Wuppertal Institut

Central phases of the energy system transformation pathway

Sixieme Journee tuniso-allemande de l'energie

„La deuxieme phase de la transition energetique“

Presentation:

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Vice President

Wuppertal Institute

December 2016

How to deal with future challenges

Introductory remark

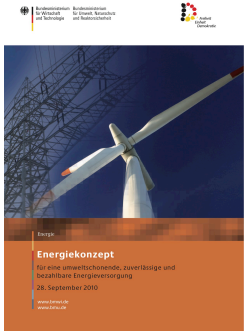
„Confidence is before you encompass the problem!“
Woddy Alan {American actor}

Source: telegraph.co.uk

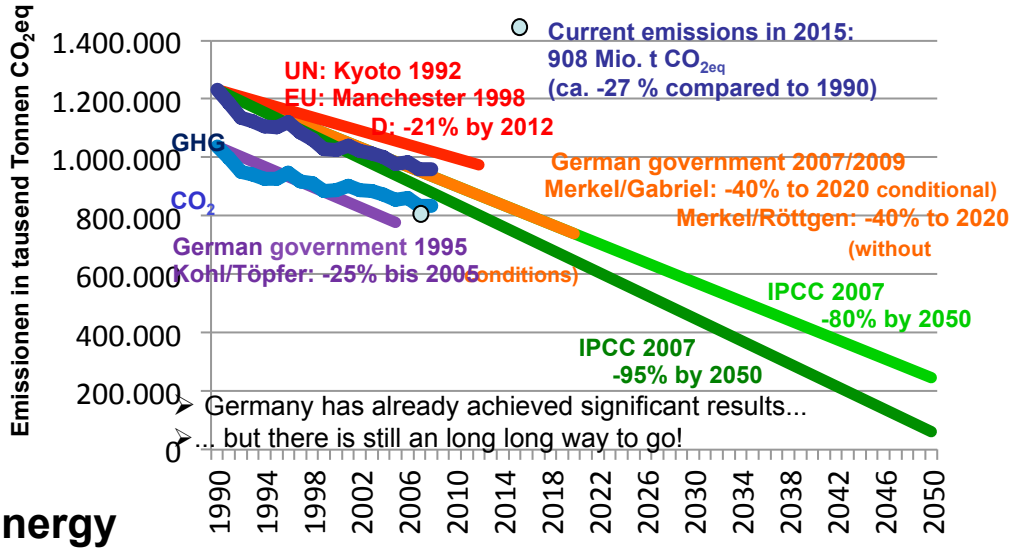
Introduction – targets and milestones for the German Energiewende (energy system transformation pathway)

Energy Concept of the German government

Central milestones and underlying sub-targets for Energiewende



German energy concept – launched in 2010 (adapted in 2011)



- **Reduction of GHG emissions:**
  80-95% until 2050
- **Renewable energy share of gross final energy consumption:**
  60% until 2050
- **Share of electricity production from renewables:**
  80% until 2050
- **Reduction of energy demand compared to 2008:**
  - Gross final energy consumption 50% until 2050
  - Gross electricity demand 25% until 2050
- **Nuclear power phase out**
  Shutdown of all nuclear power plants until 2022

Achieving the goals while guaranteeing competitiveness, taking social concerns and system stability into consideration (sustainability triangle as underlying principle)

Source: BMWi 2011

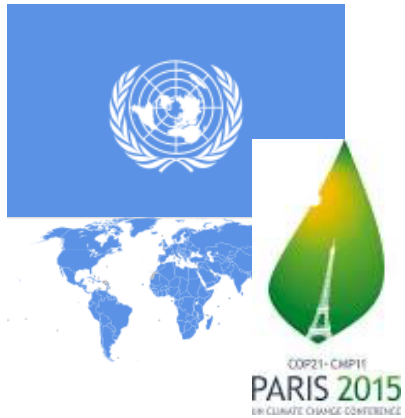
Background

German energy and climate policy is embedded in a multi-level policy regime

The Multi-Level Approach – from framework setting to practical

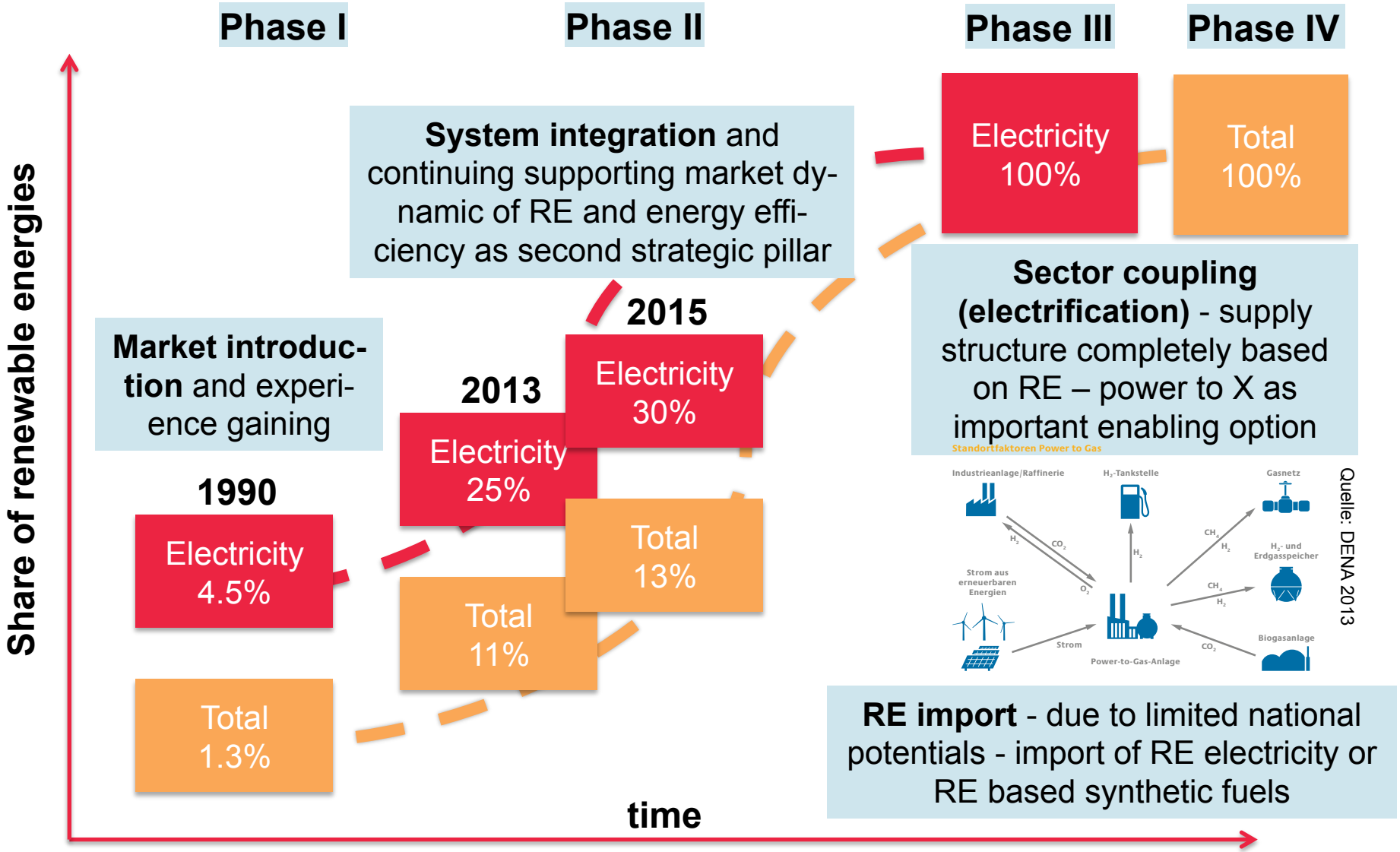
implementation ⟷ framework setting

local and regional level	national and state level	confedera-tion level (EU)	supra-national level



The different phases of a complex transformation process

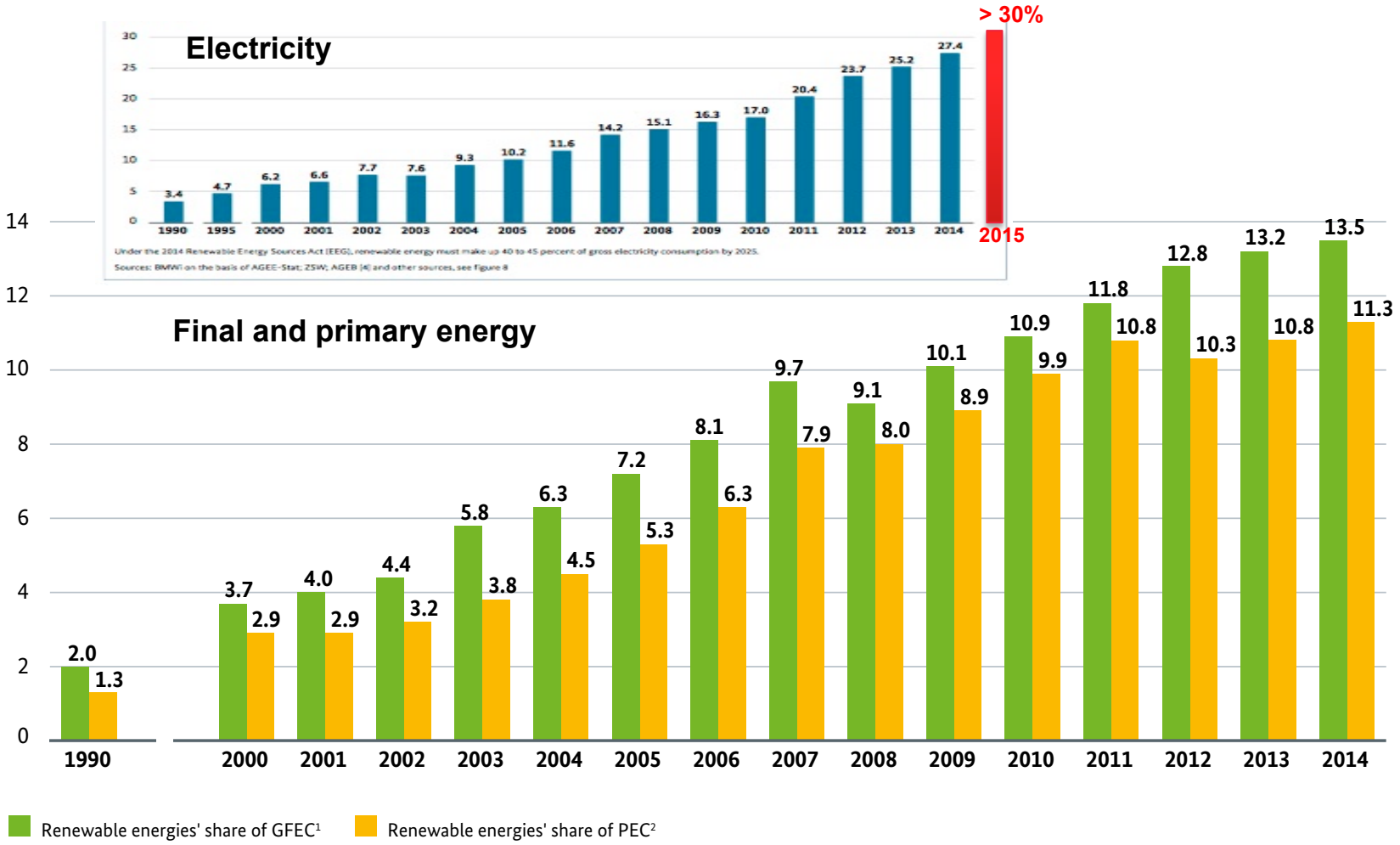
The different phases of a complex transformation process



Phase 1: Market introduction

Phase 1: Market introduction of renewable energies

Two different velocities: Renewable energy shares of final and primary energy demand and electricity in Germany (in %)



1 calculation of the share of renewable energy in gross final energy consumption **without** using special calculation rules set out in EU Directive 2009/28/EC
See Annex, section 1 for details on how the share was calculated

2 declining share in primary energy consumption caused by a methodological change starting with the year 2012, previous years not yet revised

Source: Renewable Energies in Numbers 2016

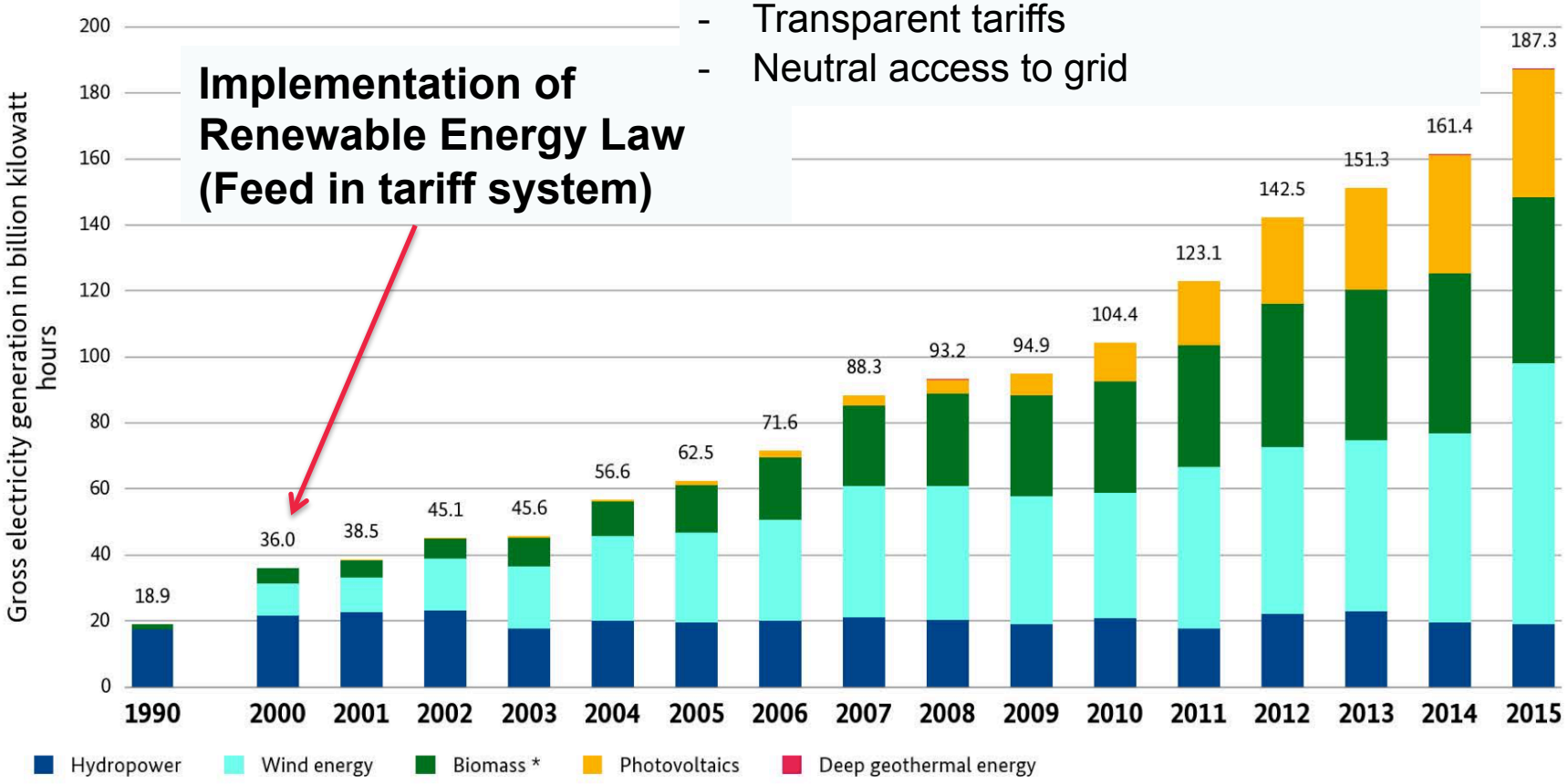
Phase 1: Political Challenge – how to shape an appropriate policy regime

Kick start of market deployment via providing attractive investment atmosphere and R&D support

Success factors e.g.:

- Secure investment conditions
- Transparent tariffs
- Neutral access to grid

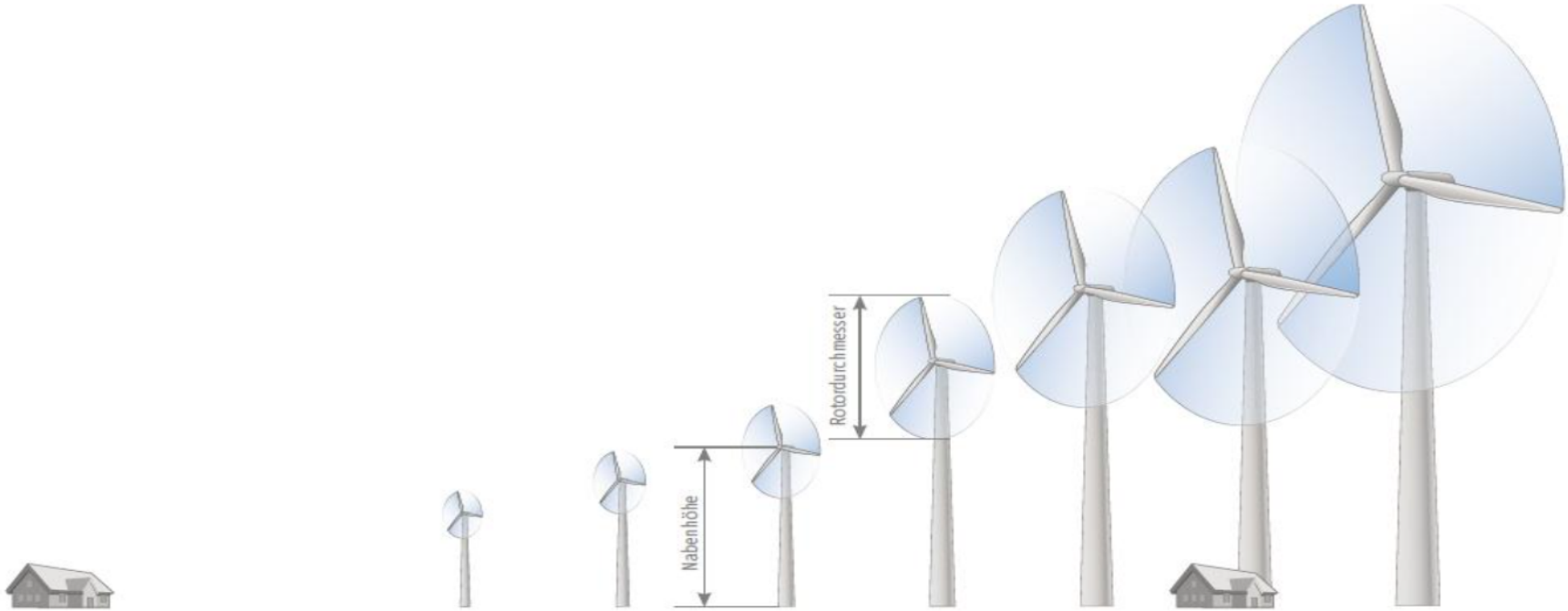
Implementation of Renewable Energy Law (Feed in tariff system)



* incl. solid and liquid biomass, biogas incl. biomethane, sewage gas and landfill gas as well as the biogenic fraction of waste, from 2010 incl. sewage sludge; BMWi based on Working Group on Renewable Energy-Statistics (AGEE-Stat); as at August 2016; all figures provisional

Phase 1: Market introduction of renewable energies

Technology progress: continuously increase of average power of installed wind mills in Germany



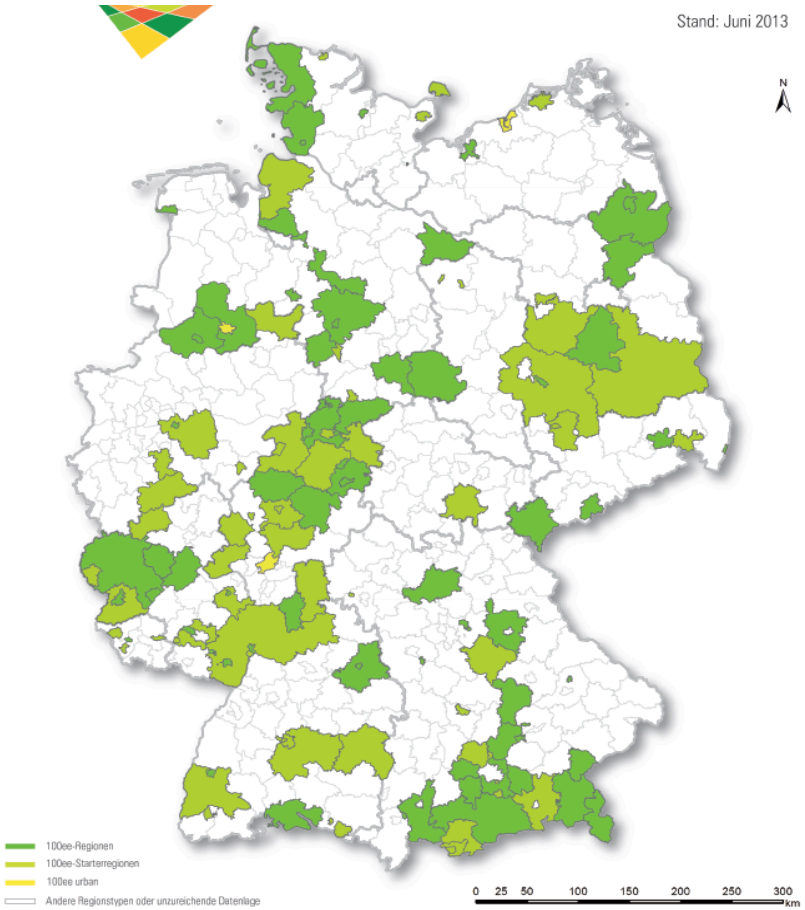
	1980	1985	1990	1995	2000	2005	2010
Nennleistung (in kW)	30	80	250	600	1.500	3.000	7.500
Rotordurchmesser (in m)	15	20	30	46	70	90	126
Überstrichene Rotorfläche (in m_)	177	314	707	1.662	3.848	6.362	12.469
Nabenhöhe (in m)	30	40	50	78	100	105	135
Jahresenergieertrag (in MWh)	35	95	400	1.250	3.500	6.900	ca. 20.000

Quelle: Sunbeam, BWE

Source: Liersch 2011

Phase 1: Energiewende and renewable energy deployment is not only driven by top down policies but based on manifold local and regional initiatives

Energiewende is triggered and backed by regions - more than one hundred 100% renewable energy communities have been already established covering 1/6 of German population



Selected criteria at the...

...target level:
- 100% RE-target in the electricity sector
- RE-target in the heating sector
- Commitment to the objectives and
- setting intermediate targets

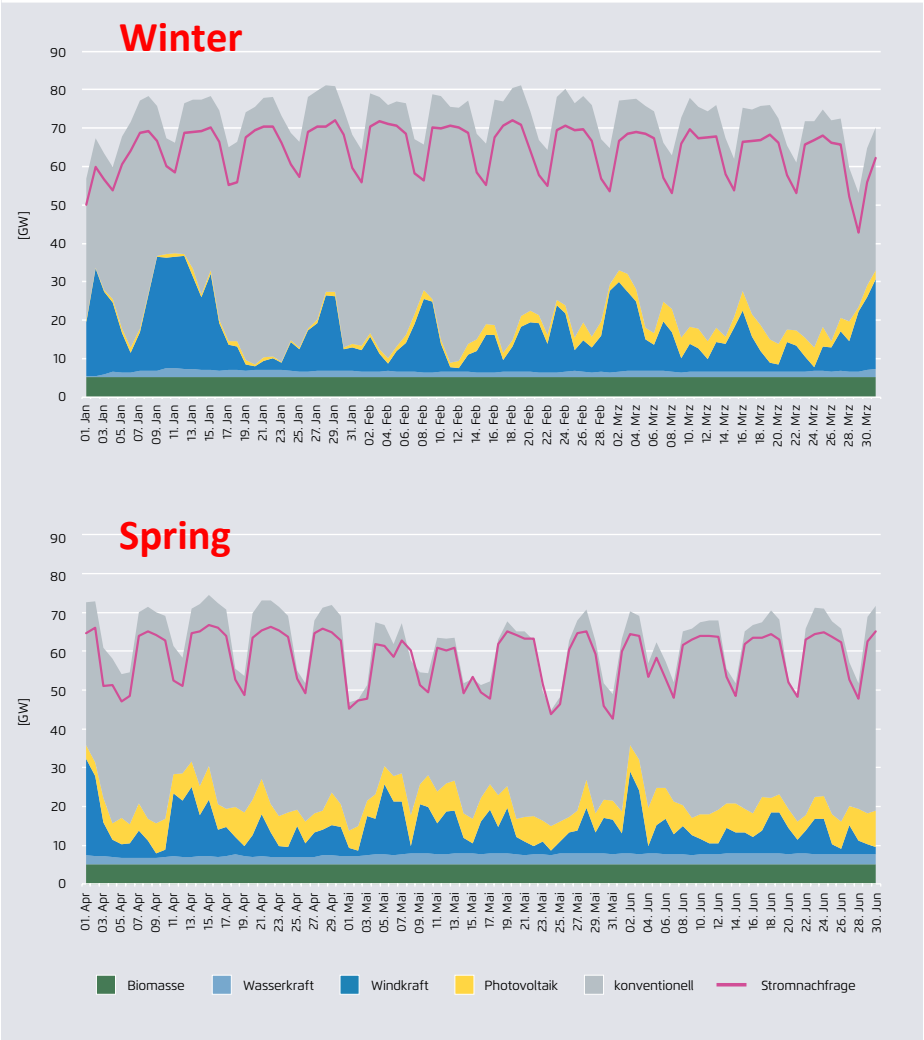
...operational level:
- Concept of measures
- Working on a potential study
- Advisory services
- Construction of renewable energy plants

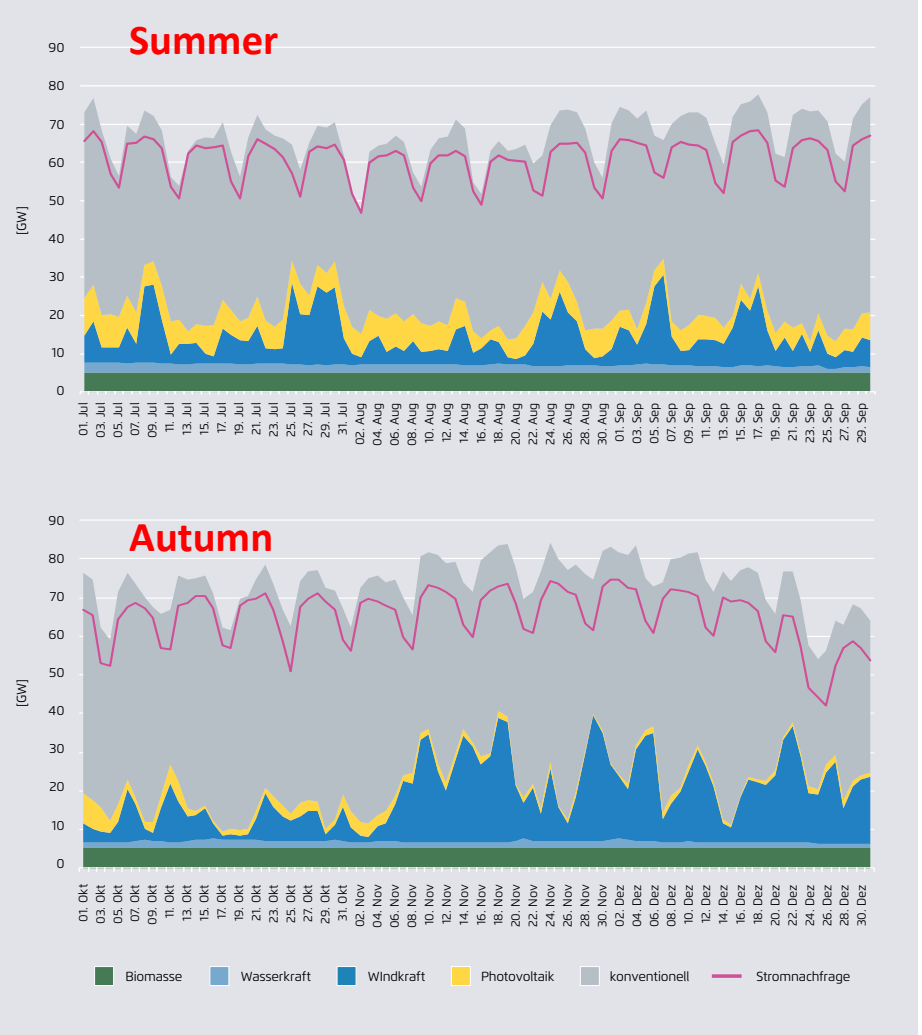
...state level:
- RE-share in electricity demand
- RE-share in heat demand
- Installed capacity photovoltaic and solar thermal energy per capita

Phase 2: System integration

Phase 2: Technological Challenge – system integration of renewable energies

Large annual variations in production and load combinations



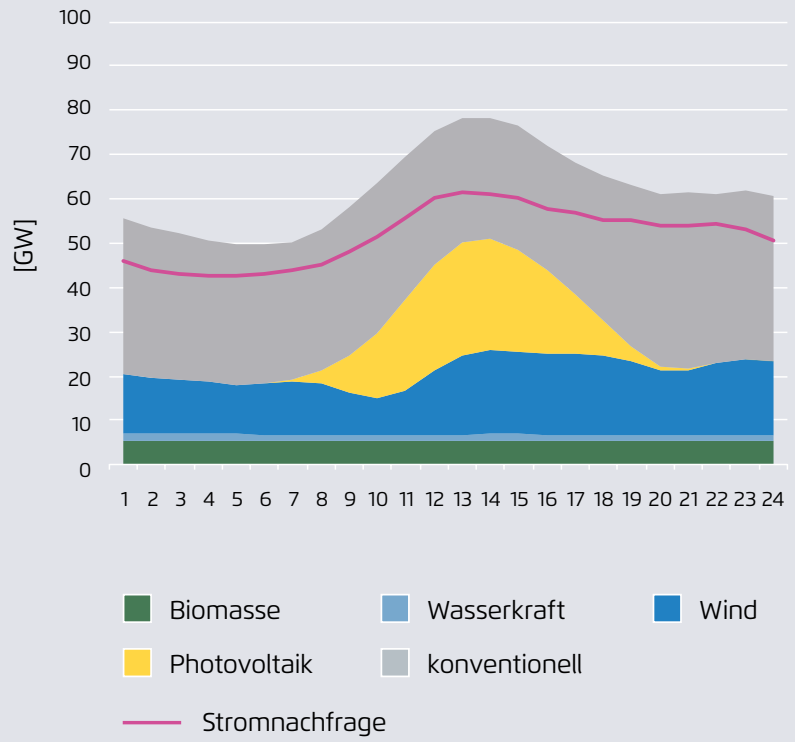


Source: Agora Energiewende 2015

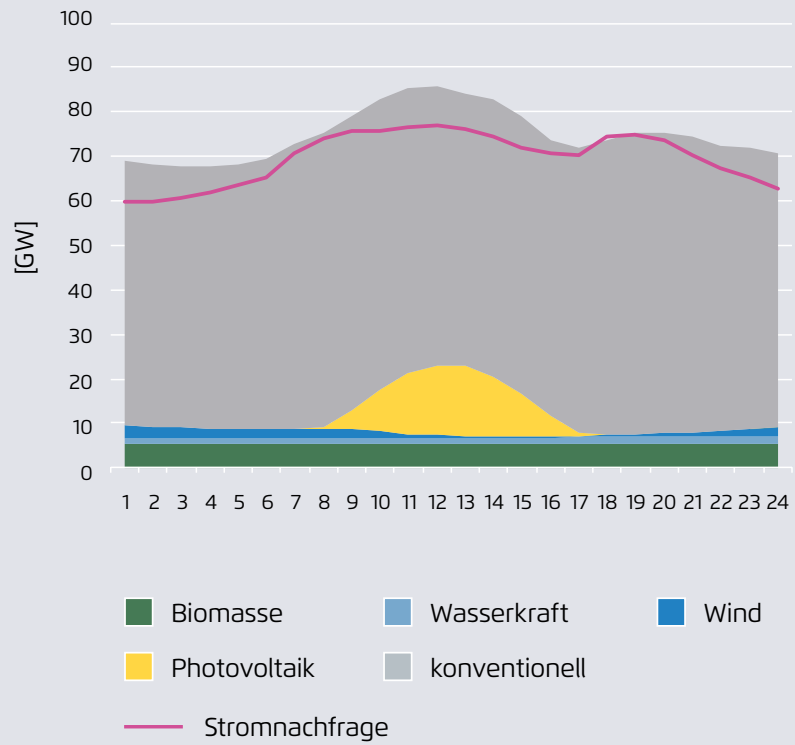
Phase 2: Technological Challenge – system integration of renewable energies

Large annual variations in production and load combinations – learn to deal with exremes

Maximaler Erneuerbaren-Anteil von 83,2 Prozent am 23. August 2015 um 13 Uhr Abbildung 31



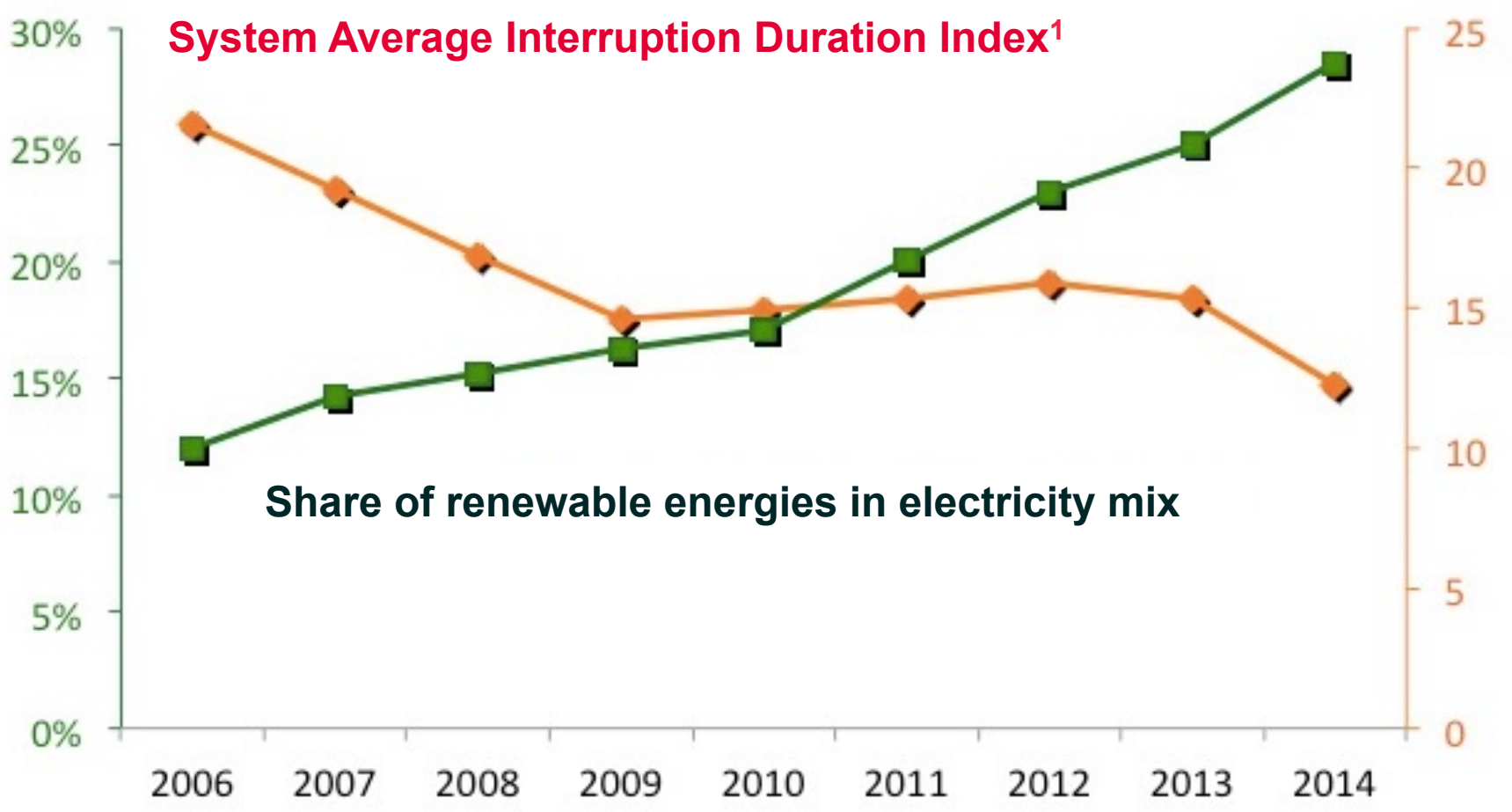
Minimale Erzeugung von Strom aus Erneuerbaren Energien am 3. November um 17 Uhr Abbildung 32



Source: Agora Energiewende 2015

Phase 2: Technological Challenge - system integration of renewable energies

So far system and grid stability and reliability could be secured - System Average Interruption Duration (SAID) Index is even shrinking

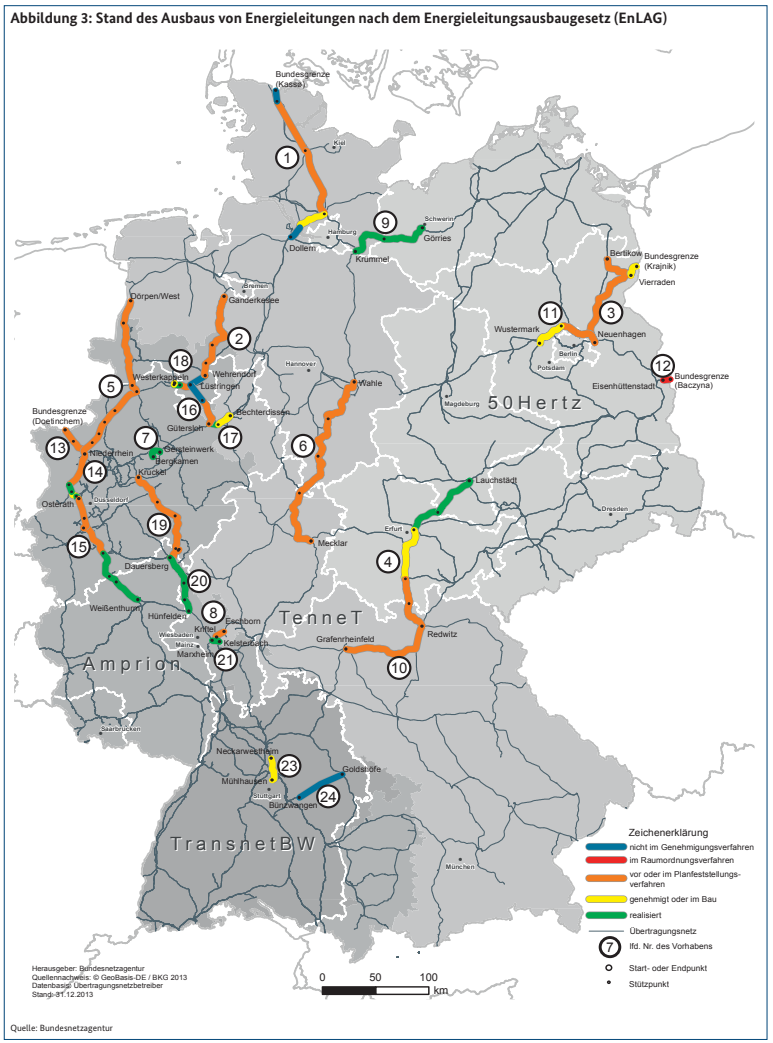


[1] „System Average Interruption Duration Index“ (SAIDI) describes the cumulative annual average blackout time for customers (for periods longer than three minutes). Currently system stability level in comparison to other countries is extremely high.

Source: BMWi 2015

Phase 2: Technological Challenge – system integration of renewable energies

Grid extension is necessary – but compensating measures can decrease although not fully replace expansion needs



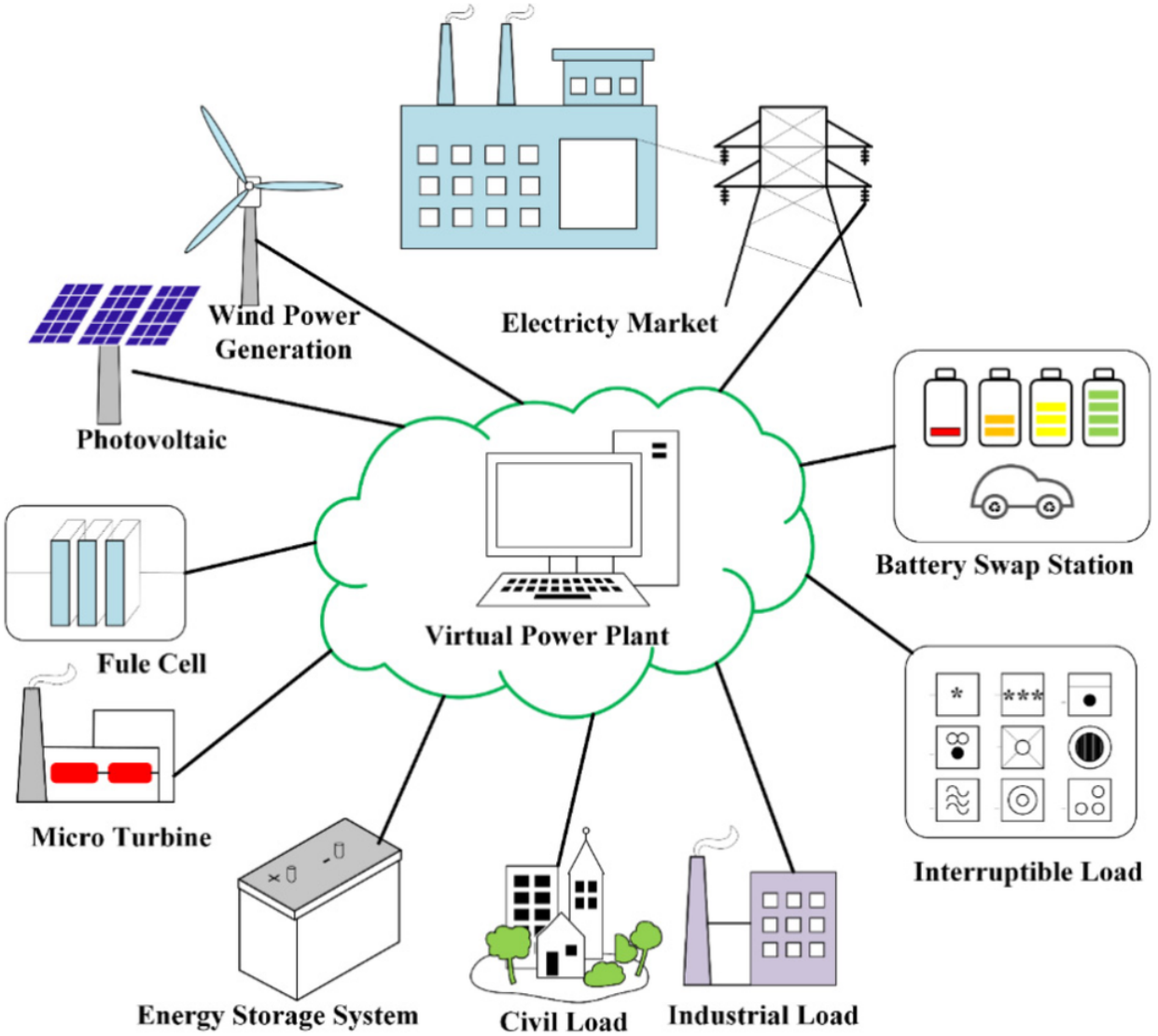
The expansion of RE sources requires grid reinforcement and extension – due to acceptance problems demand should be limted by compensation options:

- Broader distribution of RE-production (north/ south)
- Underground cables
- Curtailment of EE-electricity
- Overhead line monitoring
- High temperature conductors
- HVDC-Overlaynet
- Re-Dispatch
- Load management
- (Seasonal) energy storage
- Use of other transport infrastructrues (H2/CH4-natural gas network)

...nonetheless remaining need for new grid capacities

Phase 2: Start to think in broader systems (provide system solutions)

Smart combination of renewable energies and energy efficiency measures (e.g. virtual power plants, smart homes) – make use of smart ICT options

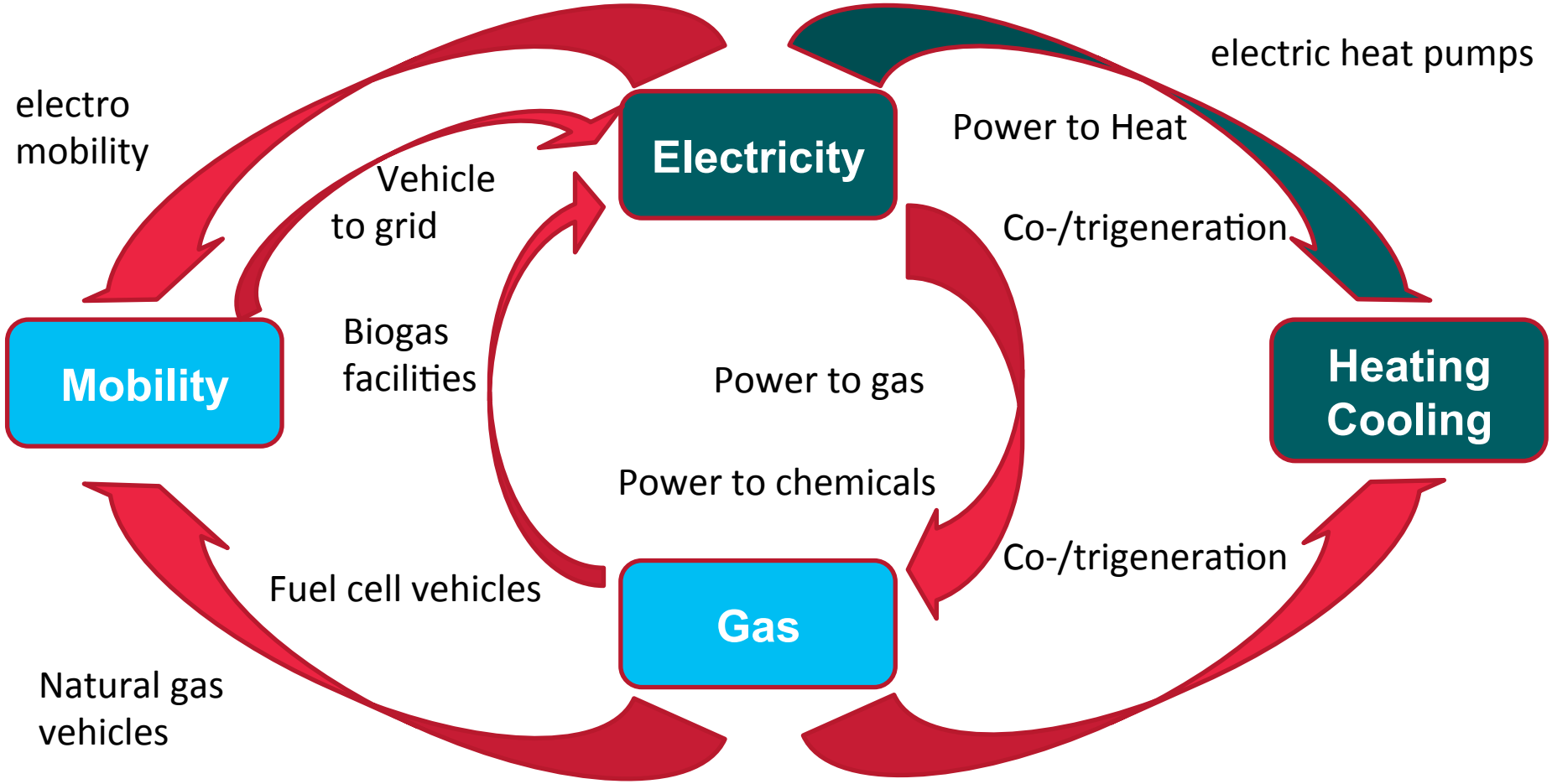


Quelle: Hao Bai et al 2016

Phase 3: Sector coupling (electrification)

Phase 3: Application of electricity becomes more and more important

Sector coupling as a main strategy element for more ambitious GHG mitigation results in end-use sectors

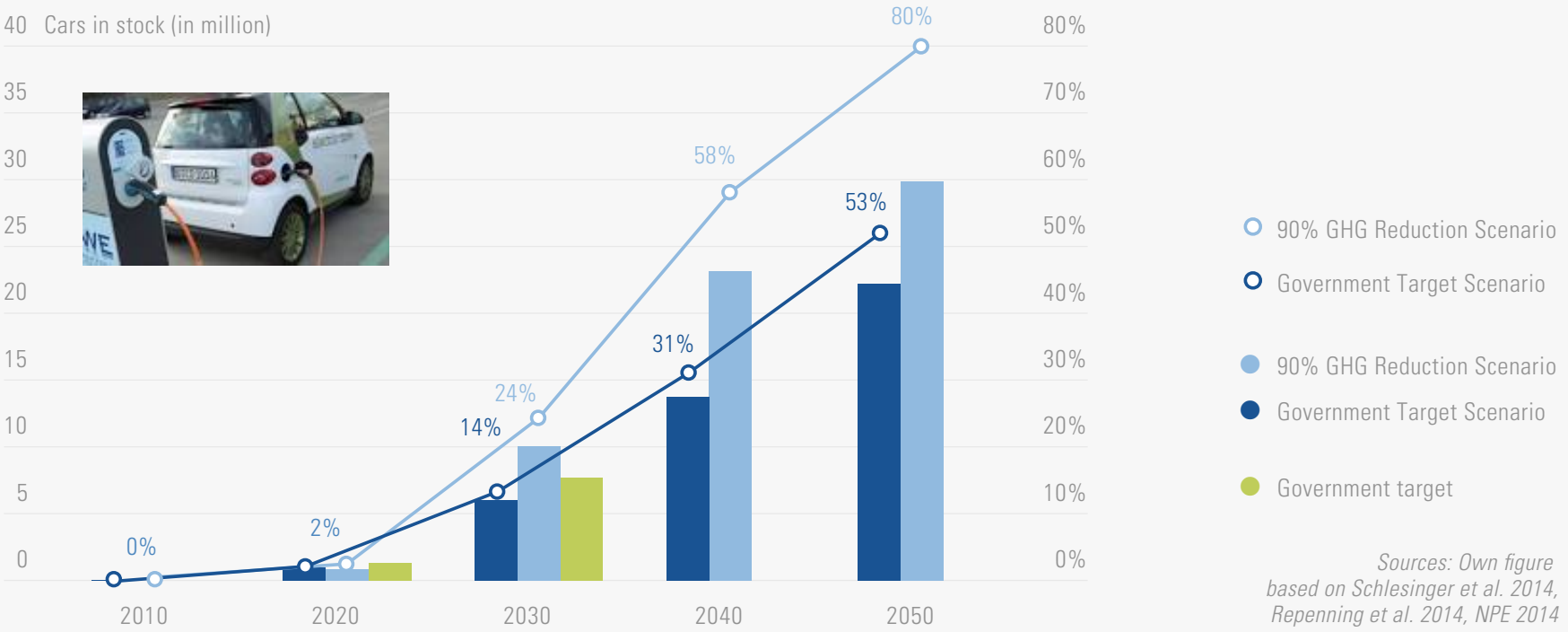


Source: Sauer 2015

Phase 3: Application of electricity becomes more and more important
Central results of a meta scenario analysis
Development of number of electric vehicles in Germany

Significant increase in number of electric vehicles, plug-in hybrids und hydrogen driven fuel cell vehicles depending as result of GHG mitigation pressure in end-use sectors

Figure 20: Number of electric passenger vehicles in stock (including hydrogen-fueled vehicles, left axis) and their share in total passenger vehicles (in %, right axis)



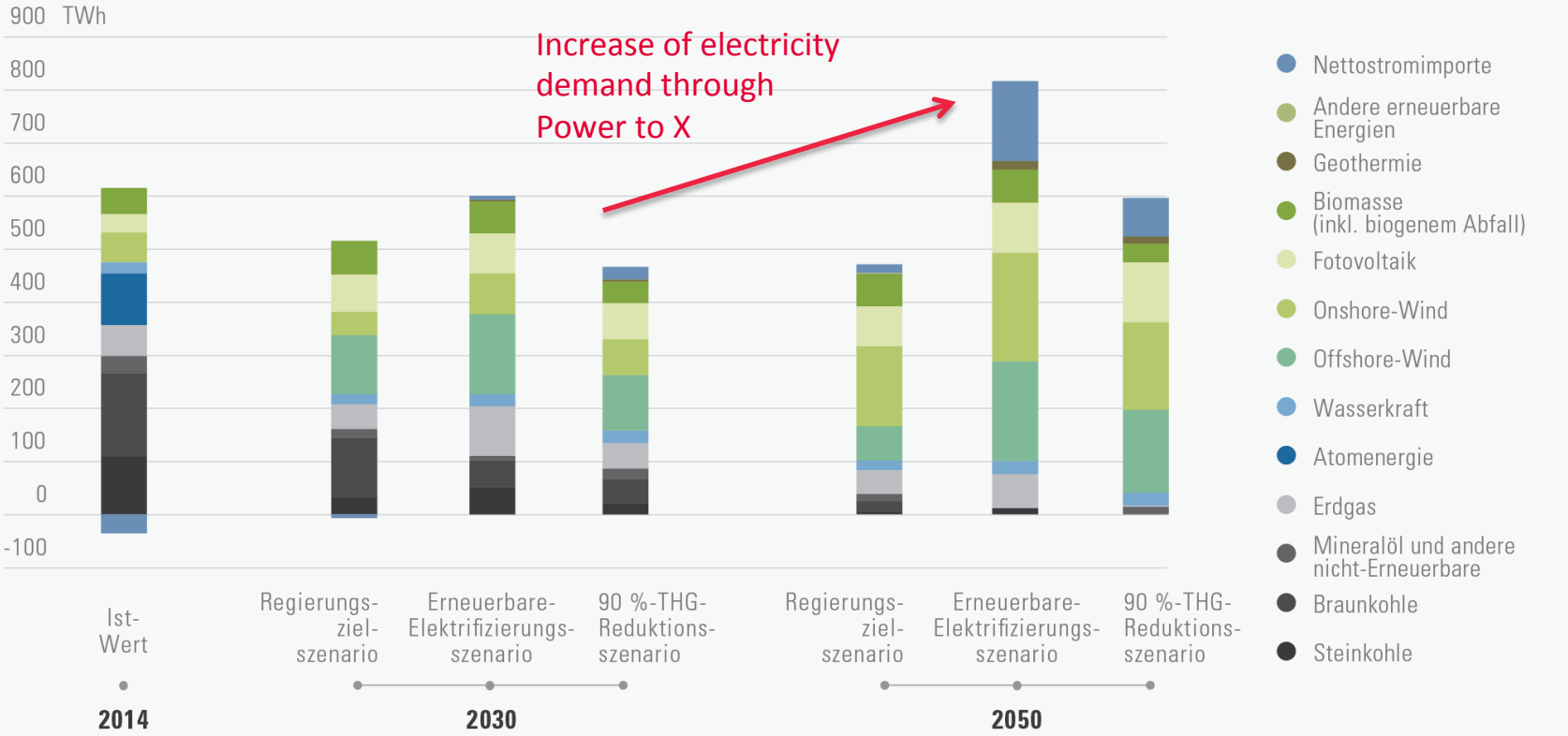
Sources: Own figure based on Schlesinger et al. 2014, Repenning et al. 2014, NPE 2014

[1] Provision of hydrogen via electrolysis

Phase 3: Application of electricity becomes more and more important
Central results of a meta scenario analysis

Development of electricity supply in TWh compared to 2014 supply mix

Illustrative GHG mitigation scenarios stress the need for a significant extension of renewable energies (particularly electricity generation) – electricity system partly contributes to decarbonization of end-use sectors via hydrogen production (Power to X)



Die Abbildung bezieht sich mit Ausnahme der Werte des Szenarios "90 %-THG-Reduktionsszenario" auf die Bruttostromerzeugung.
Für das genannte Szenario wird hingegen die Nettostromerzeugung angegeben, da keine Angaben für die Bruttostromerzeugung vorliegen.

Quellen: Eigene Darstellung nach Angaben in Schlesinger u. a. 2014, Repenning u. a. 2014, Nitsch 2014, Nitsch 2015 (persönliche Kommunikation vom 30. April 2015), Harthan 2015 (persönliche Kommunikation vom 11. Mai 2015), AGEB 2015c.

Source: WI 2015

Phase 3: For Germany wind and solar based electricity generation play major role

Share of variable electricity generation

Illustrative GHG mitigation scenarios show growing share of fluctuating sources in electricity mix

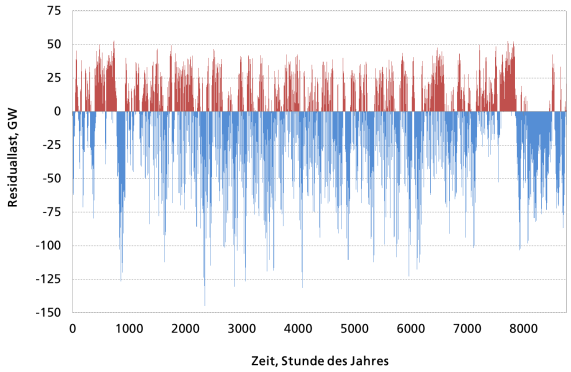
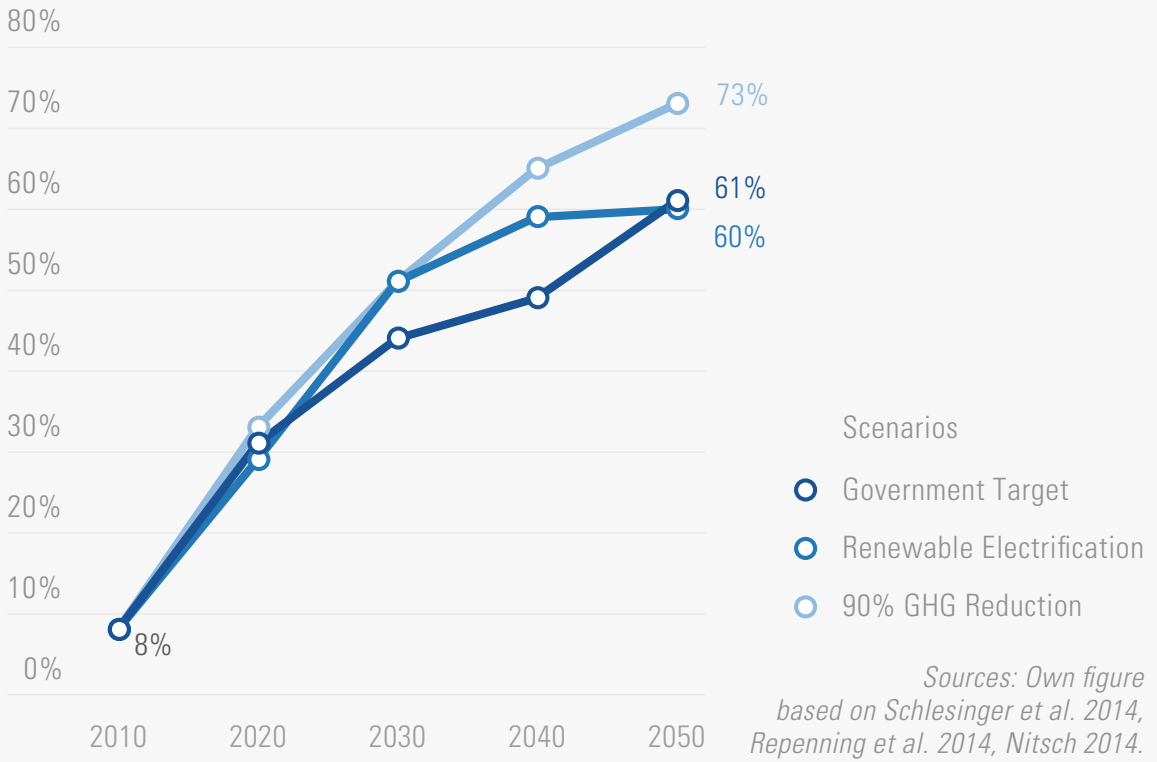


Figure 7: Share of fluctuating sources (defined as domestic solar PV, onshore and offshore wind) in total electricity supply (in %)

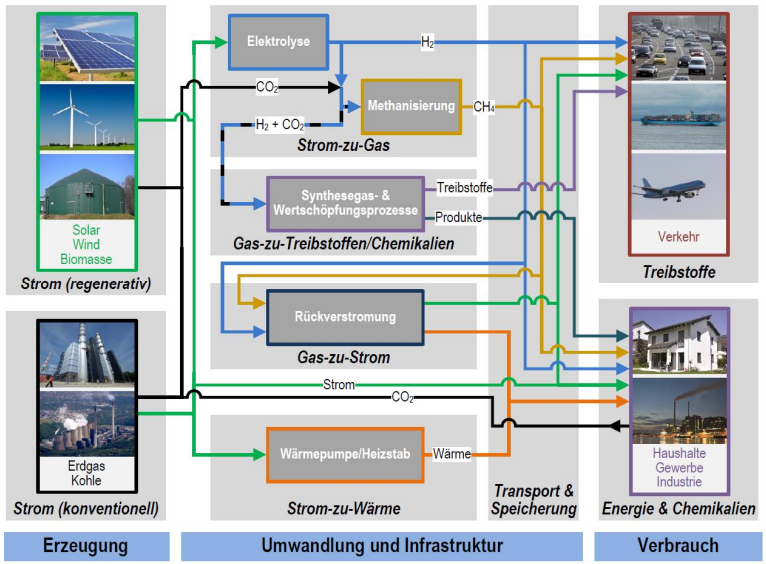


Sources: Own figure based on Schlesinger et al. 2014, Repenning et al. 2014, Nitsch 2014.

Source: WI 2015

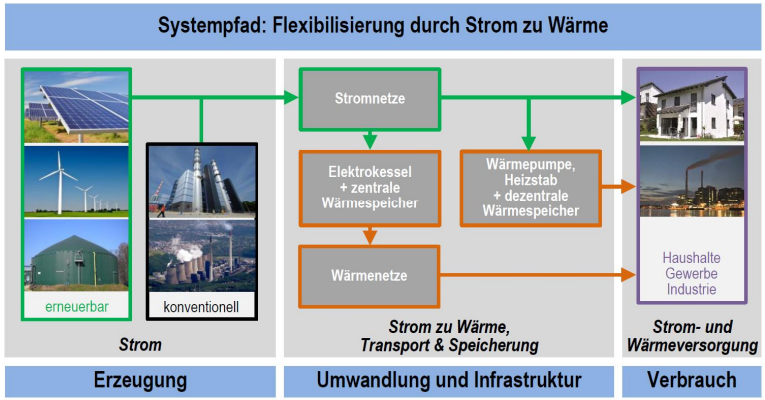
Phase 3: Broad portfolio of flexibility options necessary and available for covering the residual load – provison of appropriate market incentives crucial

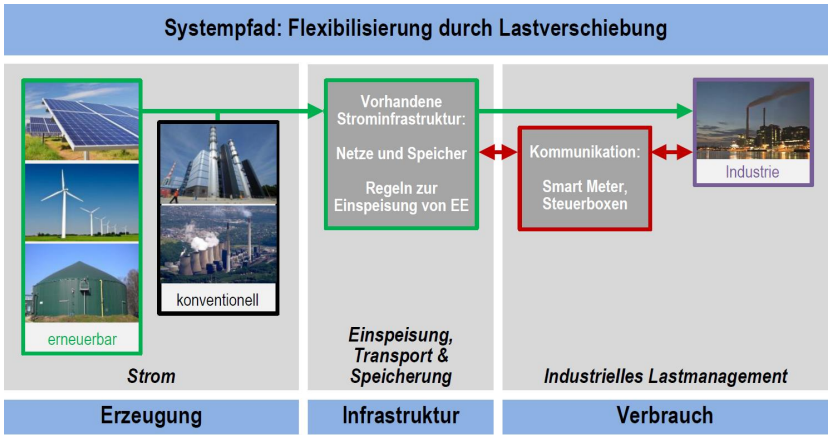
Range of flexibility options reduces storage requirements



Flexibility Options, e.g.:

- Flexible fossil fired power plants
- Flexible cogeneration units (incl. heat storage facilities)
- Flexible EE-power plants (e.g. biogas)
- Demand side management (DSM)
- Power to heat
- Power to X (gas, fuels, chemicals)
- Power storage (incl. batteries, pumped storage stations)



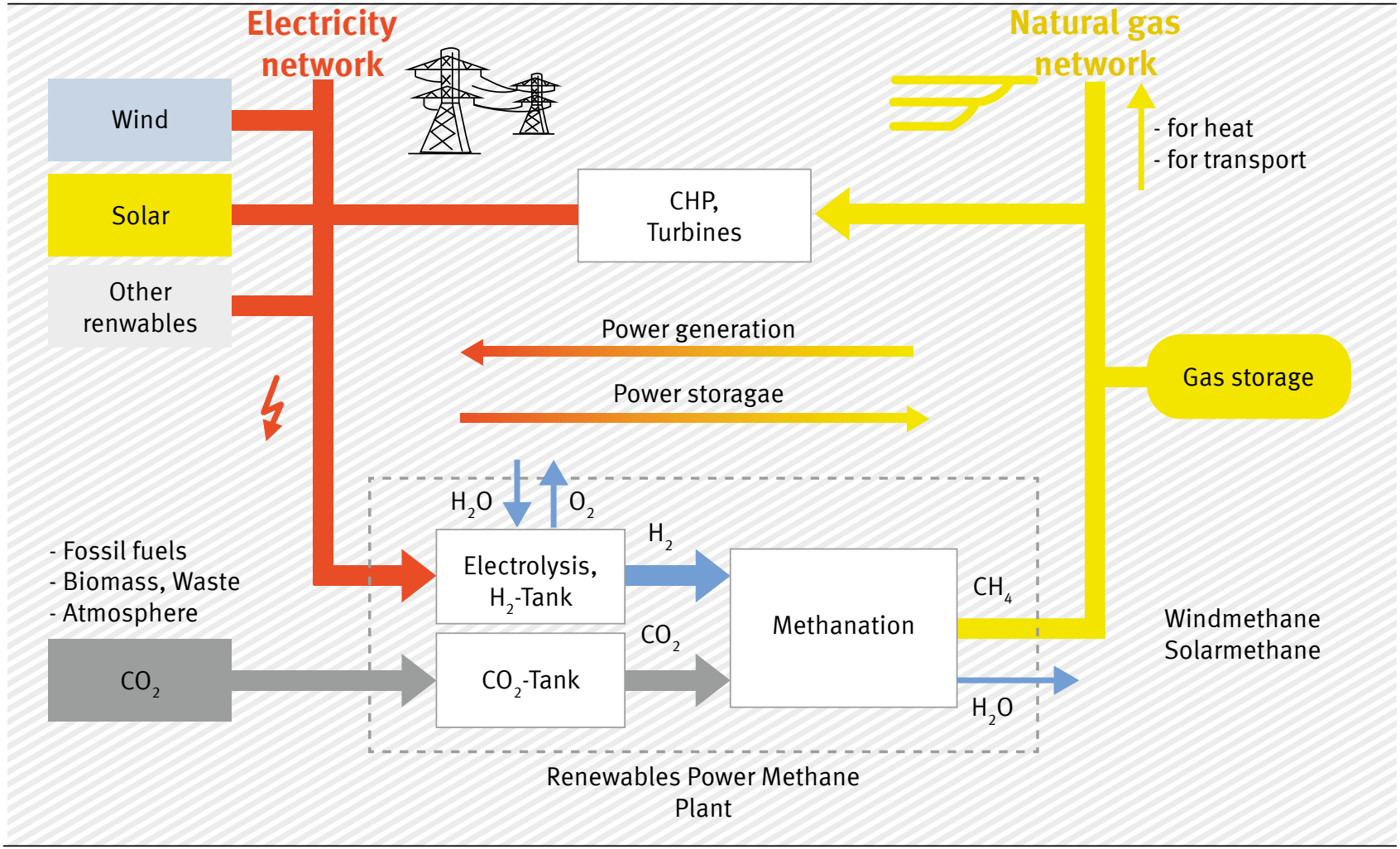


Source: Virtuelles Institut Power to Gas 2015

Phase 3: Phase relevant for step by step market introduction of PtX-products - synthetic gases, fuels and feedstocks based on RE electricity

Basic principles of Power to X (various opportunities)

X = Heat, Hydrogen, synthetic natural gas and fuels, feedstocks for chemical industry

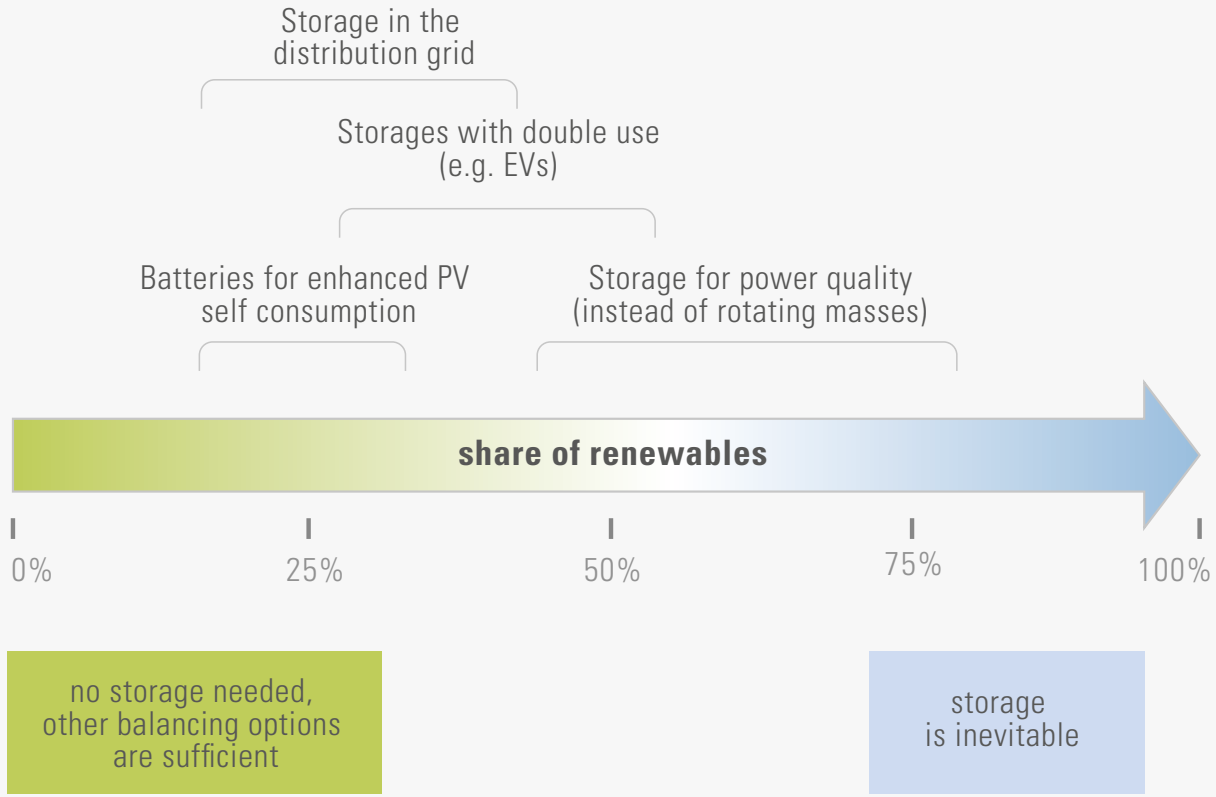


Phase 3: Long-term storage needed if share of renewable energies exceeds 65%

Regarding the time axis that corresponds with the time frame where storable PtX-products are necessary to start full decarbonisation of end-use sectors

Due to a broad spectrum of flexibility options large-scale (energy) storage is inevitable only above a specific share of renewable energies in the system

Figure 18: Share of renewable electricity generation and resulting storage demand.



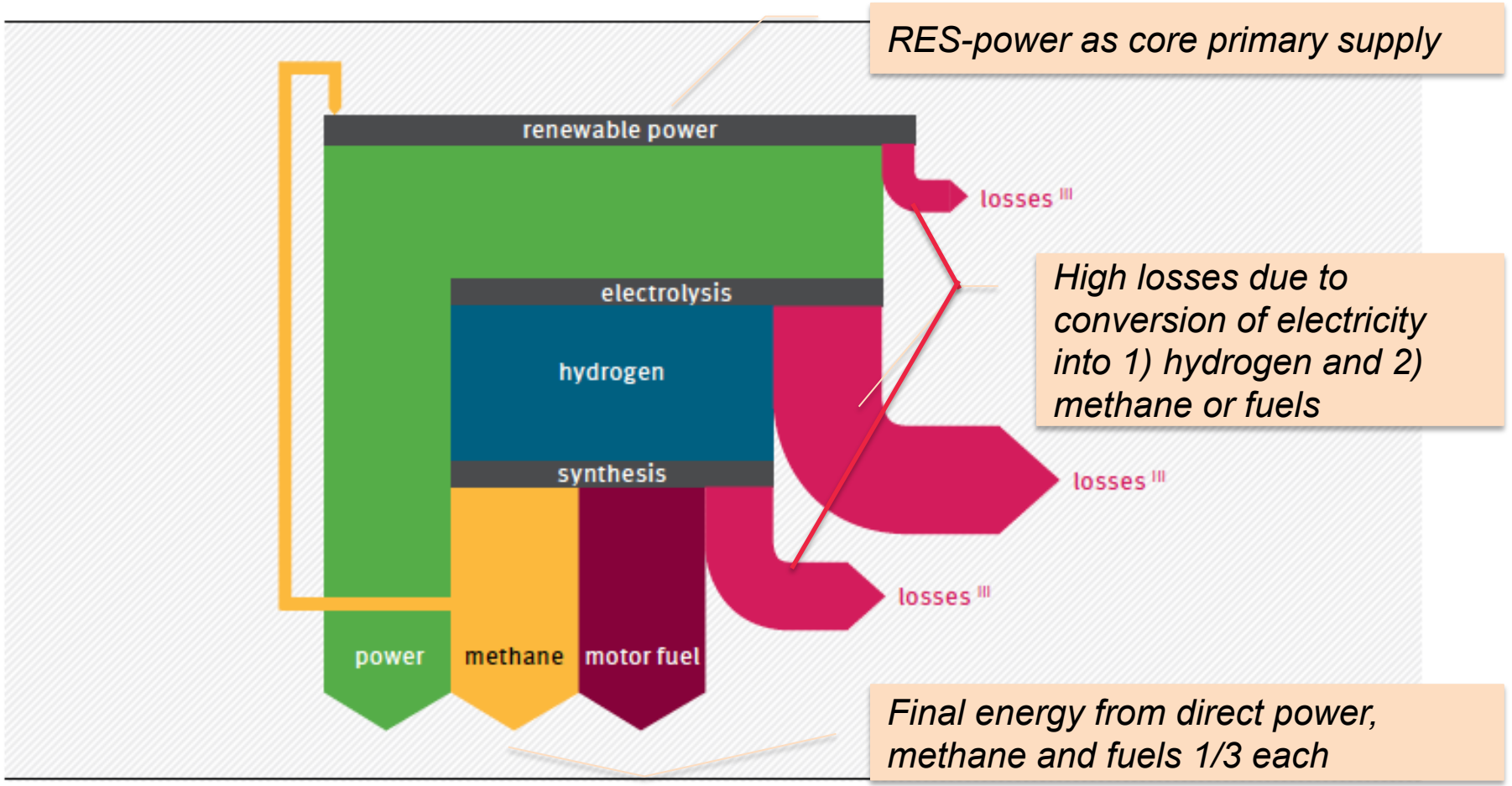
Source: Own figure based on Adamek et al. 2012, EFZN 2013, Agora Energiewende 2014 b.

Phase 4: RE-Import or import of PtX-products

Phase 4: Full decarbonisation of end-use sectors through use of PtX options?

Supply structures must be fully based on renewable energy based electricity

Qualitative representation of the energy flow in the UBA THGND 2050 Scenario [I,II]



RES-power as core primary supply

High losses due to conversion of electricity into 1) hydrogen and 2) methane or fuels

Final energy from direct power, methane and fuels 1/3 each

I Including demand for renewable inputs for the chemical industry.

II Representations of energy flows are proportional to the energy flows required.

III Including line losses, losses from reconverting methane into power and losses from converting biomass into power

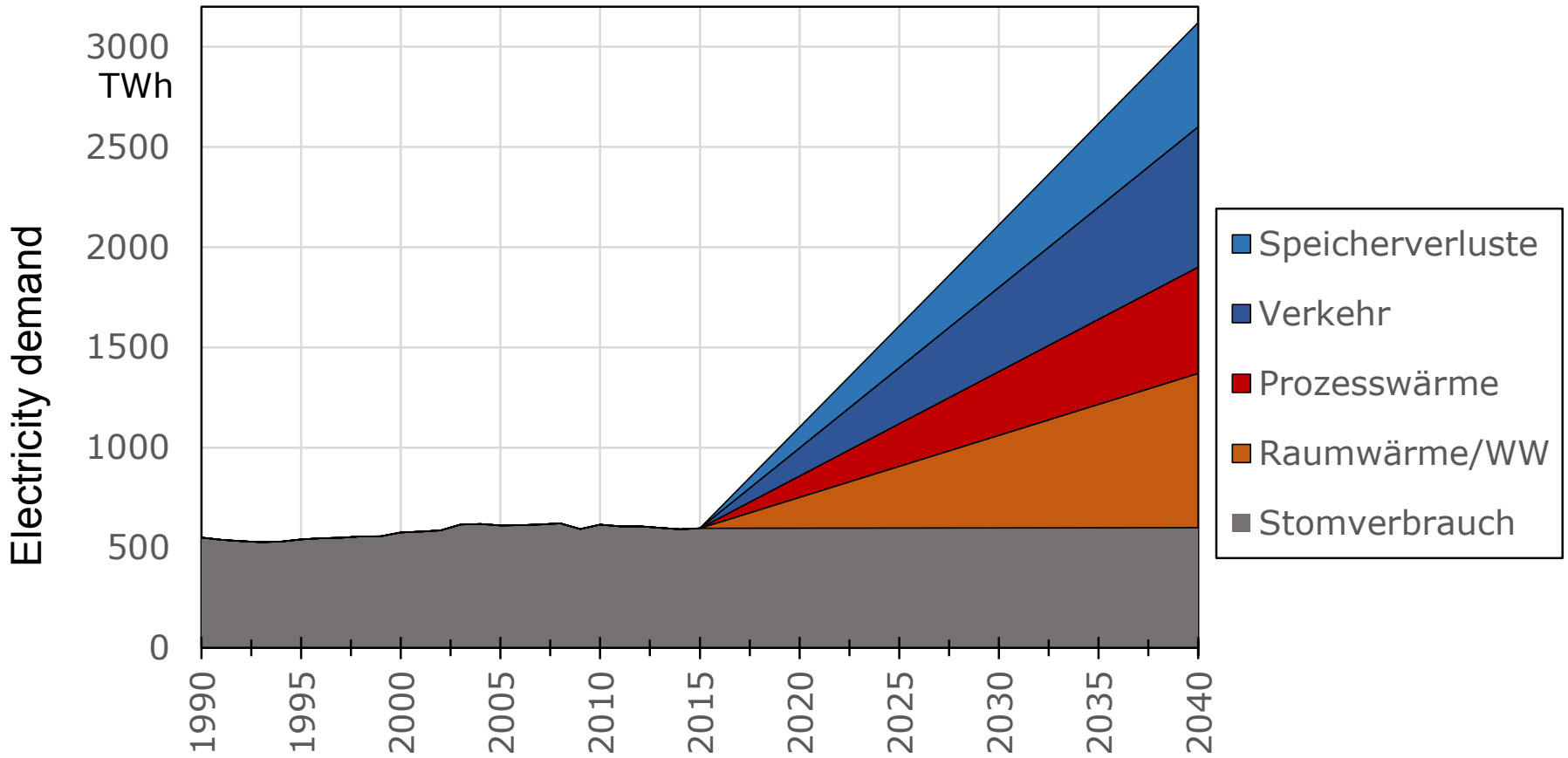
Source: Umweltbundesamt

Source: UBA 2015

Phase 4: Full decarbonisation of end-use sectors through use of PtX options?

Supply structures must be fully based on renewable energy based electricity

Full decarbonisation would lead to an extremely high electricity demand – without energy efficiency offensive 3,000 TWh might be needed (cf. circa 600 TWh in 2015)



Source: Quaschning 2016

Phase 4: Full decarbonisation of end-use sectors through use of PtX options?

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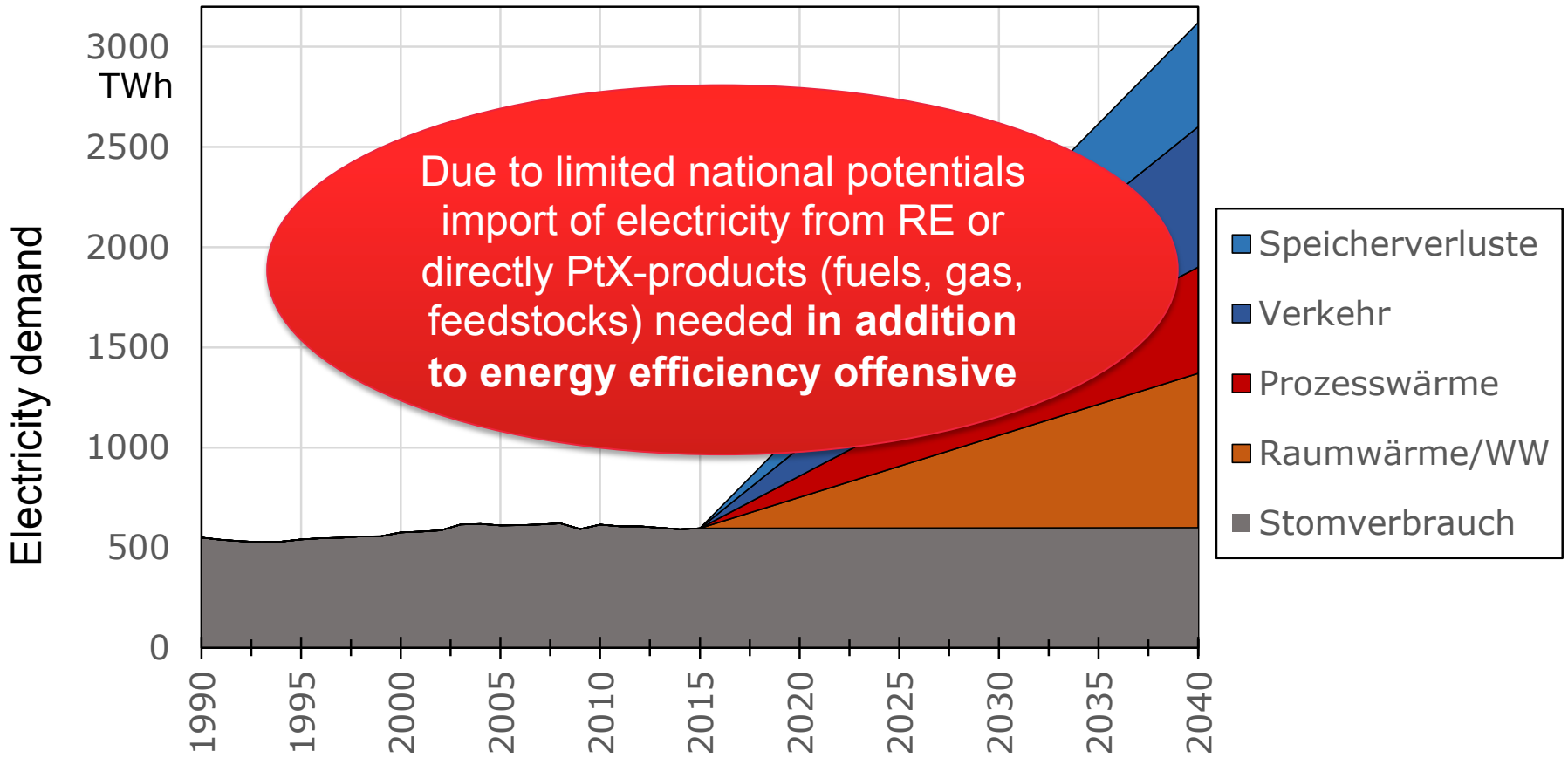


Source: Quaschning 2016

Conclusions

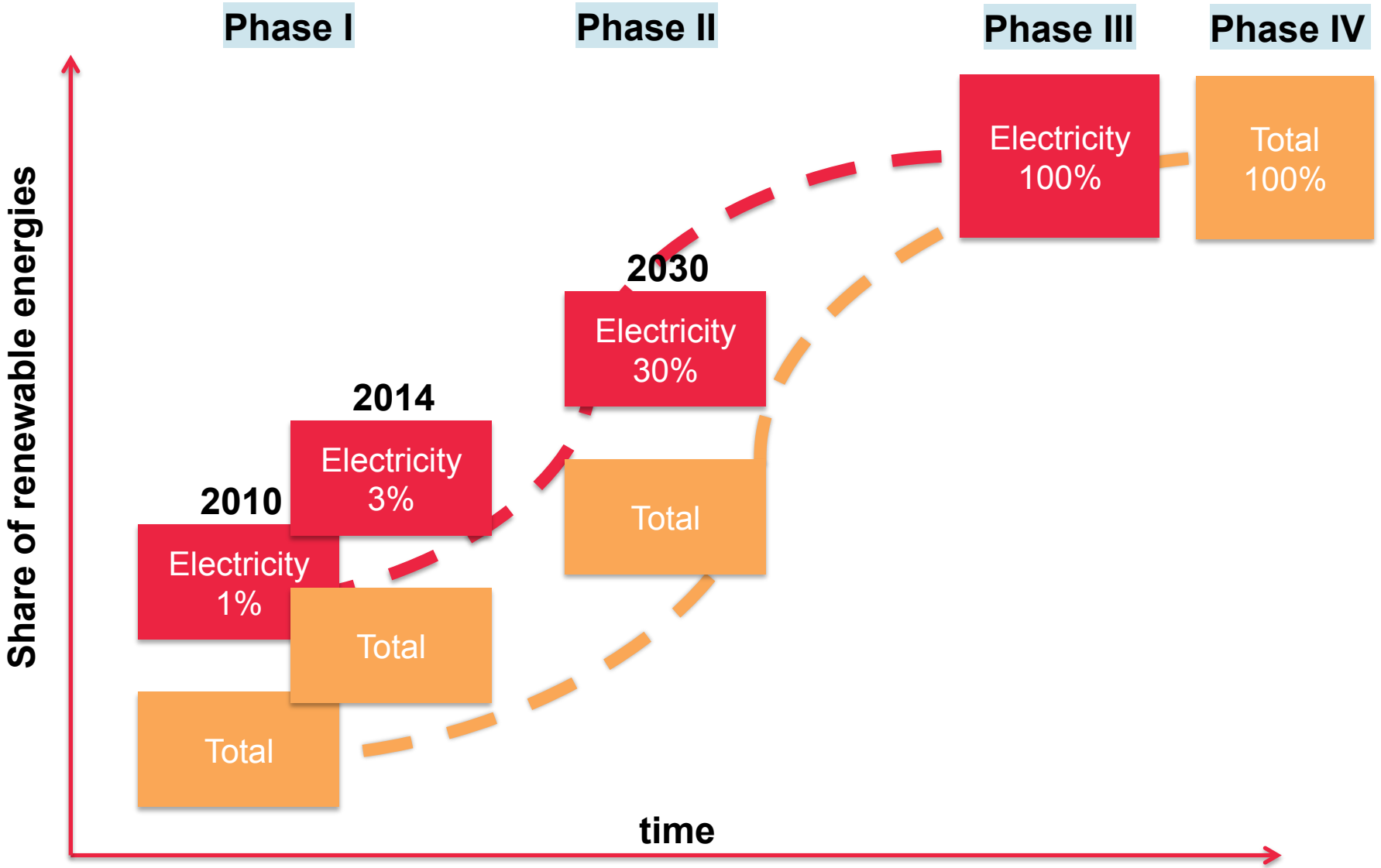
The different phases of a complex transition process in summary

Phase 1 „Market Introduction“	Phase 2 „System integration“	Phase 3 „Sector coupling (electrification)“	Phase 4 „RE-Import“
CO_2-reduction ~ 0-20%	CO_2-reduction ~ 20-50%	CO_2-reduction ~ 50-75%	CO_2-reduction ~ 75-100 %
■ Development and introduction of basic technologies (resp. adapted options) ■ Trigger significant cost reductions based on learning curves ■ Deployment associated without significant implications on the system structure	■ Identification and management of system integration needs ■ Demand Side Management ■ Continued public support of market deployment ■ System solutions (RE and efficiency) Regional economic impact (added value)	■ Management of increasing negative residual load situations ■ Use of full portfolio of flexibility options needed ■ Generation of electricity based fuels and gases/ chemical feedstocks (sector coupling)	■ Complete displacement of fossil resources in all sectors (incl. end-use sectors) ■ Import of renewable energy based electricity or electricity products (fuels, gas, chemical feedstocks- e.g. from MENA)

- In parallel: continuously increase of energy efficiency in all areas, e.g.
  - Improvement of insulation in building stock
  - Reduction of electricity demand in traditional fields of application (e.g. lighting, pumping, traction)
- Continuously extension of share of electricity in final energy mix (electrification)

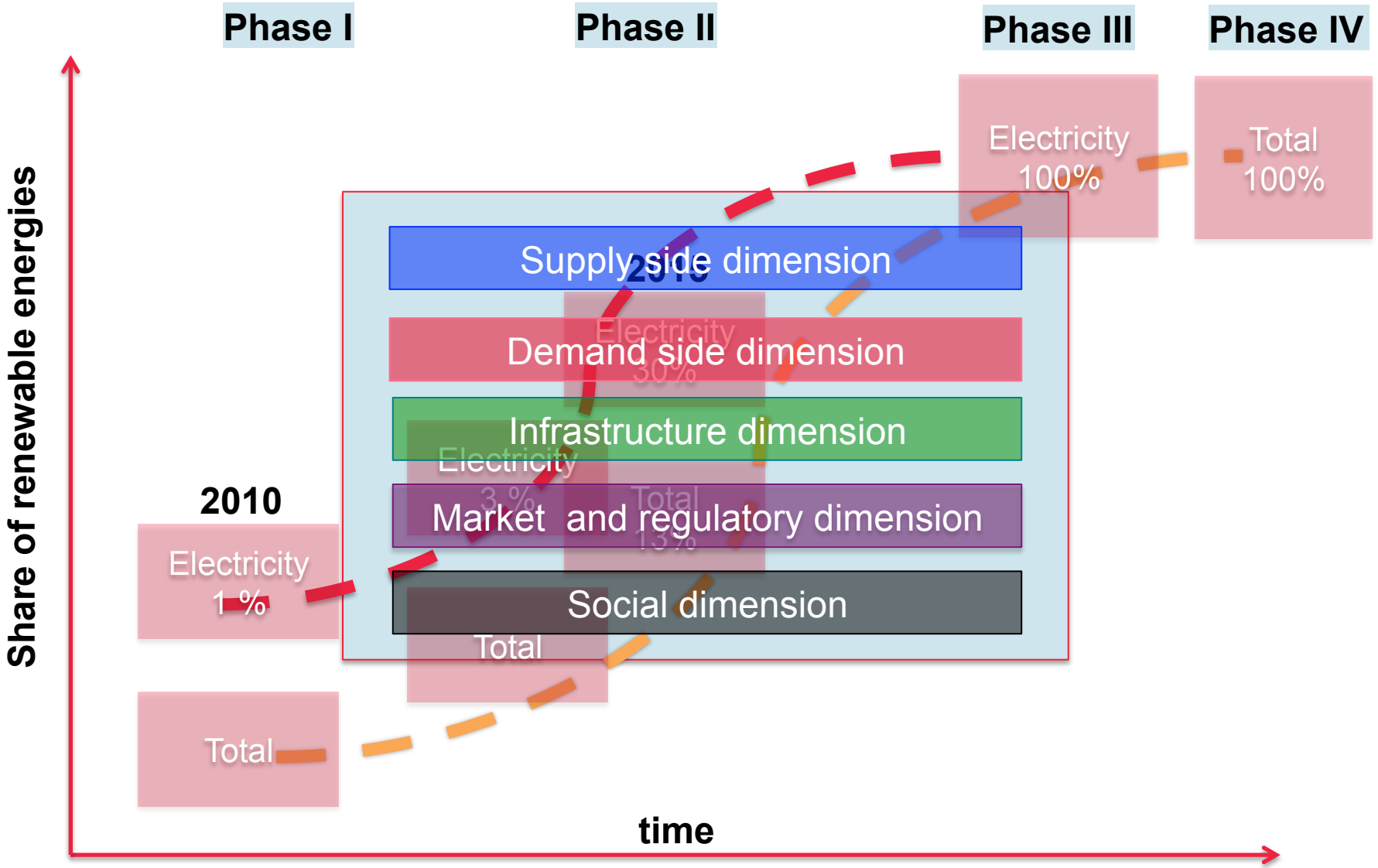
Outlook - the different phases for Tunisia: where does the country stay and where to go

The different phases of a complex transformation process (Tunisia)



The different phases of a complex transition process (Tunisia)

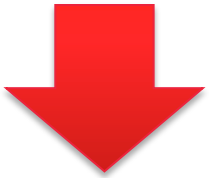
It is more than a pure technological challenge of electricity generation – different dimension have to be considered



The different phases for Tunisia: where does the country stay and where to go

Where is the country in the phase model located and where the country should be prepared for?

- Tunisia is still at the beginning of building up a renewable energy system: **phase1**



If **smart and stable policy conditions** are provided a significantly faster progress is possible – **leapfrogging to phase 2**

- To leapfrog the transition to **phase 2** preparatory steps should be done and are possible

- In addition potential anchor points for a **phase 3 and 4** should be considered early and first concepts should be discussed (e.g. in terms of export opportunities for PtX-products (fuels, feedstocks)

The different phases for Tunisia: where does the country stay and where to go I

Where is the country in the phase model located and what should be done in the current situation?

- Tunisia is still at the beginning of building up a renewable energy system: **phase1**
  - Stable market conditions (attractive investment conditions) crucial: set the right political framework for small and large-scale applications/projects
  - Gain experience at national and international level (including success factors for certain policy instruments, e.g. tendering models) and pick up lessons learned
  - Conduct accompanying research for small and large scale projects
    - Socio-economic impacts (cf. Social CSP project for CSP plant Quarzazate (Morocco))
    - Employment and market options along the value chain
  - Secure sufficient options for stakeholder to participate in market deployment (e.g. attractive conditions for small scale applications, access to grid without discrimination) – public acceptance

The different phases for Tunisia: where does the country stay and where to go II

Where is the country in the phase model located and what should be done in the current situation?

- Tunisia is still at the beginning of building up a renewable energy system: **phase1**
  - ….
  - Provide opportunities for new market options (e.g. private-to-private sale of electricity from renewable resources)
  - Motivate energy utilities to provide specific services around renewable energies
    - One shop packages for home owners to facilitate installation and operation
    - Identification of appropriate system solutions according to the specific conditions in the country (including: electricity, heating/cooling, e-mobility, ICT/communication: smart home, smart districts
    - System solutions have to be based on solid needs assessment (make use of co-creation mechanism like living laboratories)
  - ….

The different phases for Tunisia: where does the country stay and where to go

Where the country should be prepared for and should take first actions?

- To leapfrog the transition to **phase 2** preparatory steps should be done and are possible
  - Define clear mid- and long-term target (currently: 30% RE-share by 2030): ambitious but realistic goals
  - Synchronize targets with broader policy perspective (particularly SDGs, NDC and long-term pathway development under Paris Agreement, energy-water nexus)
  - Define associated infrastructure requirements, identify appropriate options, prepare implementation plan and start step by step realisation
    - Grid extension (including international cooperation/networks)
    - Flexibility options (e.g. DSM, storage systems)
  - Set a stronger focus on energy efficiency as efficiency gains facilitate achievement of RE targets significantly
  - Monitor real development and adapt targets and necessary accompanying measures accordingly

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Thank you very much for your attention