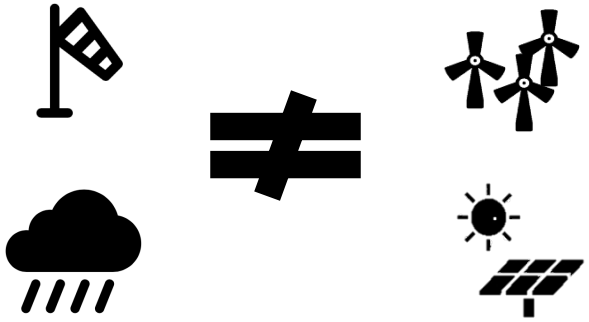


100% Regenerative Energy Supply is not feasible by now.

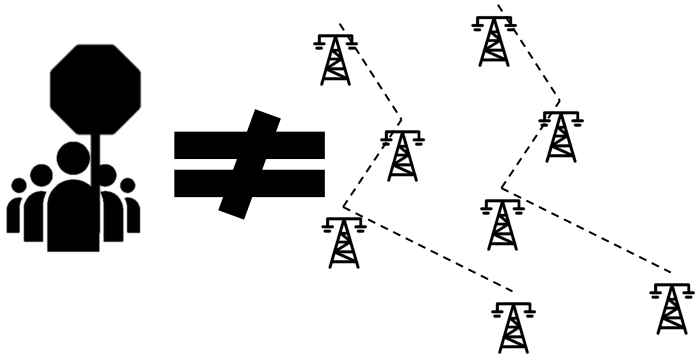
Transition to 100 % Regenerative



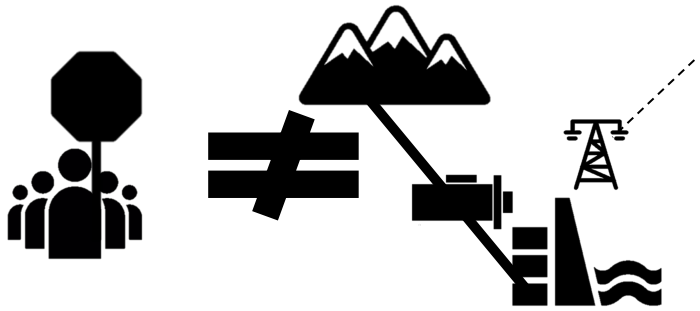
Supply Security



Network Extension

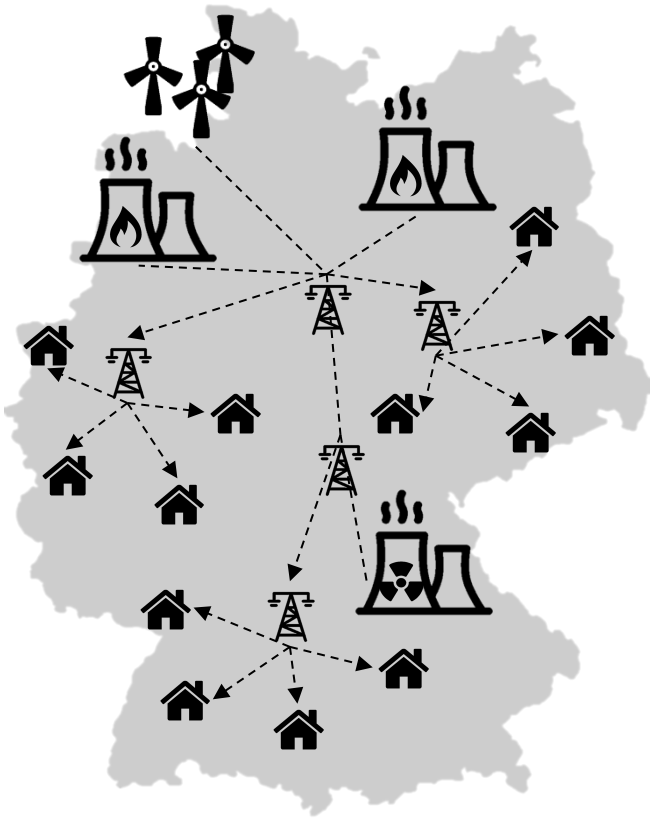


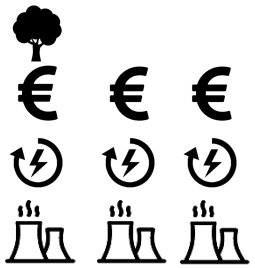
Energy Storage



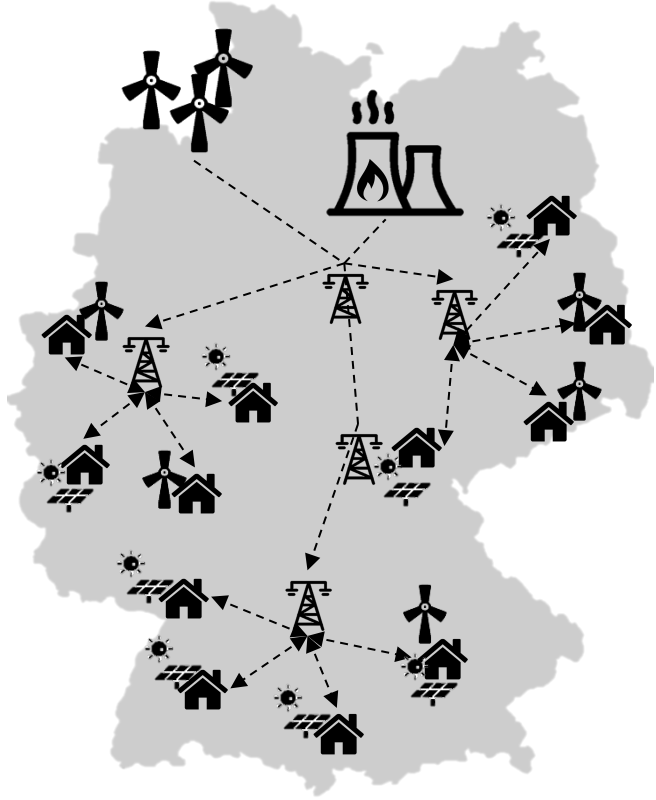
THE LOCAL MARKET APPROACH IS A STEP TOWARDS A MORE SUSTAINABLE ENERGY MARKET.

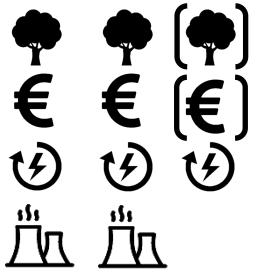
CENTRAL ENERGY MARKETS



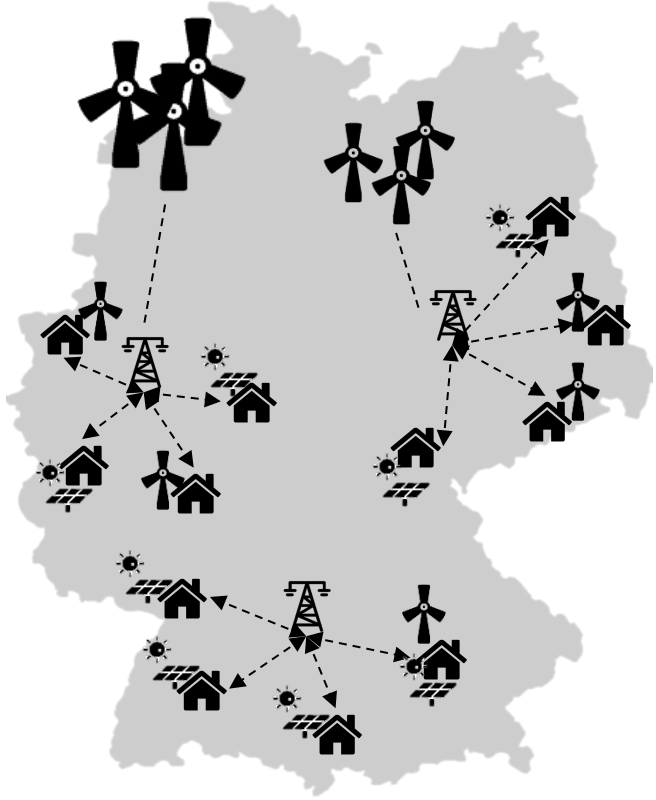


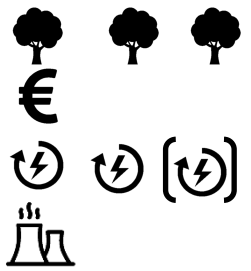
HYBRID MARKET





LOCAL ENERGY MARKETS





LOCAL

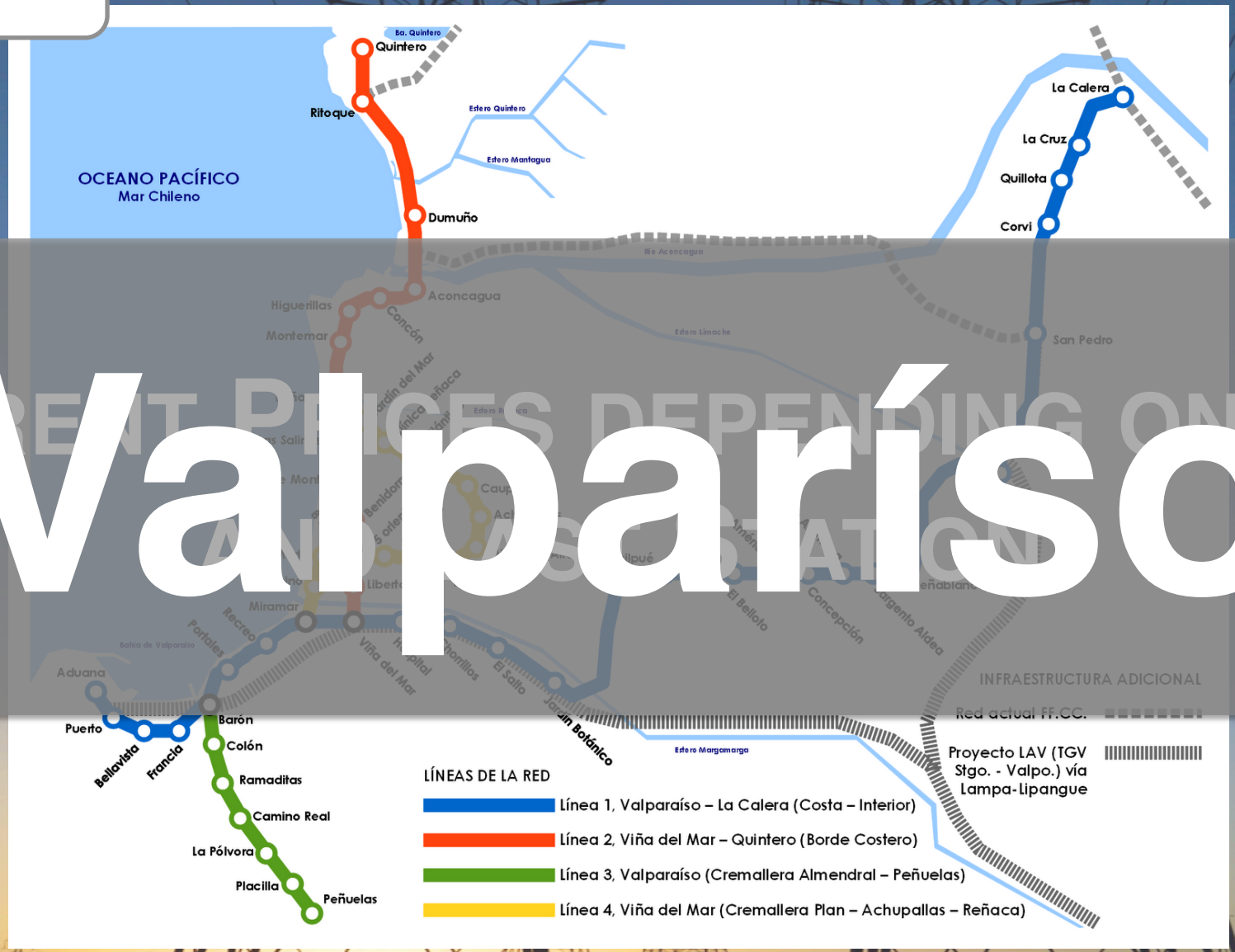
74 Santiago

HORA PUNTA ANYWHERE!

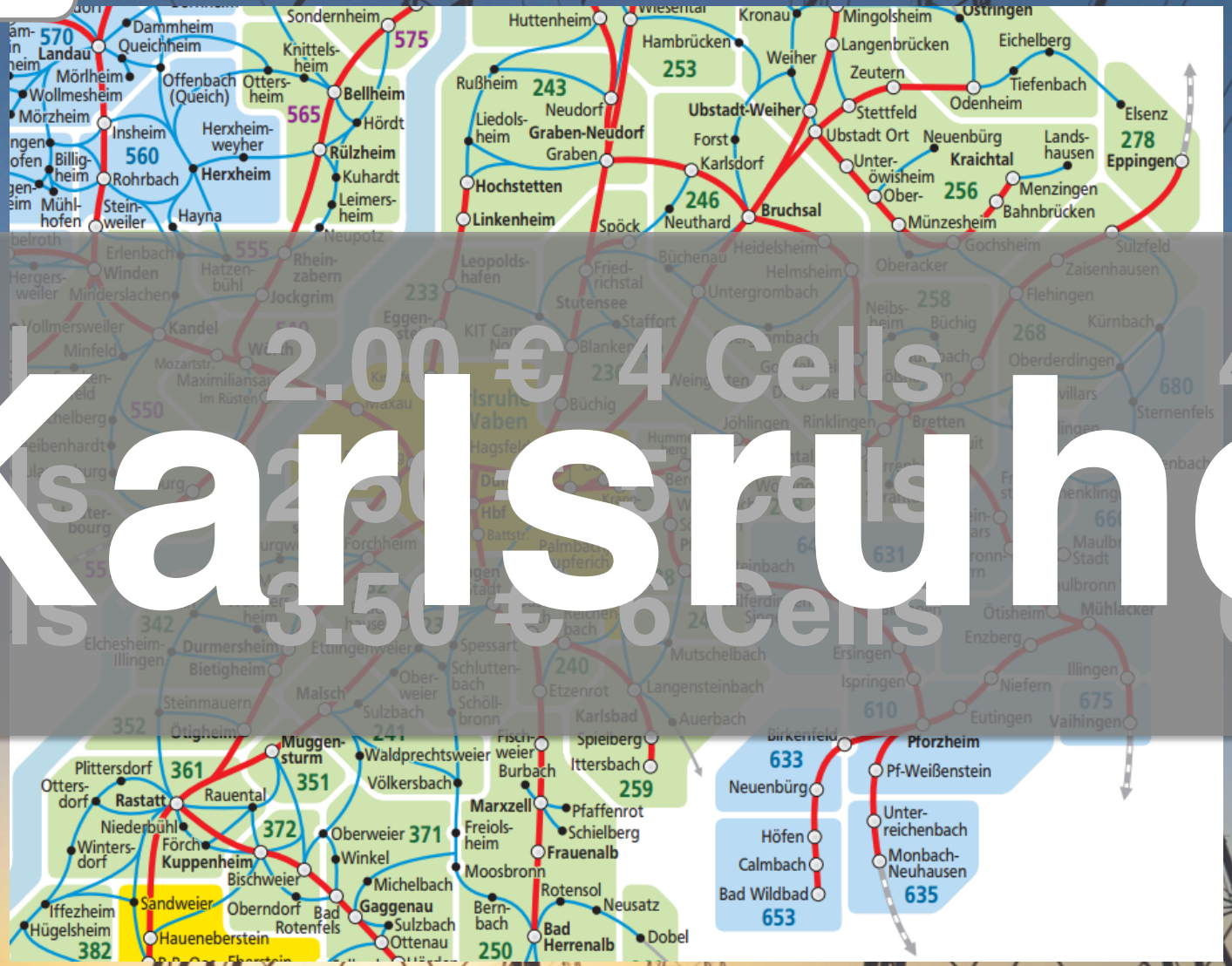
Local

Valparíso

Different Prices depending on First and Last Station



LOCAL



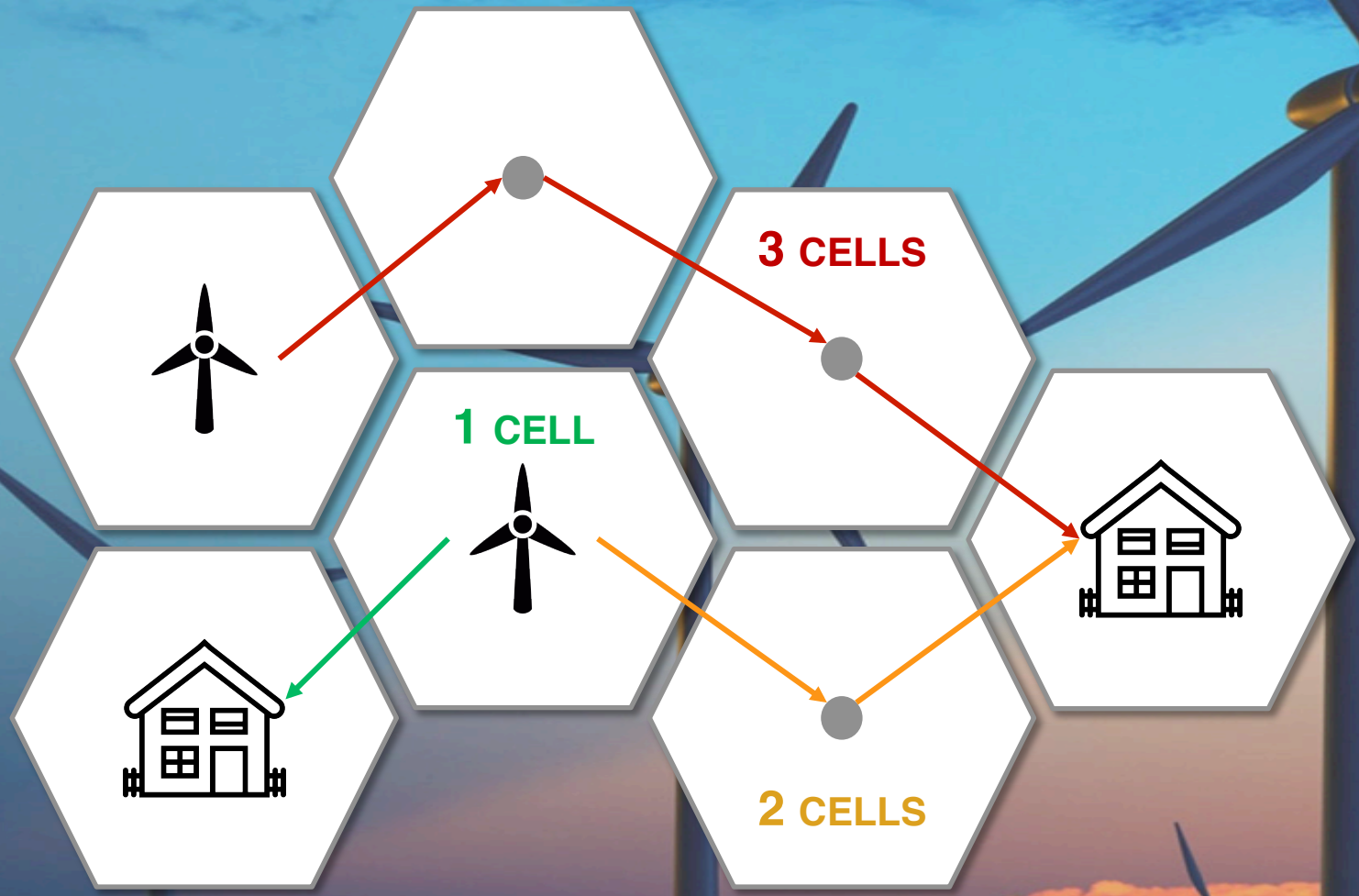
1 Cell 2.00 € 4 Cells 4.30 €

2 Cells 3.50 € 5 Cells 5.20 €

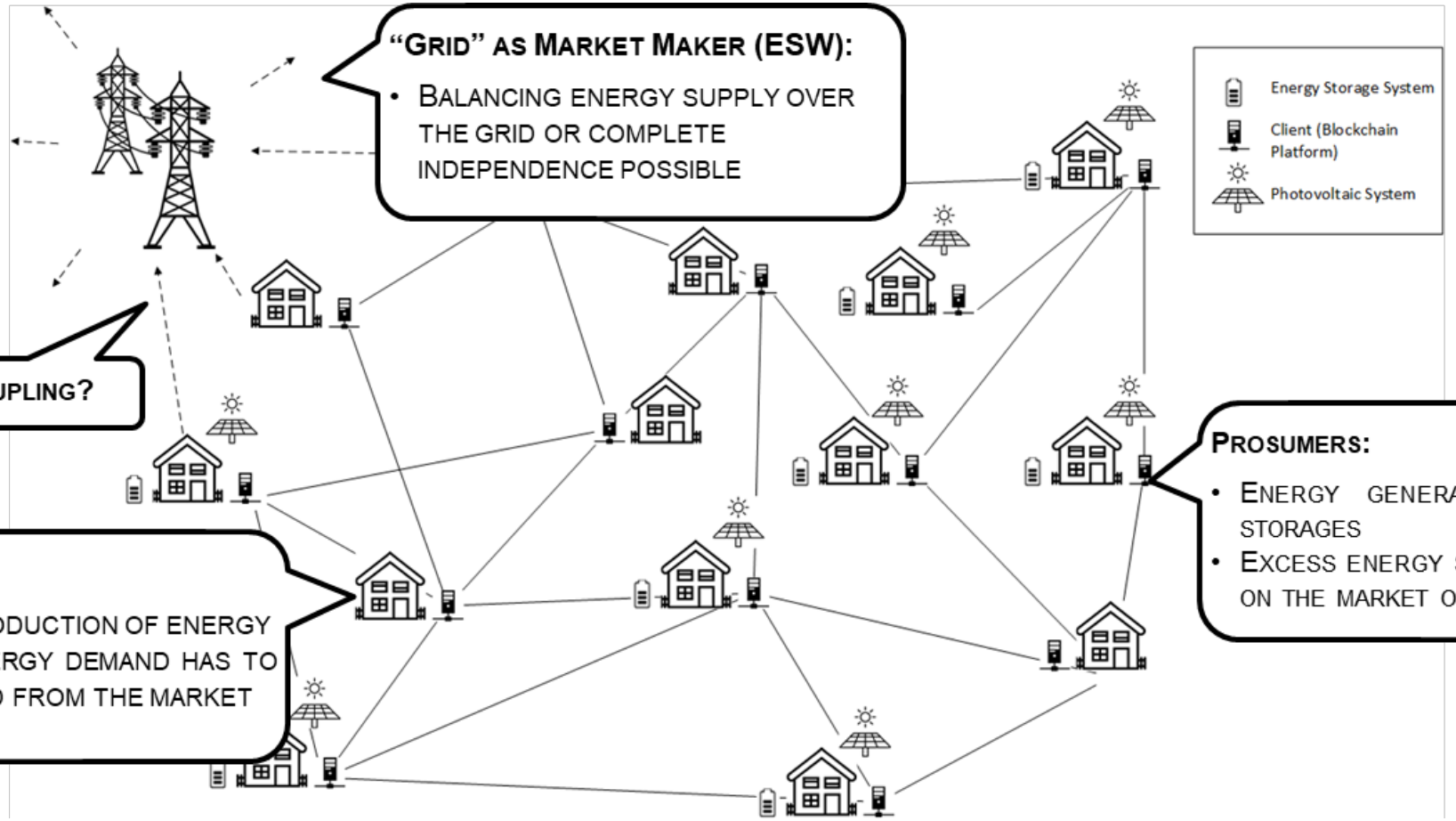
3 Cells 3.50 € 6 Cells 6.10 €

Karlsruhe

LOCAL



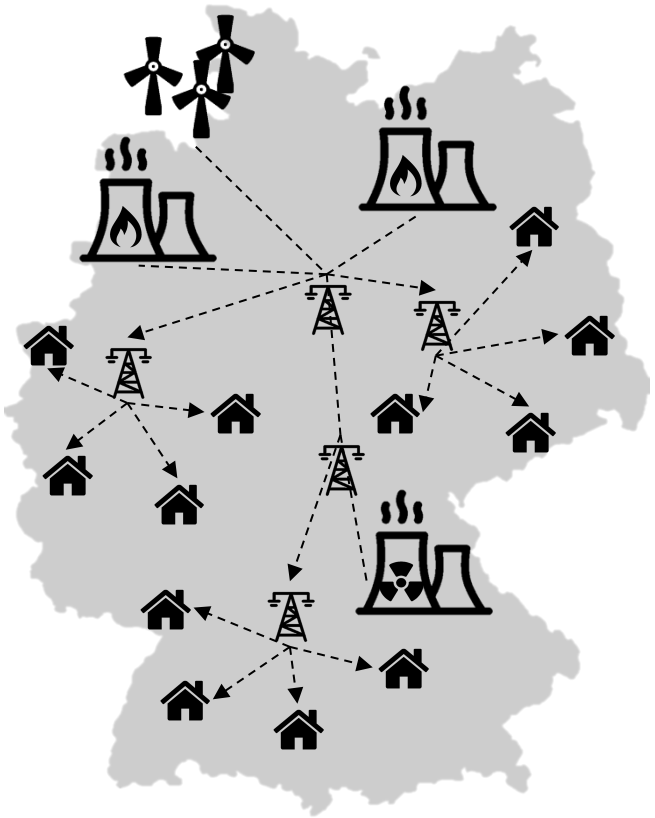
COLLABORATIVE

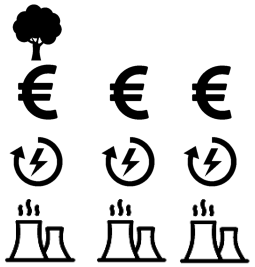


PEER-TO-PEER ENERGY TRANSACTIONS BETWEEN MARKET AGENTS

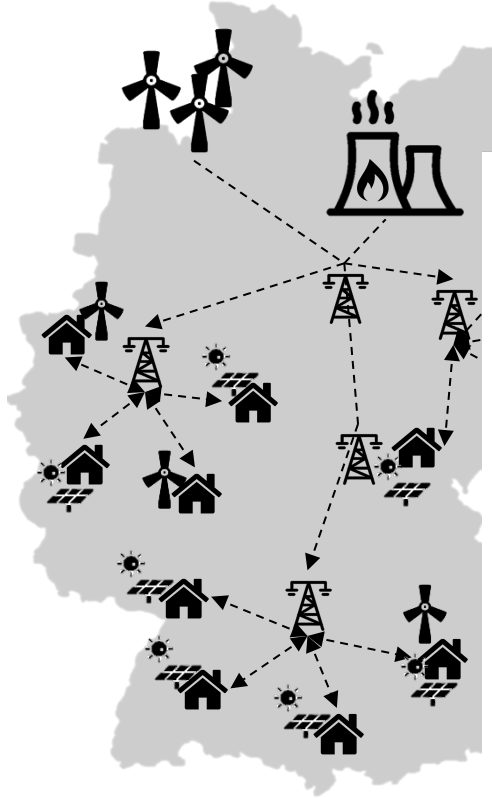
THE LOCAL MARKET APPROACH IS A STEP TOWARDS A MORE SUSTAINABLE ENERGY MARKET.

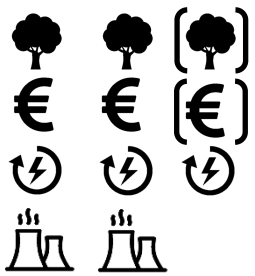
CENTRAL ENERGY MARKETS

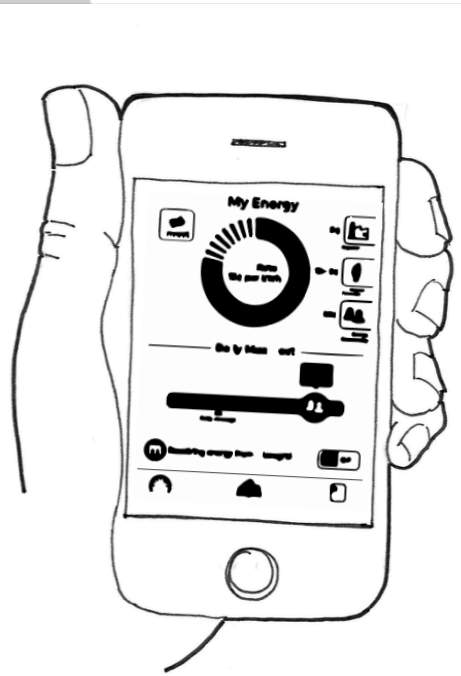




HYBRID MARKET

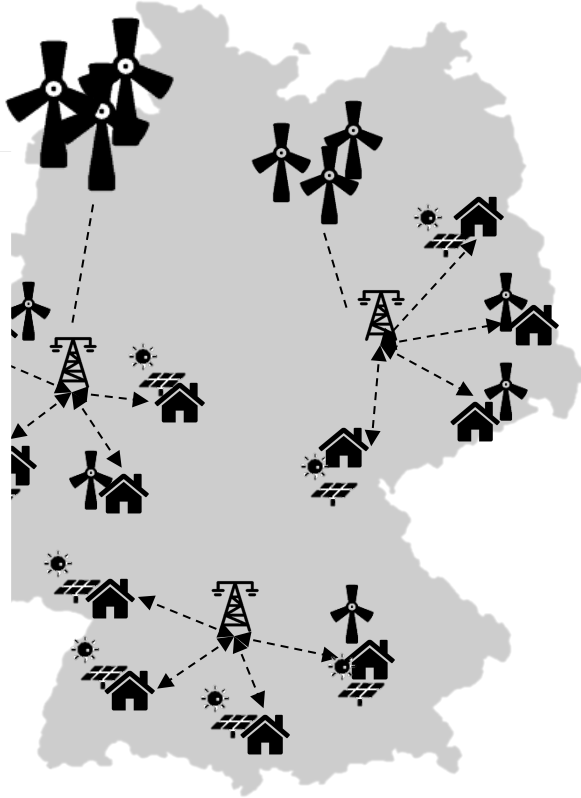


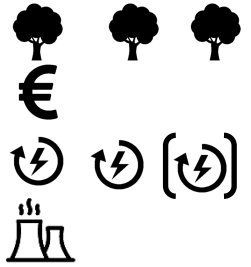




REDUCTION OF COORDINATION COSTS

LOCAL ENERGY MARKETS

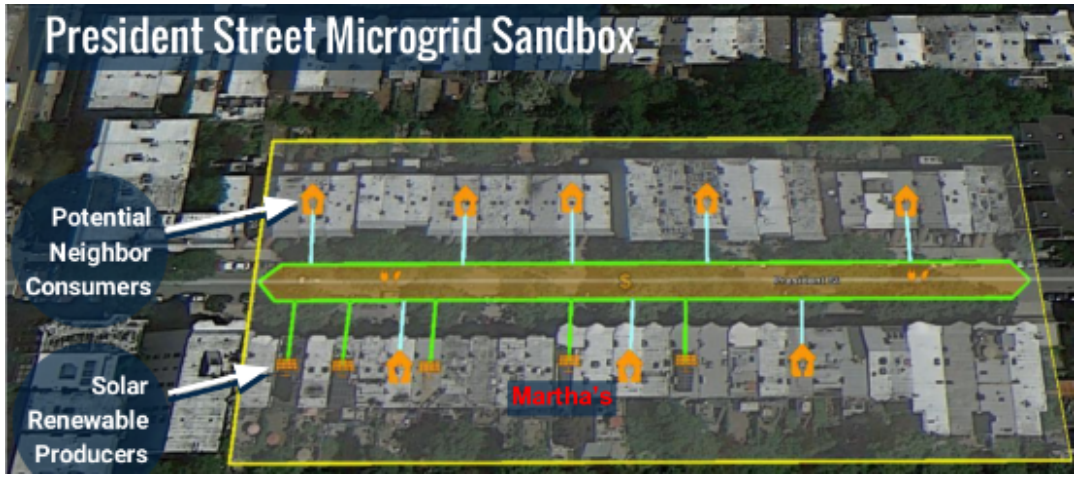




Challenges for the design of future energy markets

- What is the **optimal market size** in local markets?
- How must local markets be **coupled**?
- How is the **connection** towards **upper grid levels** of markets to be designed?

Decentralized P2P Trading
The Brooklyn Microgrid Project



Blockchain-Technology…

Goals:

- Support local P2P energy trading
- Strengthen community and reduce risk of power outages
- Create incentives for local investments
- Traceability of trading of „green“ energy

LAZARETTGARTEN MICROGRID PROJECT (LAMP)

LAMP
Landau Mikrogrid Projekt

Scope

- EXPERIMENTAL **SANDBOX**
- 130 APARTMENTS/HOUSES, 19 BUSINESSES
- ESTIMATED ELECTRICITY CONSUMPTION 300,000 KWH P.A.
- ESTIMATED DISTRICT HEATING 750,000 KWH P.A.

Methods

- IMPLEMENTATION FOR **10-20 PARTICIPANTS**
- INSTALLATION OF A **LOCAL ENERGY MARKET** (1 CELL)
- REGULATORY **FREEDOM** FOR ANY MARKET DESIGN (AREAL GRID)
- PHYSICAL **MICROGRID** WITH THE POTENTIAL TO INCLUDE NEARBY COMMUNITIES → AUTARKY POSSIBLE?

LO3 ENERGY

EnergieSüdwest
Strom | Erdgas | Wasser | Wärme

THE LAZARETTGARTEN

Blockchain and IoT Technology

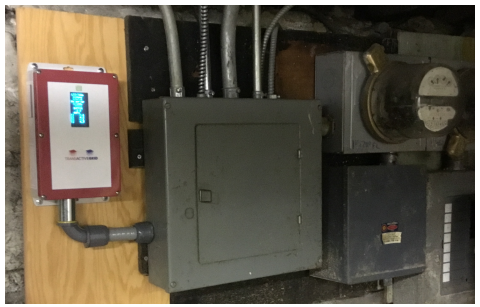
LAZARETTGARTEN MICROGRID PROJECT (LAMP) – CUSTOMER SIDE

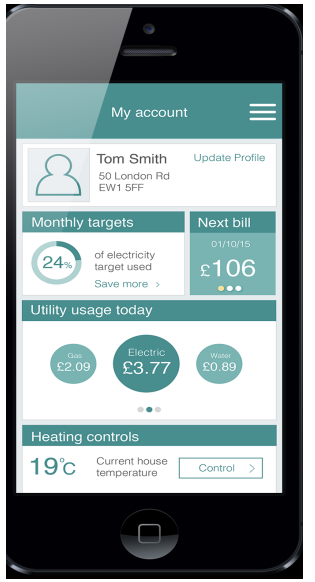
LAMP
Landau Mikrogrid Projekt

- **BOUNDED RATIONALITY**: SETTING YOUR PREFERENCES ONCE
- AUTOMATIC **BIDDING** WITH PREPROGRAMMED AGENTS AND SET MARKET MECHANISM
- **GRAPHICAL EVALUATION** OF GENERATION, CONSUMPTION, PRICE, ENERGY SUPPLY MIX
- RESETTING PREFERENCES AT WILL

LO3 ENERGY

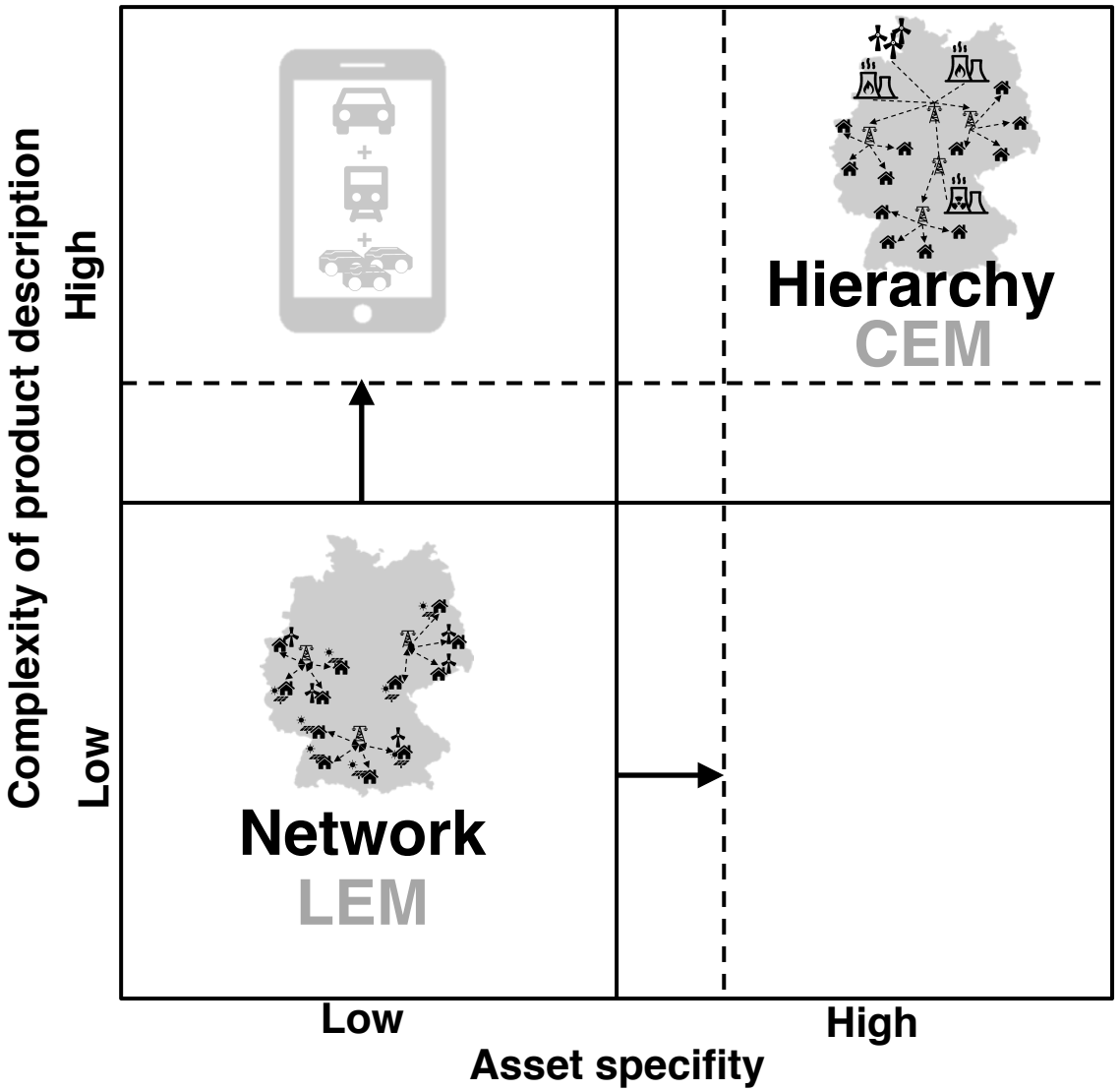
EnergieSüdwest
Strom | Erdgas | Wasser | Wärme





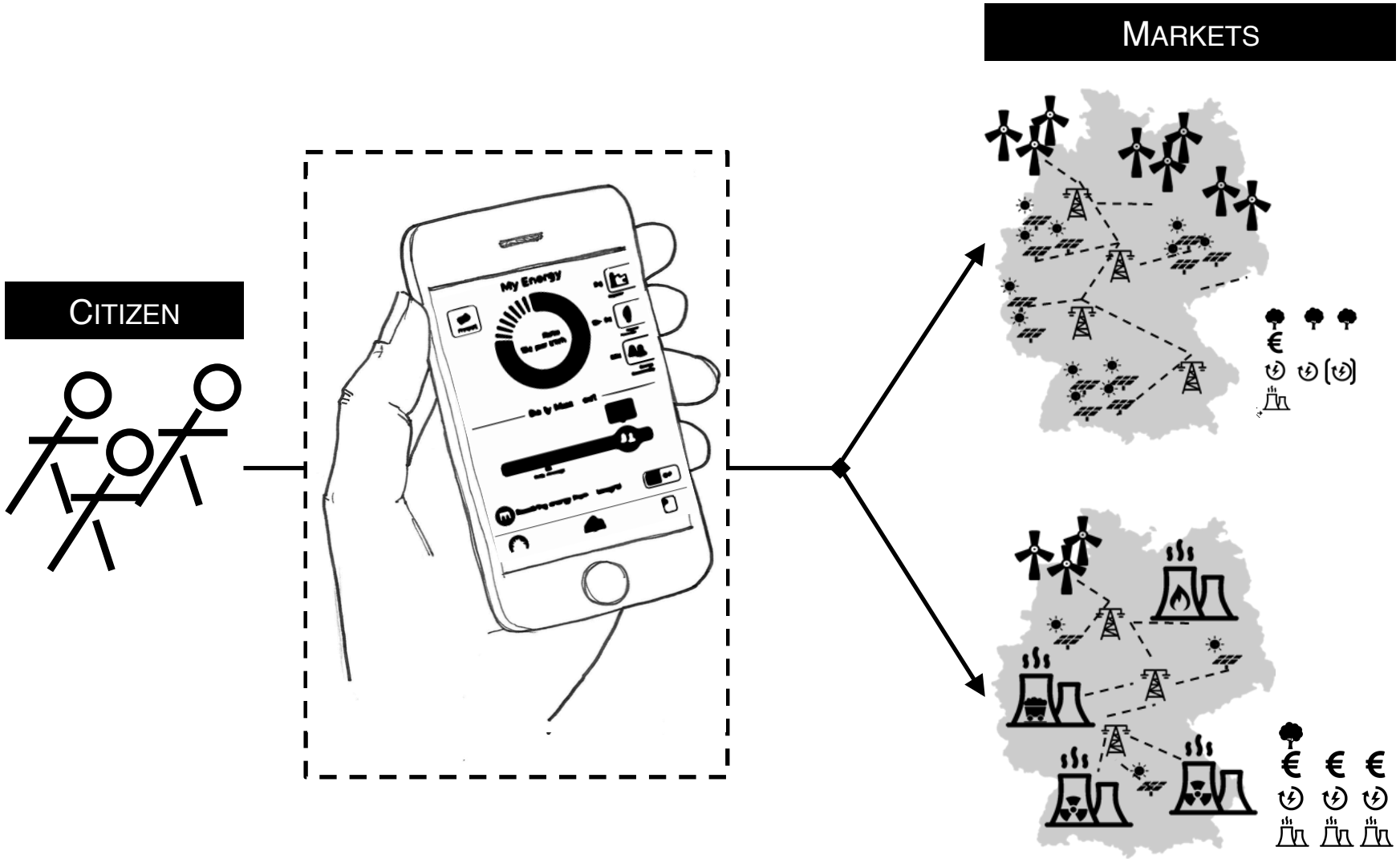
→ **ENERGY-IS PROVIDE CONVENIENT ACCESS TO SOPHISTICATED ORGANIZATION STRUCTURES.**

Coordination effort is a significant Energy supply of mode choice decisions.



[Malone, 1987; Williamson 1980]

ENERGY-IS CAN CONTRIBUTE TO MORE SUSTAINABLE ENERGY DECISIONS.



[CLIMATE CENTRAL, 2017]

FLEXIBLE

COST BASED PRICING

VALUE BASED PRICING

Infrastructure in the Internet of Energy

Today

Yearly Bill:

1 Data Point per Year

Trend

High-Frequency Measurements (sec)

For all Consumptions

1800 values per hours per household

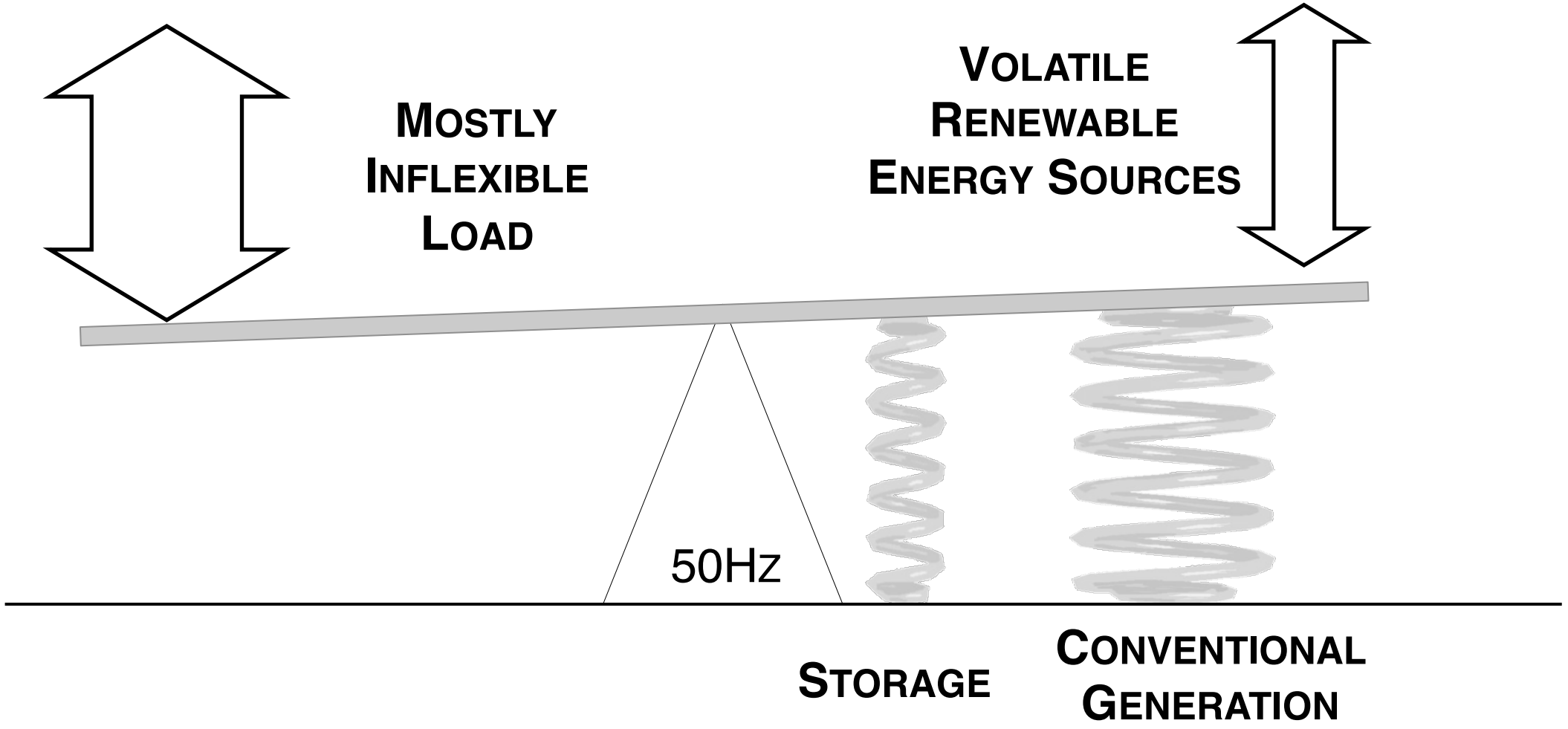
→ 15,7 Mio. Data points per Year

Internet of Things

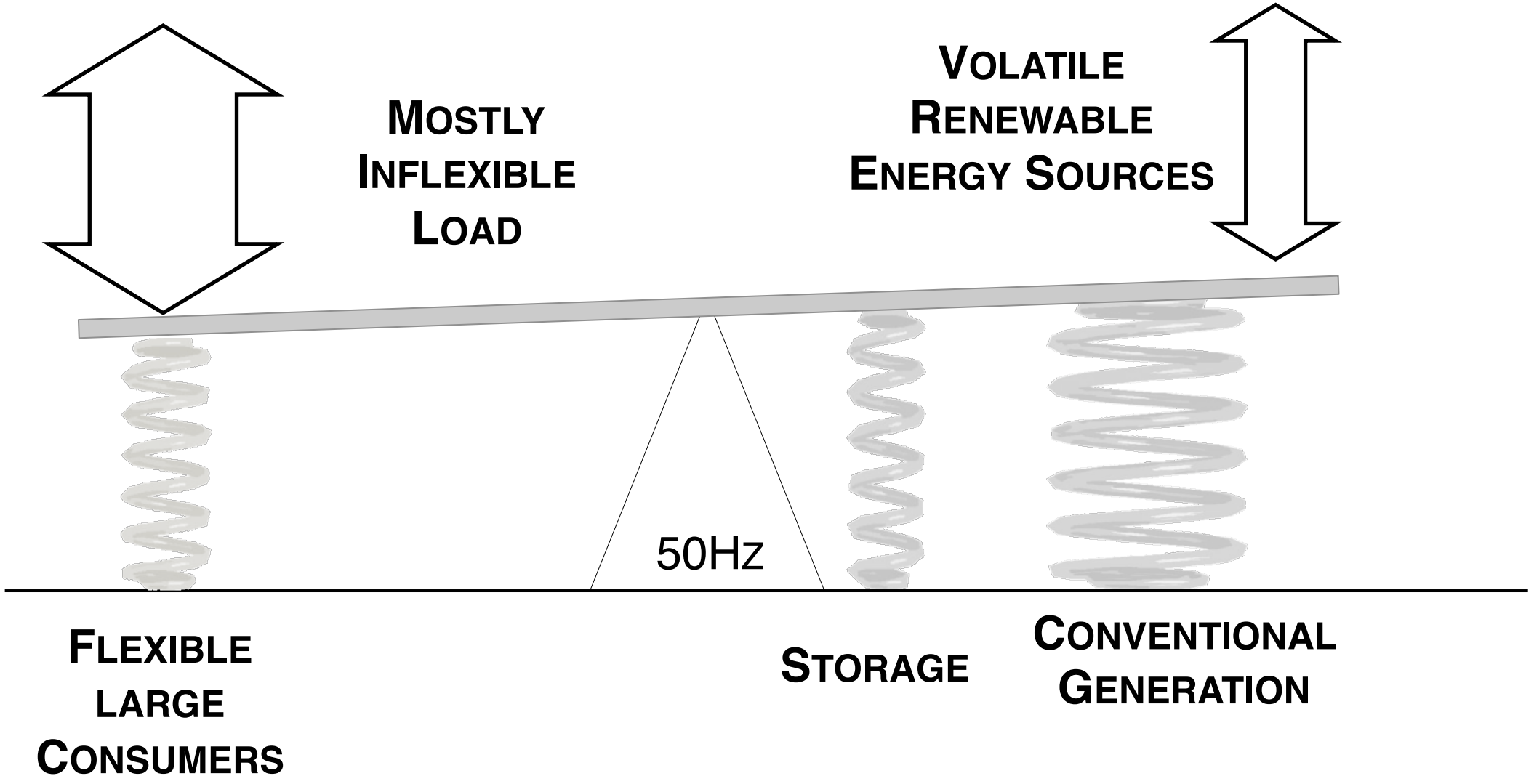
Billions of connected

Sensors in the Power Grid

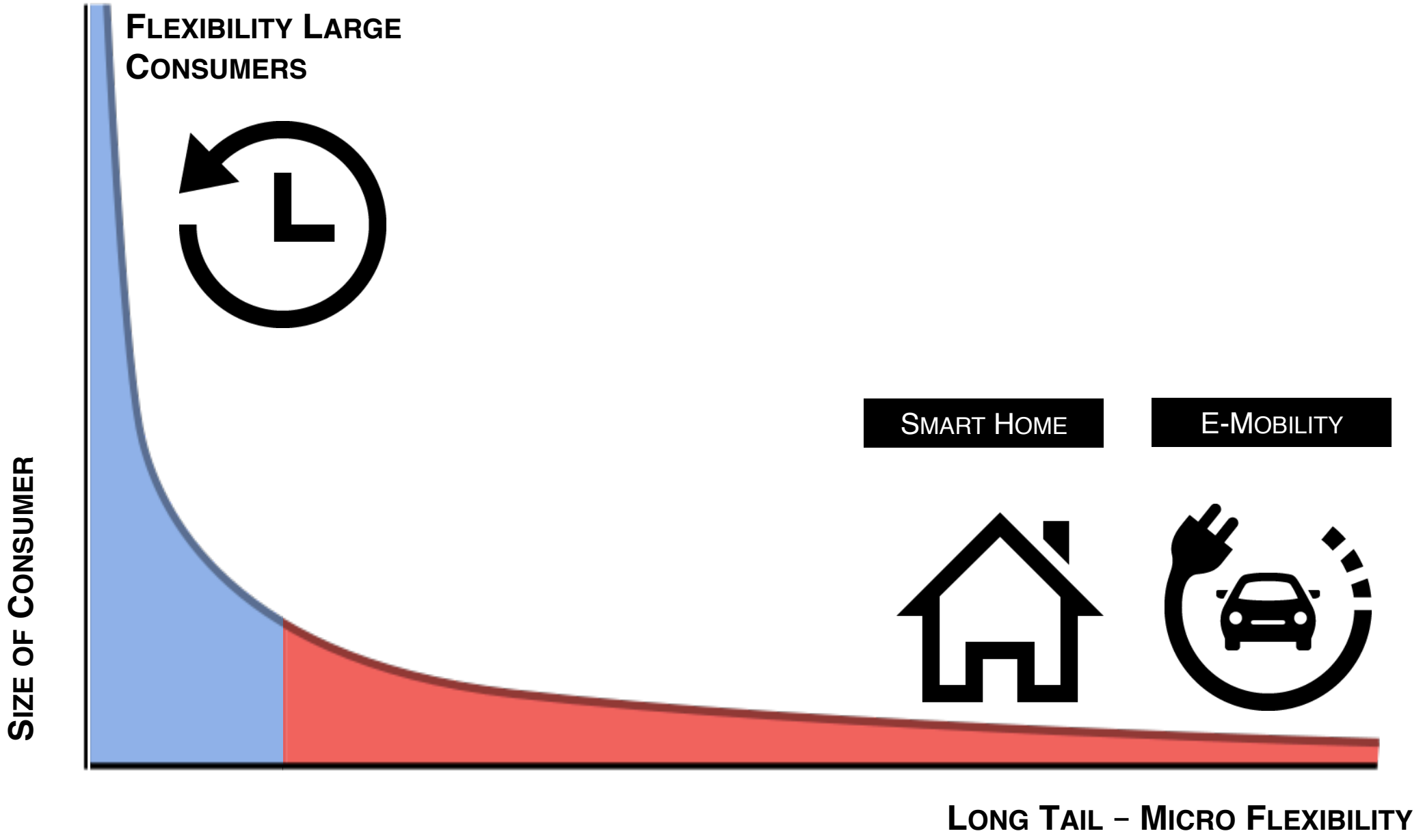
TODAYS CONTROL PARADIGM



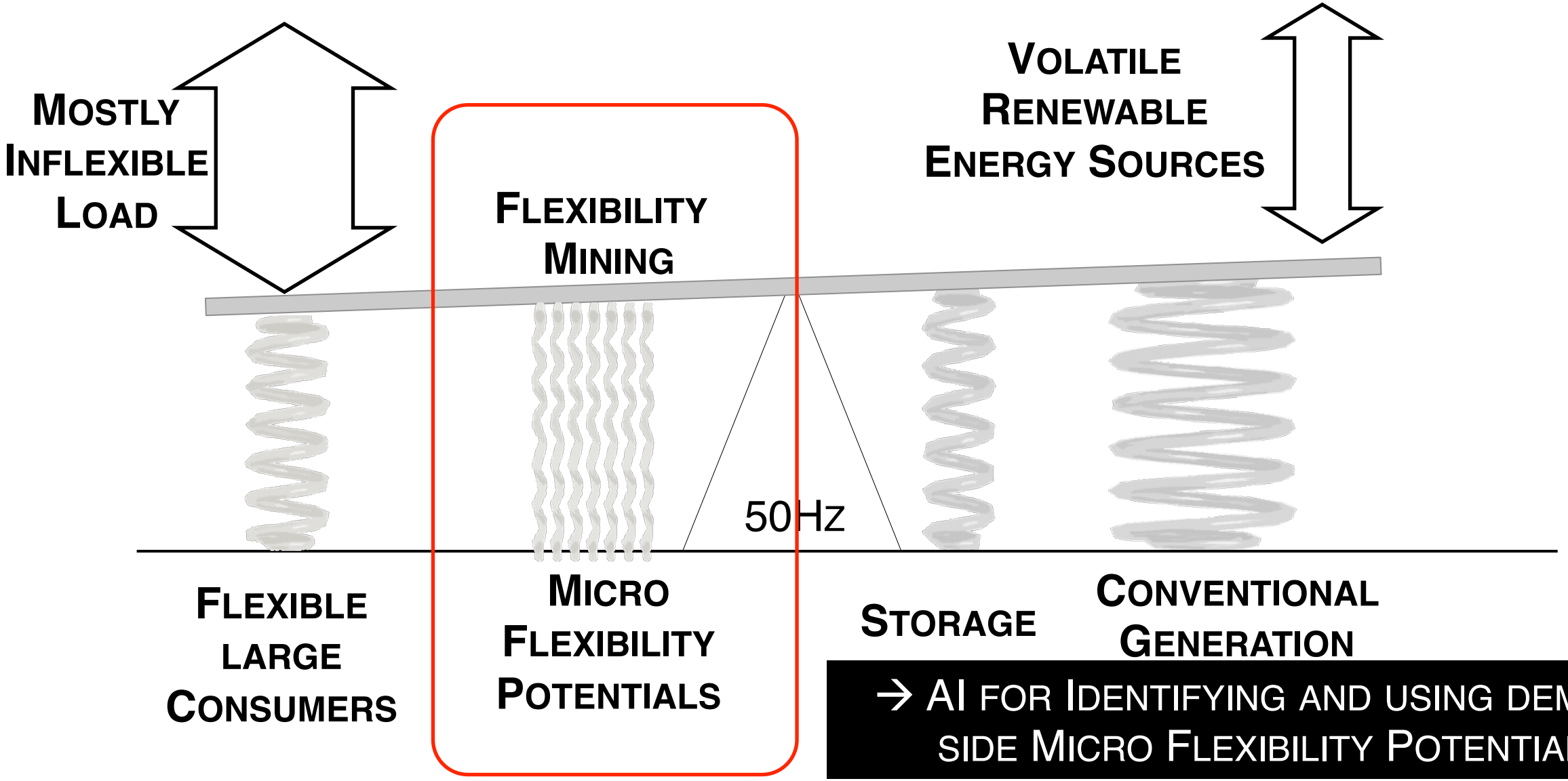
Classic Demand Side Management aims at Large Consumers



Smart Data allows for using Micro Flexibility – The Long Tail

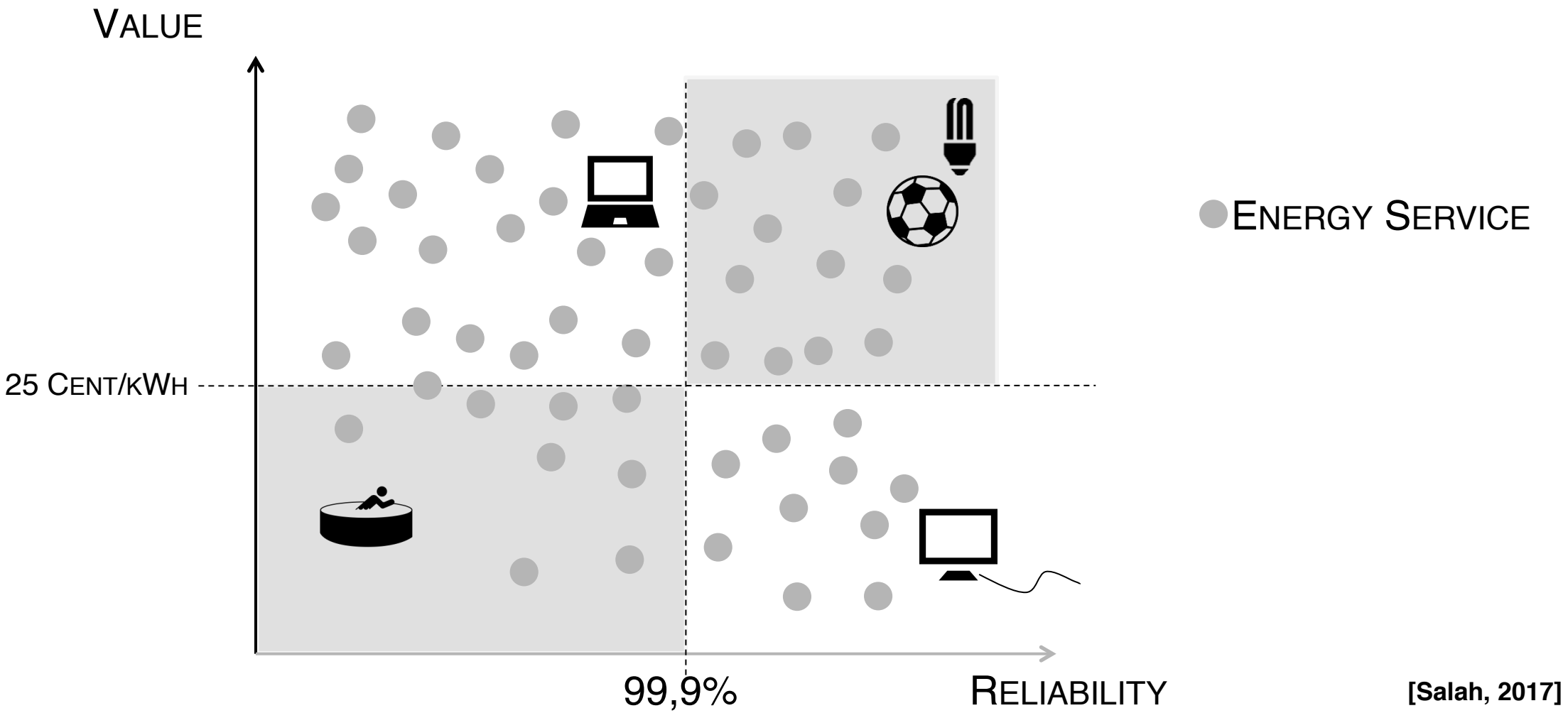


Classic Demand Side Management aims at Large Consumers



→ AI for Identifying and using demand-side Micro Flexibility Potentials

Heterogeneous Demand and Quality of Service



[Salah, 2017]

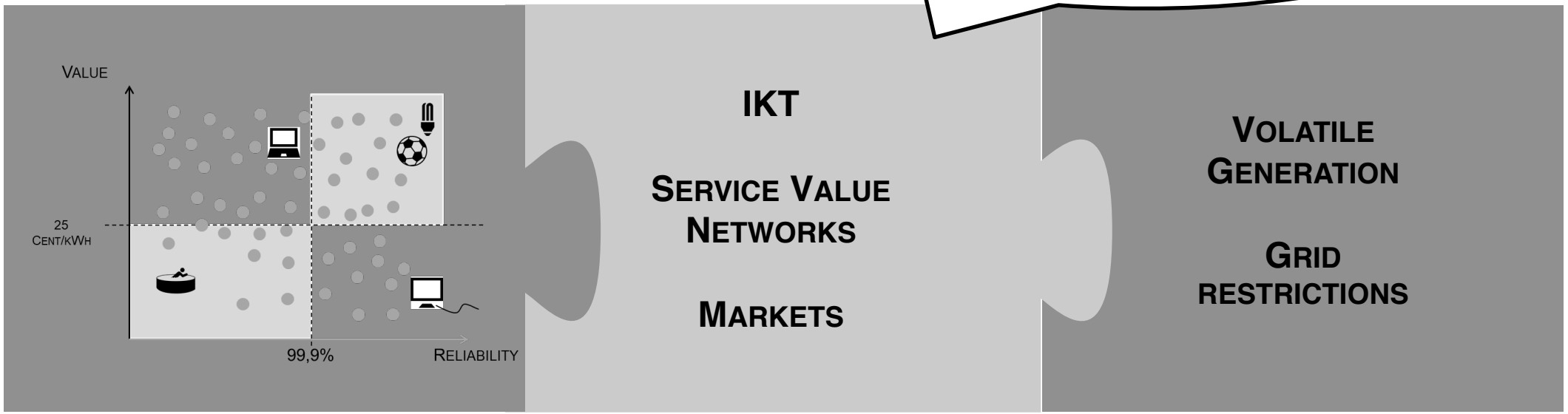
Heterogeneous valuable, flexible demand for energy services enables a large potential for quality of service differentiation

Better Coordination Through…

Quality-Differentiated Services

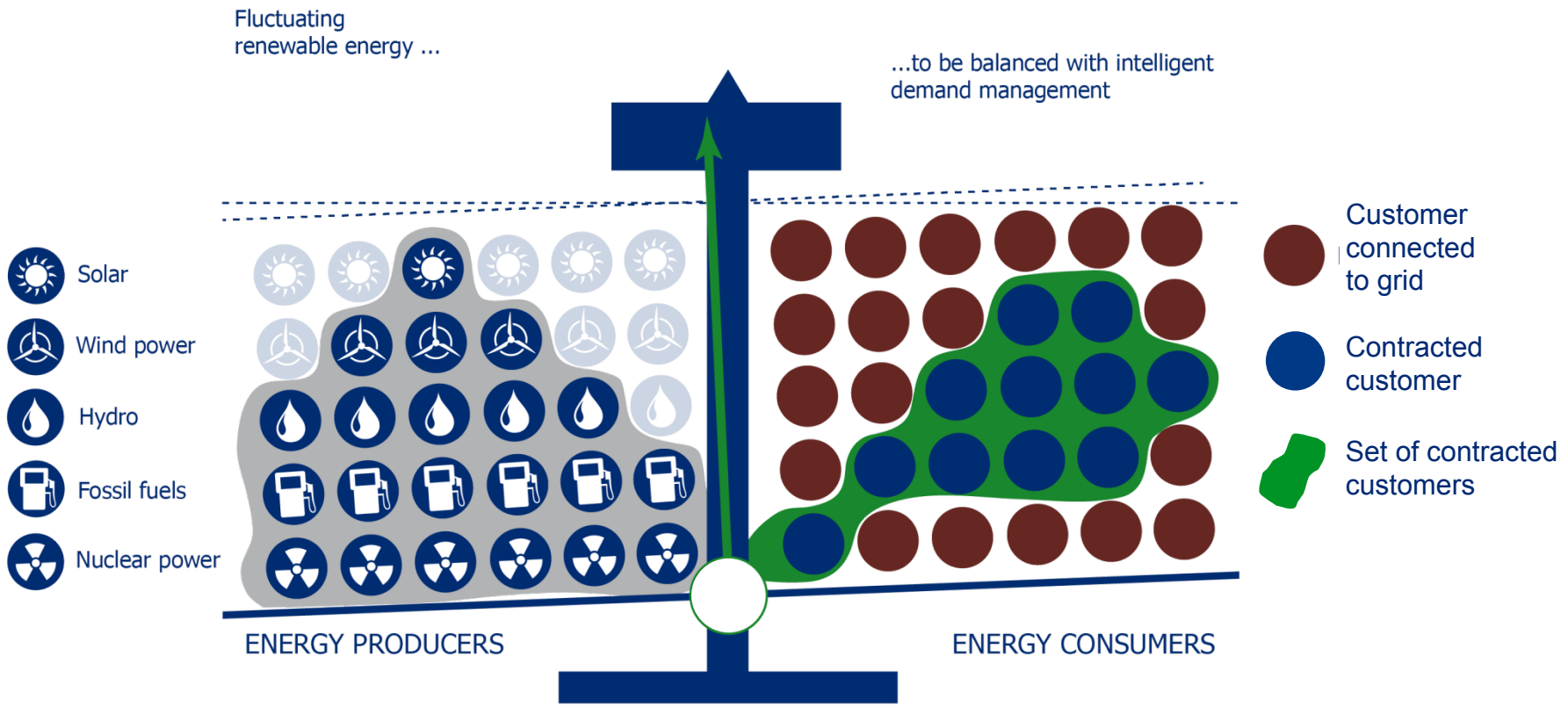
Huge potential for current and emerging players: Aggregators, Brokers, Intermediaries, Service Providers

Security of Supply?
Sure, but…

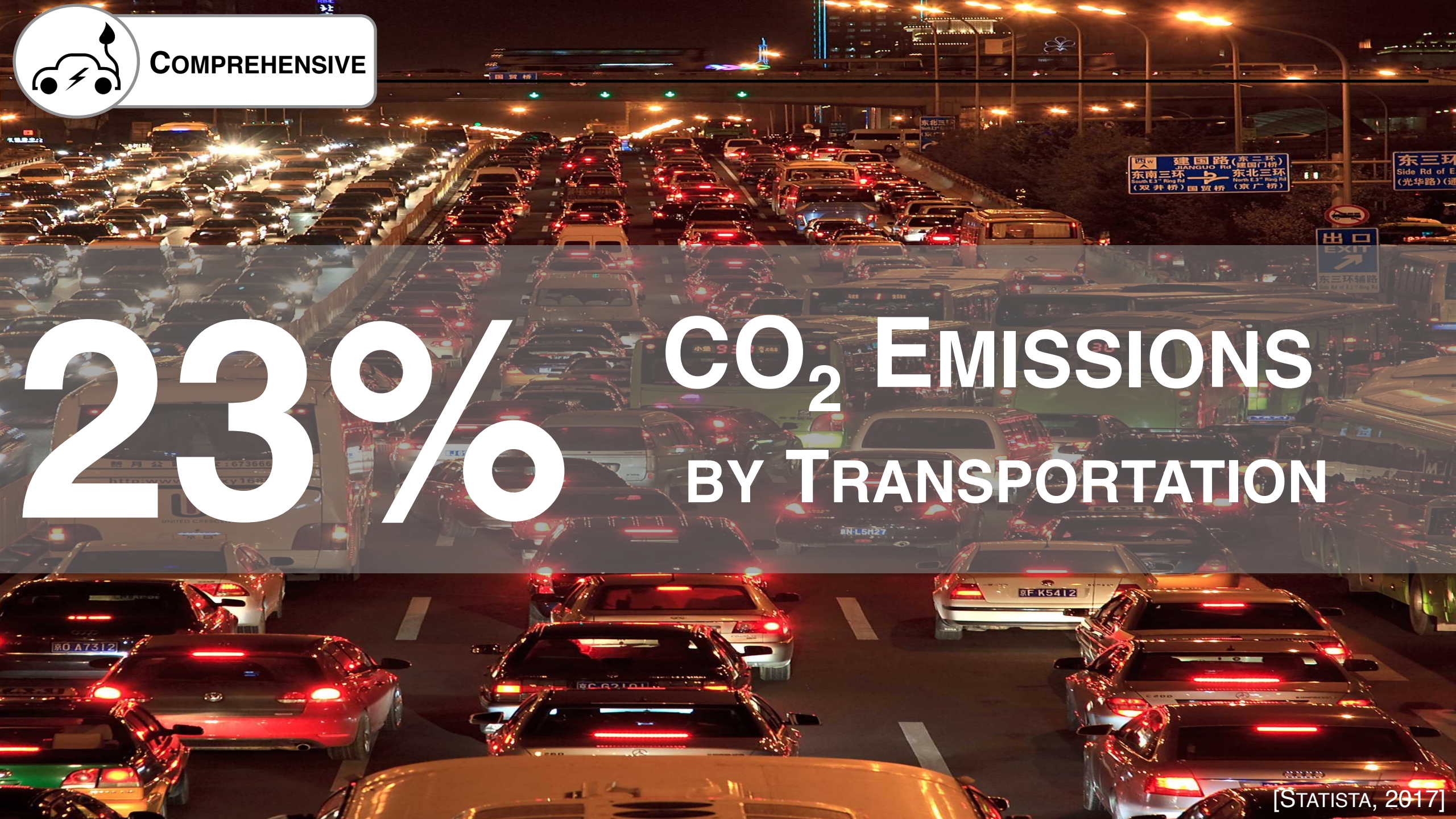


Innovative Design of Future Energy Markets

FLEXIBLE



[Gärttner, 2016]


COMPREHENSIVE
23%
CO_2 EMISSIONS
BY TRANSPORTATION
[STATISTA, 2017]

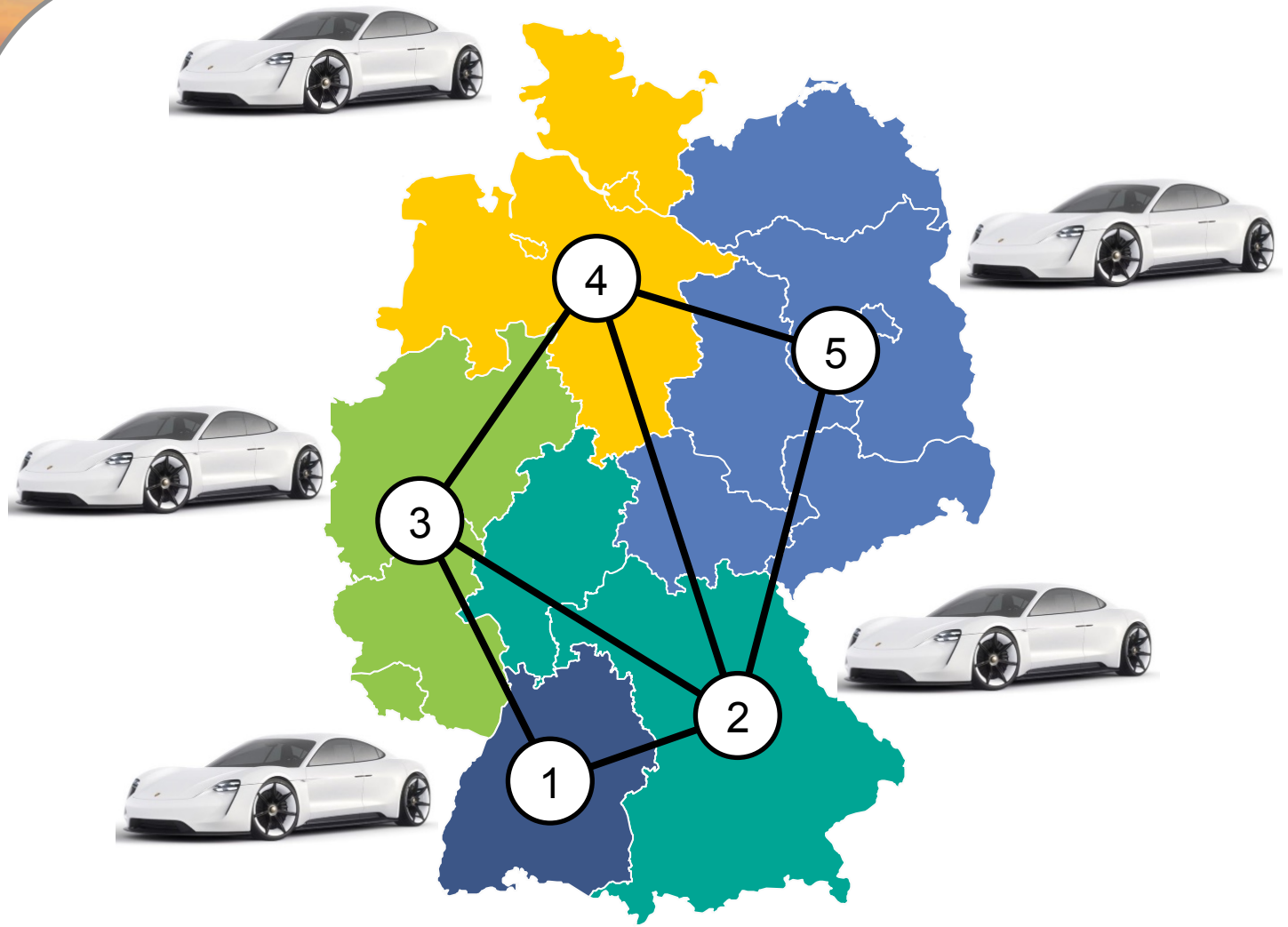
COMPREHENSIVE
e-parken
in Baden-Württemberg
Tarife
Schukostecker
(Haushaltsstecker 230 V / 16 A)
Je angefangene Stunde 0,50 €
Tageshöchstsatz 5,00 €
OEM - Typ 2 - Stecker
(Turbostecker 400 V / 32 A)
Je angefangene Stunde 2,00 €
Tageshöchstsatz 5,00 €
PBW
P BW 3106
5 Million
ELECTRIC CARS BY 2030

COMPREHENSIVE

EV ‘contribution’

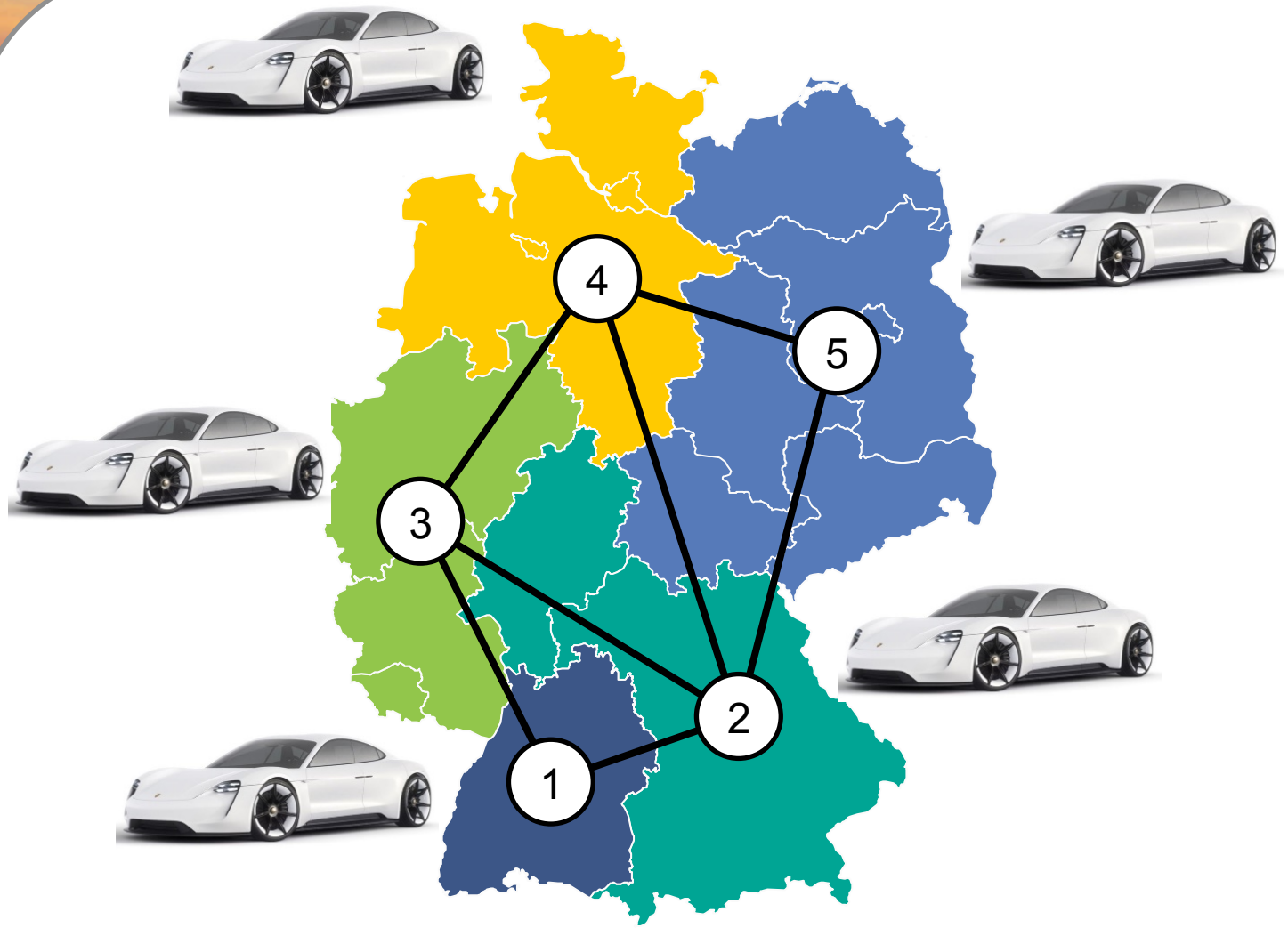
TO FUTURE ELECTRICITY SYSTEMS

COMPREHENSIVE



[Working Paper, Staudt, 2017]

COMPREHENSIVE

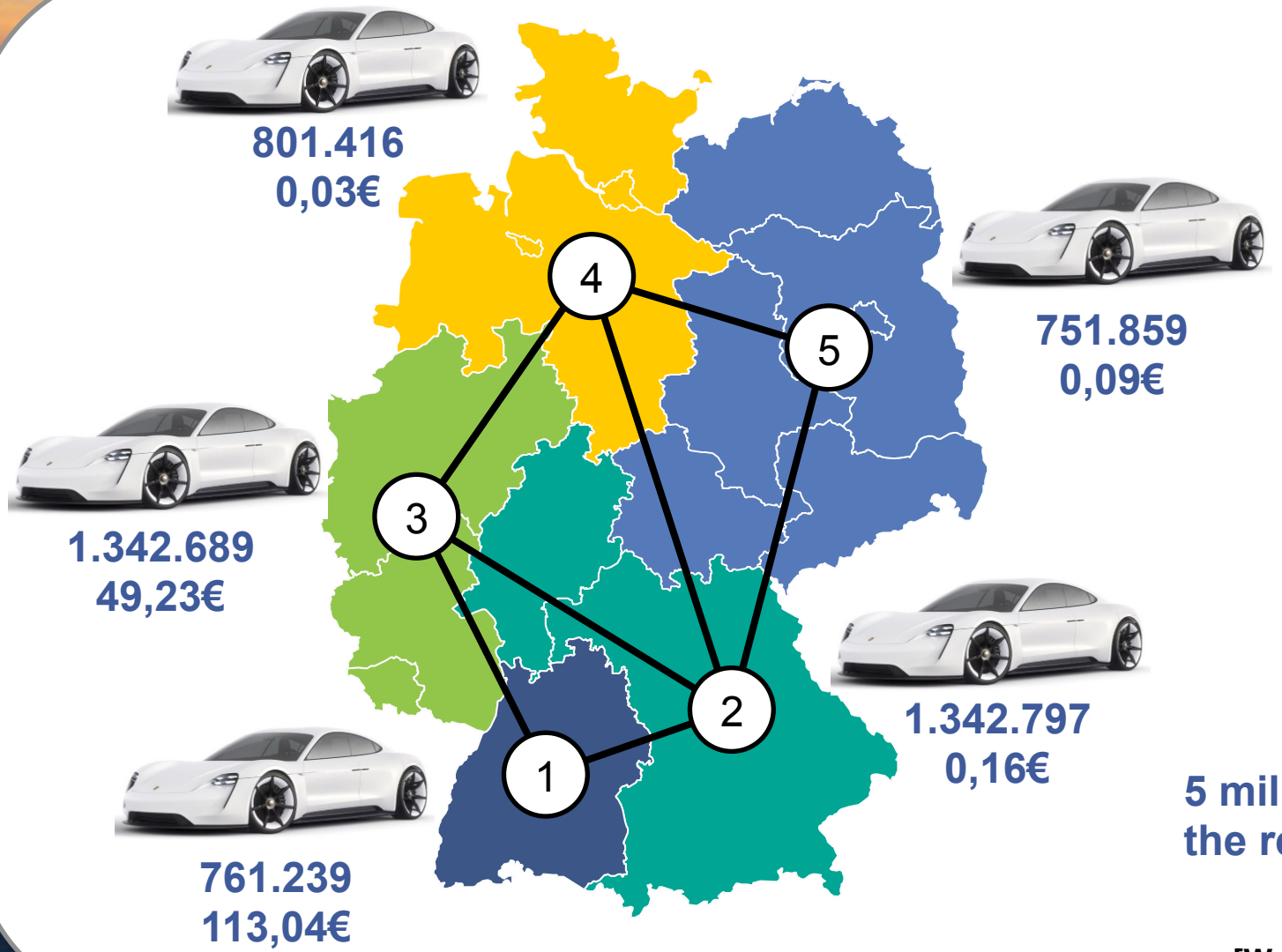


Assumptions:

1. Renewable generation 2015
2. Reduced network model (5 nodes)
3. All EVs contribute as V2G to system
4. Actual electricity generation park used

[Working Paper, Staudt, 2017]

COMPREHENSIVE



Assumptions:

1. Renewable generation 2015
2. Reduced network model (5 nodes)
3. All EVs contribute as V2G to system
4. Actual electricity generation park used

5 million EVs compensate the redispatch entirely!

[Working Paper, Staudt, 2017]

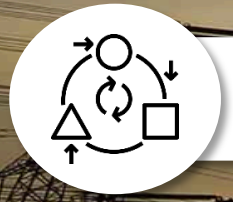
Summary

Future electricity systems need new market structures and designs

Hybrid markets as intermediate state towards full decentralization

Local markets incentivize consumers to collaborate

P2P IS allow prosumers to interact without central authority



Flexibility fosters innovative services for smart grids

Emobility might even help to solve structural problems

Thank you! ?

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www.im.iism.kit.edu