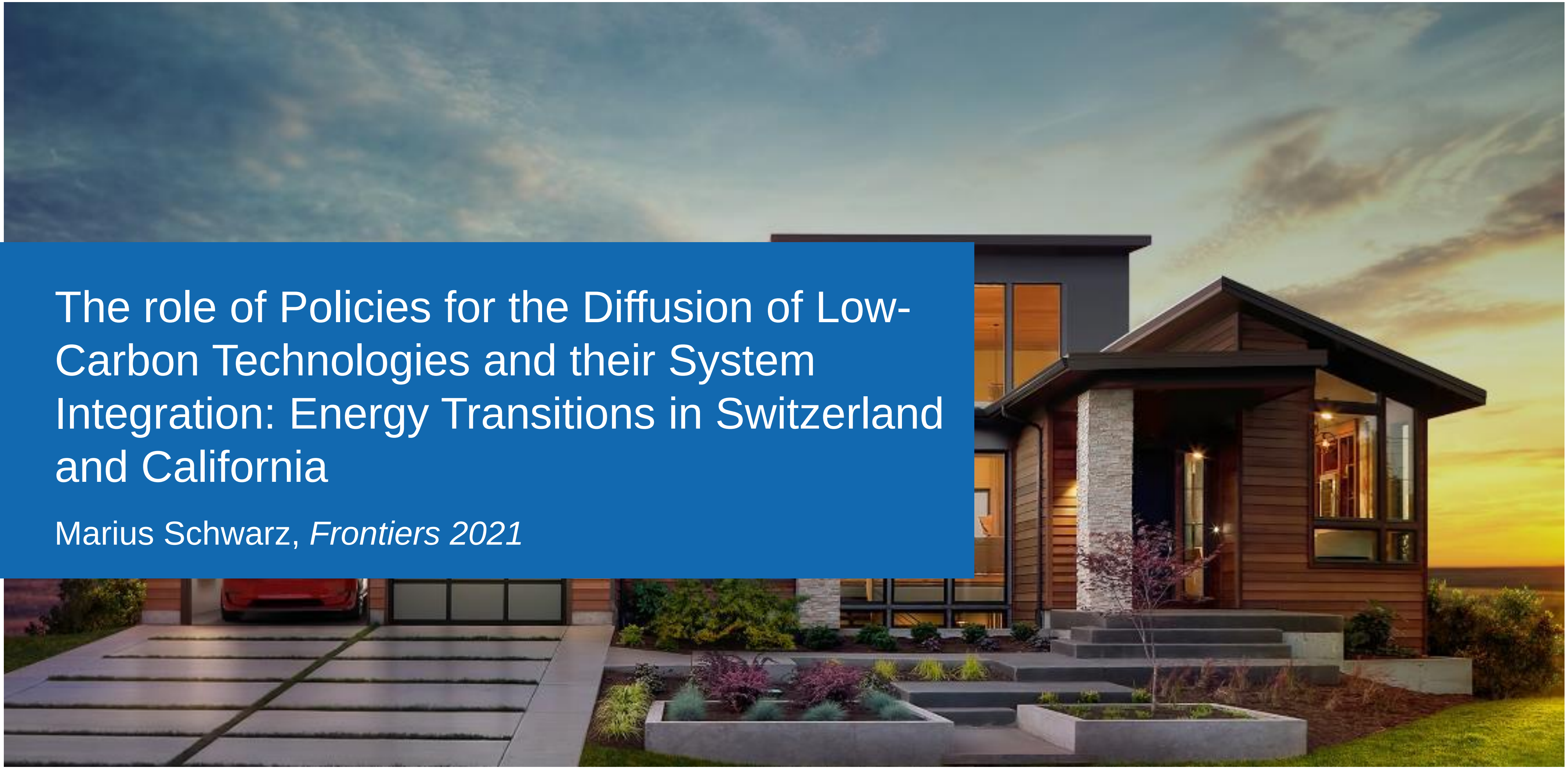
ETH zürich

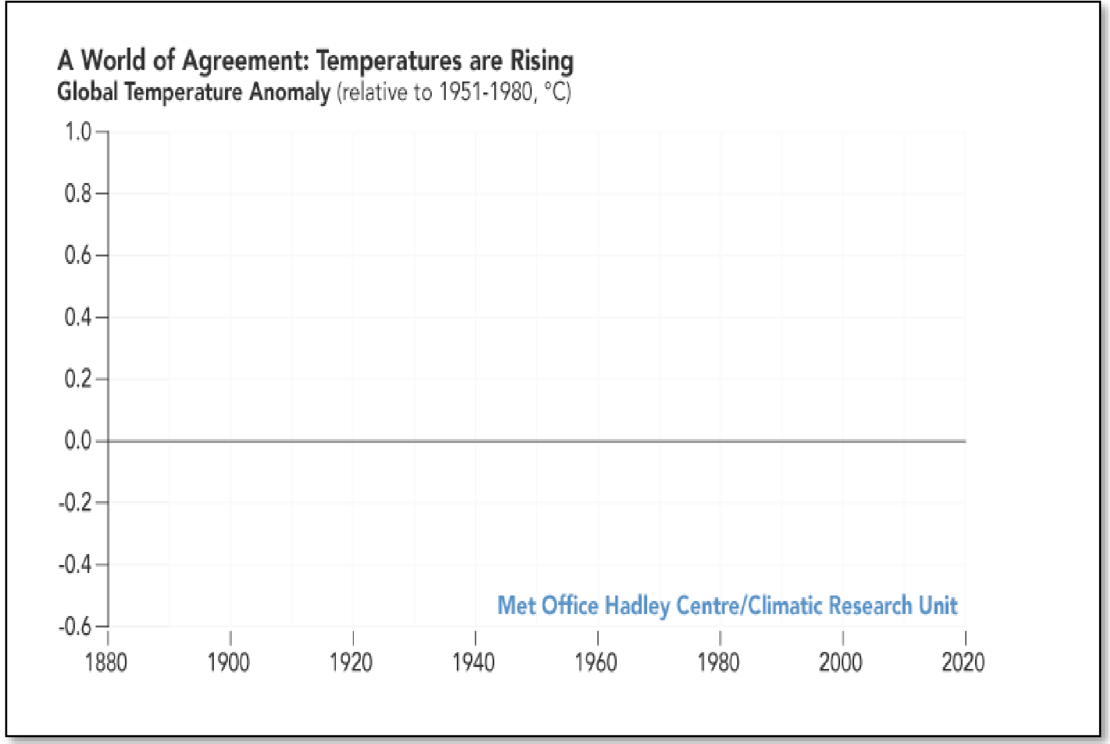
Group for Sustainability
and Technology, D-MTEC



# The role of Policies for the Diffusion of Low-Carbon Technologies and their System Integration: Energy Transitions in Switzerland and California

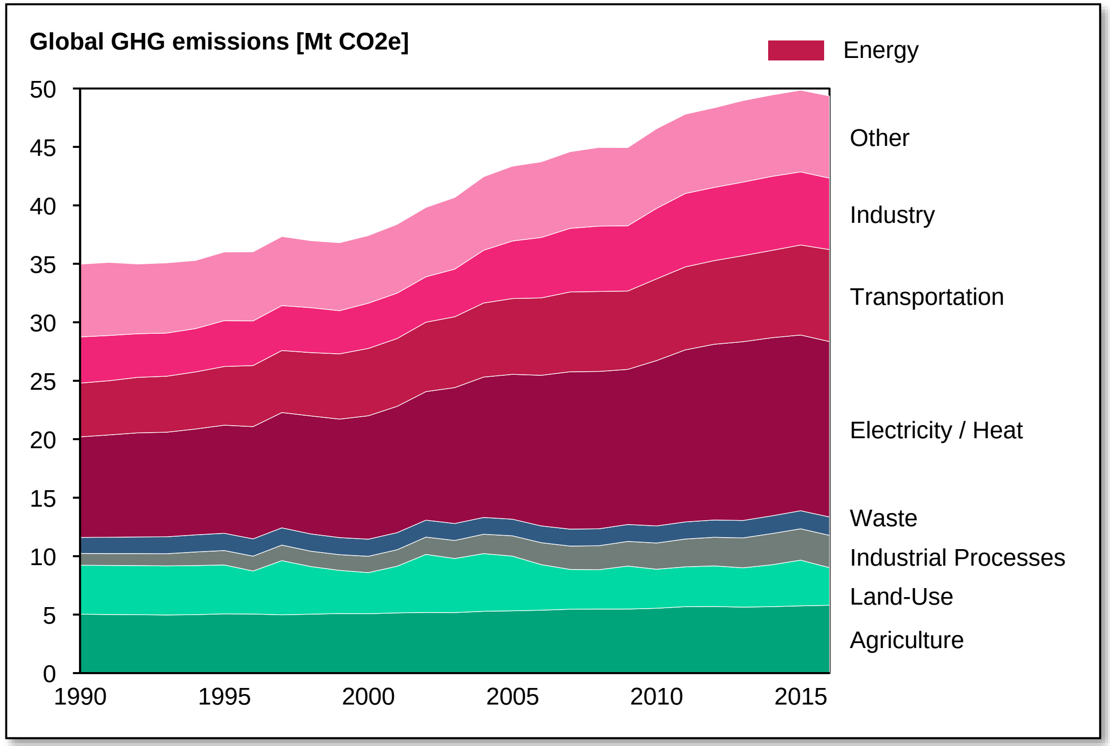
Marius Schwarz, *Frontiers 2021*

# The energy system is responsible for three-quarters of global GHG emissions, making its decarbonization pivotal for combating climate change




**Top priority: Keep global warming below 1.5°C**

Data: (NASA, 2020)




**The decarbonization of energy use is pivotal**

Data: (CAIT, 2020)

# The decarbonization of the energy system advances in four phases:

### Phase 1: Technology Diffusion

In 1983, Growian, the first large-scale (3MW) wind turbine in Germany was built. It was mostly out of service and was dismantled in 1988.

Image: energiewinde.orsted

### Phase 2: System Integration

Bhadla Solar Park is the world's largest solar park located in India and spread over a total area of 57 km$^2$, with a total capacity of 2'245 MW.

Source: MercomIndia, 2020

### Phase 3: Sector Coupling

In June 2020, the first fast-charging station for electric cars in Switzerland was put into operation at the Inseli rest stop on the A2.

Source: (ASTRA, 2020)

### Phase 4: Hard-to-decarbonize sectors

In May 2017, climeworks opened the world's first commercial project for carbon sequestration from ambient air in Switzerland.

(Climeworks, 2017)

*How can policies support the diffusion of low-carbon technologies and their system integration?*

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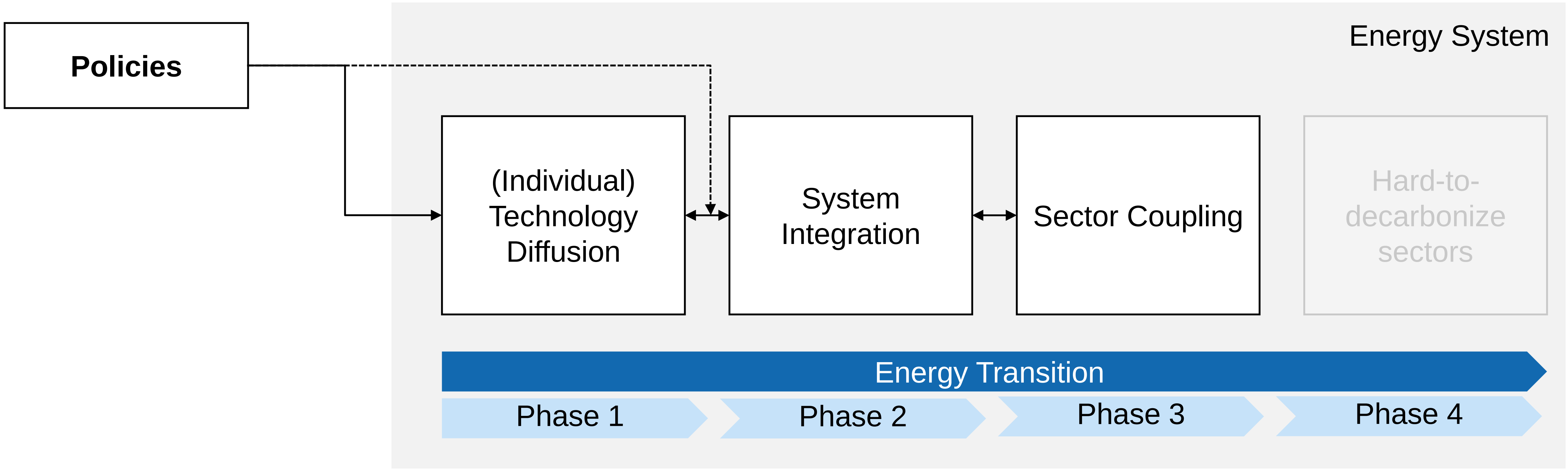

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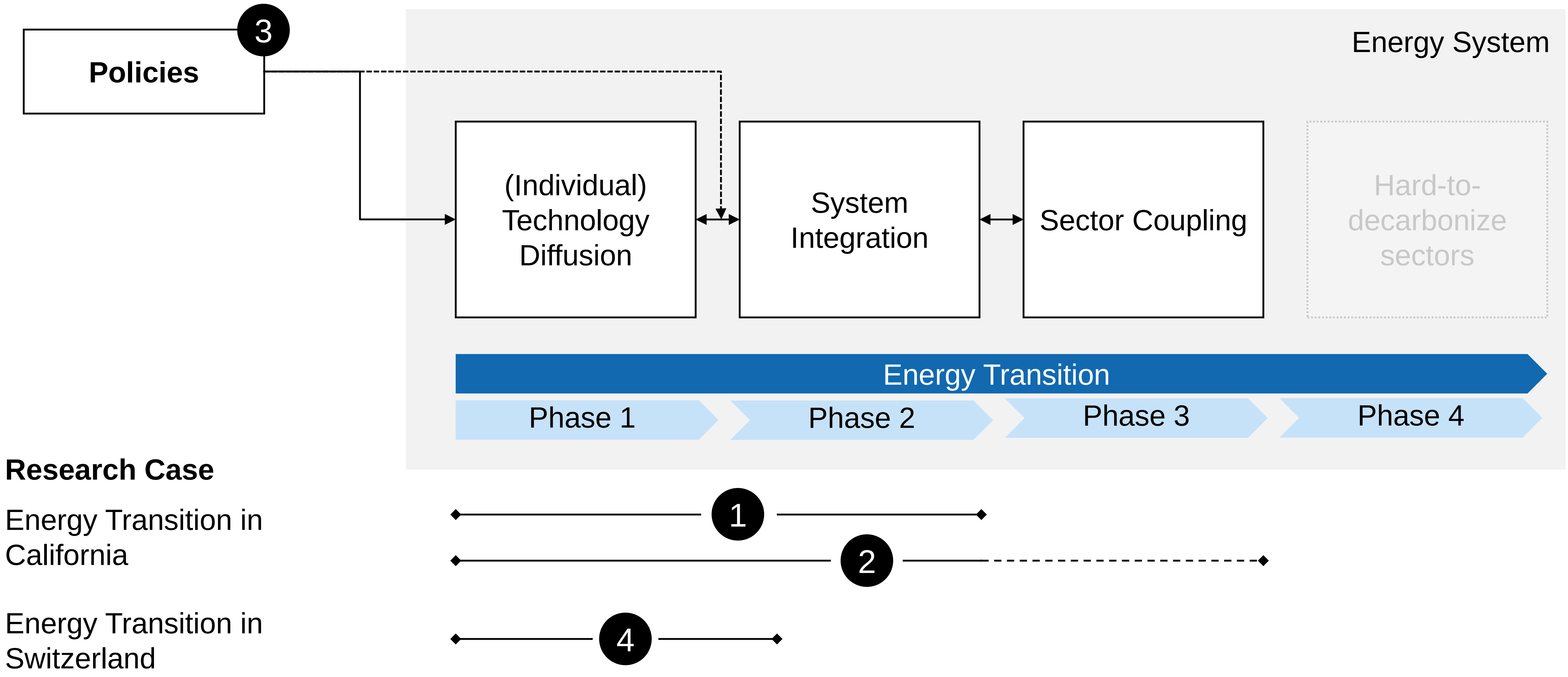


# Overview of Articles

1

## Addressing integration challenges of high shares of residential solar photovoltaics with battery storage and smart policy designs

M. Schwarz, J. Ossenbrink, C. Knoeri, V.H. Hoffmann

**Research Question**
How can policies support the diffusion of residential solar photovoltaics and battery storage while addressing their system integration challenges?

**Method and scope**
Agent-based modeling,

California, 2005-2030

Published in *Environmental Research Letters*

3

## Innovative designs of building energy codes for building decarbonization and their implementation challenges

M. Schwarz, C. Nakhle, C. Knoeri

**Research Question**
How can innovative policy designs overcome current limitations of building energy codes, and what challenges do policymakers face when implementing them?

**Method and Scope**
Semi-structured interviews

Switzerland, 4 other European countries

Published in *Journal of Cleaner Production*

2

## Can electricity pricing leverage electric vehicles and battery storage to integrate high shares of solar photovoltaics?

M. Schwarz, Q. Auzepy, C. Knoeri

**Research Question**
How can electricity pricing leverage electric vehicles and battery storage to address integration challenges of solar PV?

**Method:**
Agent-based modeling
California, 2005-2030

Published in *Applied Energy*

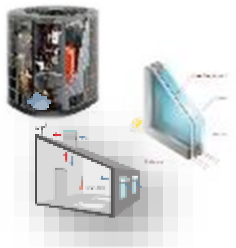
4

## Put the pedal to the metal – How policies can accelerate the diffusion of energy-efficient building technologies

M. Schwarz, C. Knoeri

**Research Question**
What is the impact of individual policies as part of a broader policy mix on the diffusion of low-carbon technologies?

**Method:**
Agent-based modeling
Switzerland, 1995-2015



Working paper for submission *Research Policy*

1

# Addressing integration challenges of high shares of residential solar photovoltaics with battery storage and smart policy designs

**Motivation**

- the growing shares of residential solar power begins to challenge existing electricity systems
    - It increases the need for fast-ramping generation capacity
    - It causes an increase in electricity prices
- Battery storage might support the integration of solar power

**Research Question**

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- Case: Energy transition in California
- Method: Agent-based modeling

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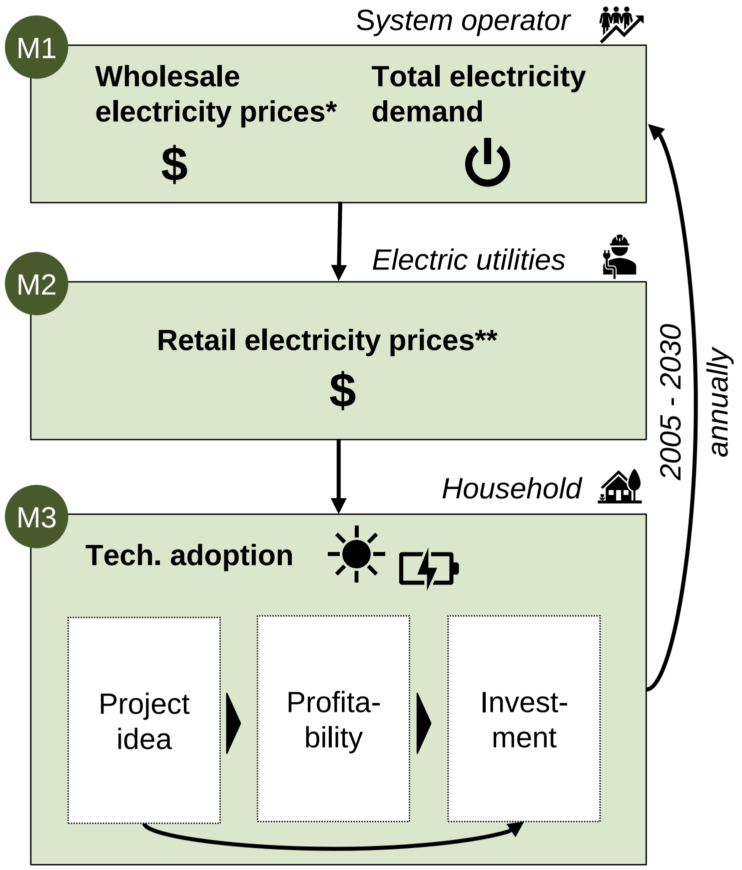
**Policy design scenarios**

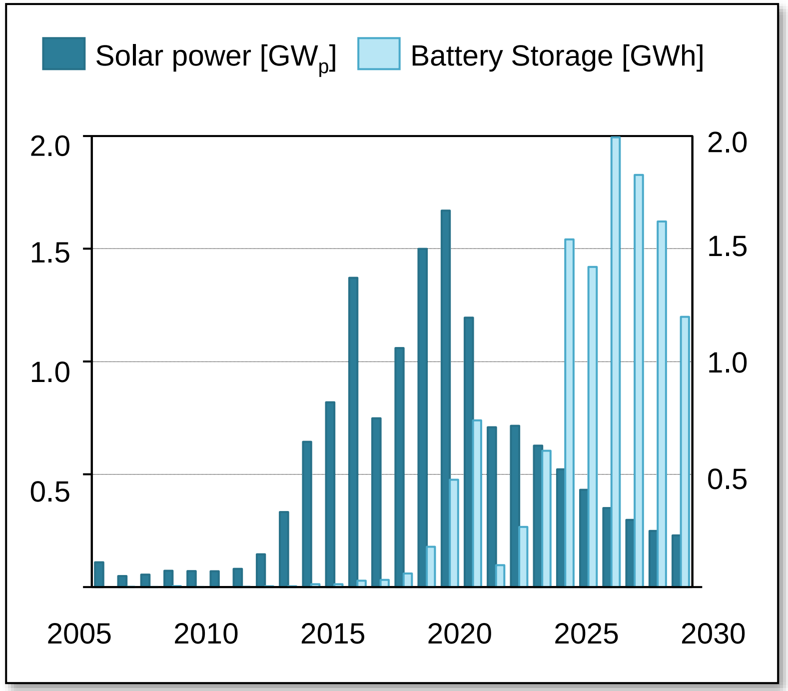
- Current Path
- 2016 Policy Freeze
- 2018 Policy Off




***:** wholesale electricity prices are paid by utilities and include the cost of electricity generation

****:** retail electricity prices are paid by end-customers and include additional fees such as for the distribution of electricity

# Policies have a substantial impact on the diffusion of residential solar PV and battery storage




**Scenario 1: Current Path**

- Policy change in 2017 causes a market fall of solar PV
- PV market temporarily recovers as PV prices fall
- PV market saturates due to late adopter characteristics
- Policy change in 2017 triggers battery storage uptake
- Battery storage market collapses due to the phase-out of upfront support but recovers due price decline

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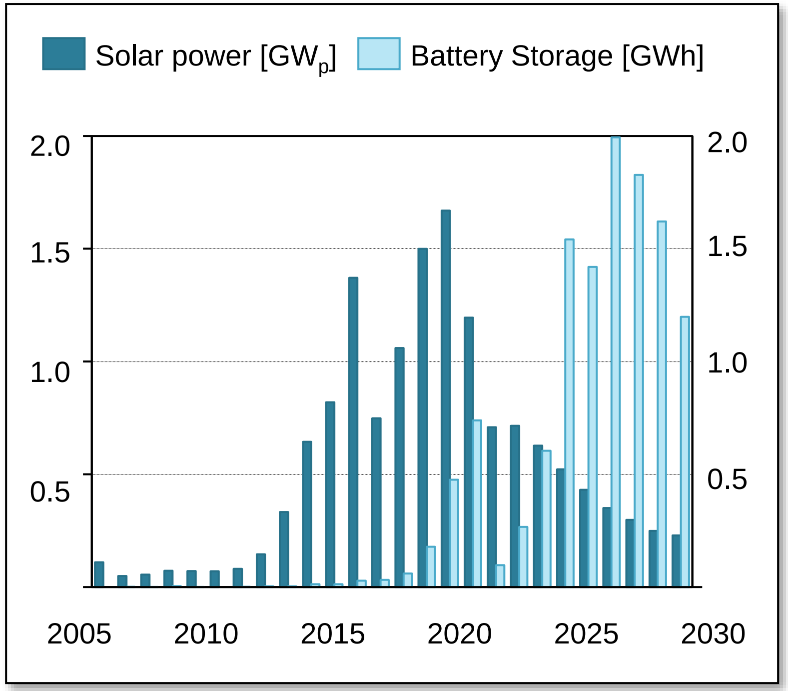


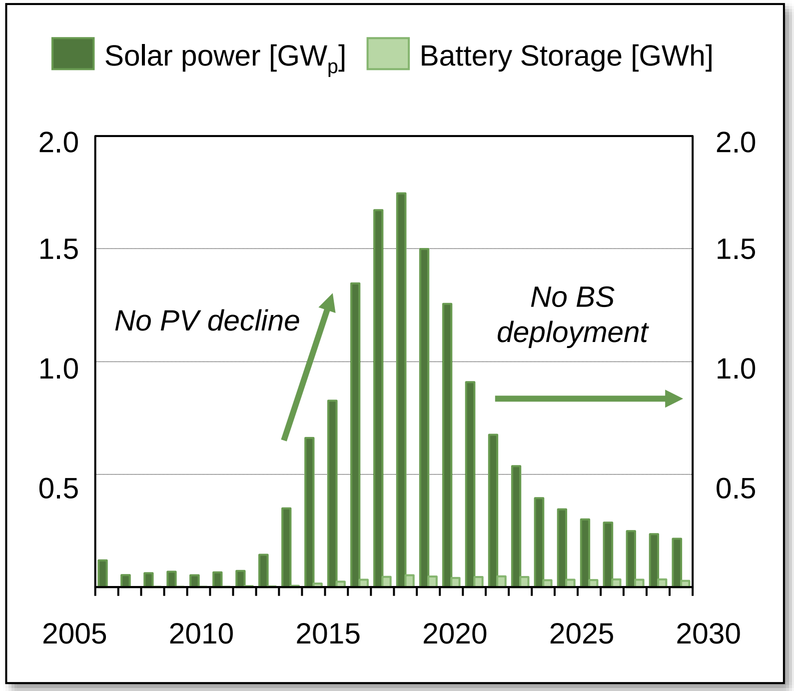


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**Scenario 2: 2016 Policy Freeze**

- No PV decline due to continuous strong policy support
- Battery storage deployment remains low until 2030.
- The electricity grid serves as a free-of-charge and unlimited storage.

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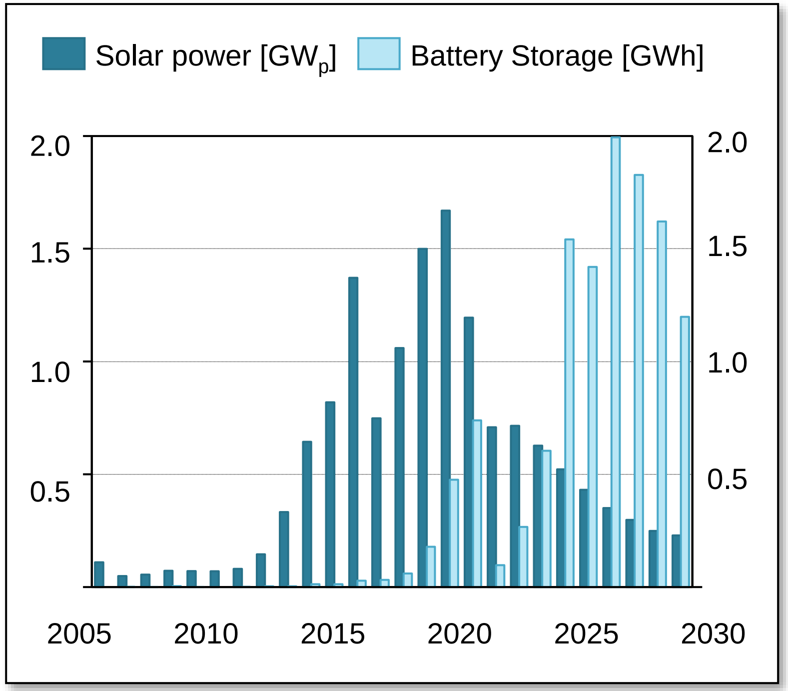


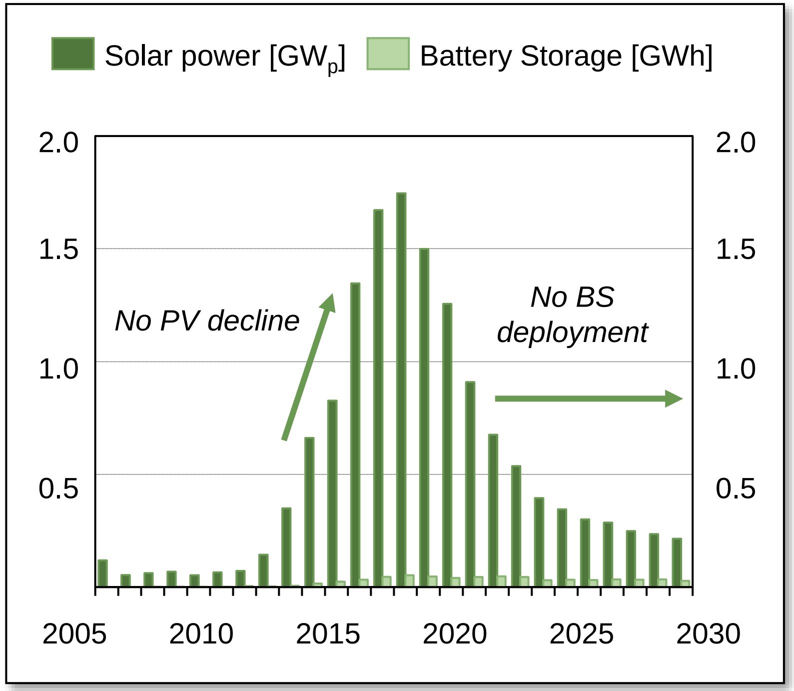


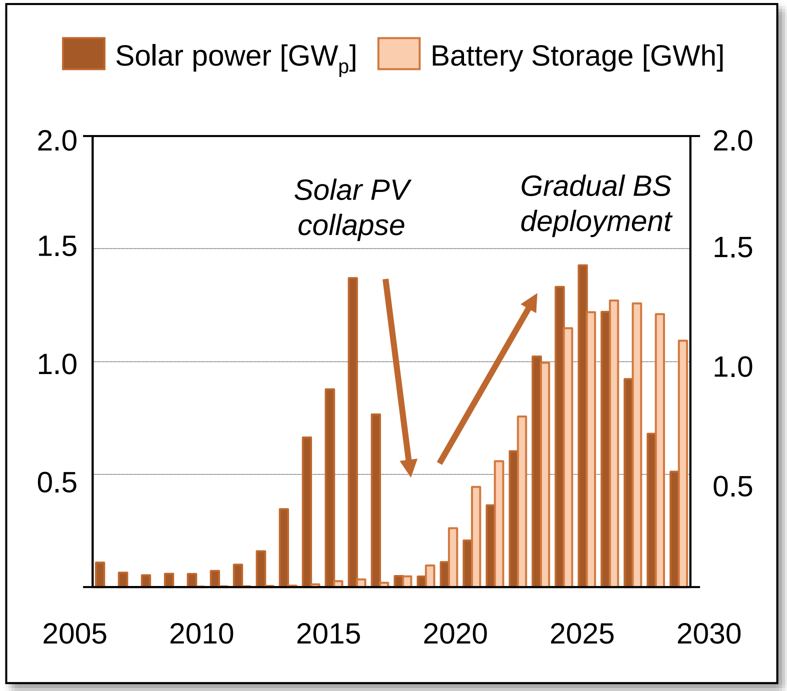


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### Scenario 2: 2016 Policy Freeze

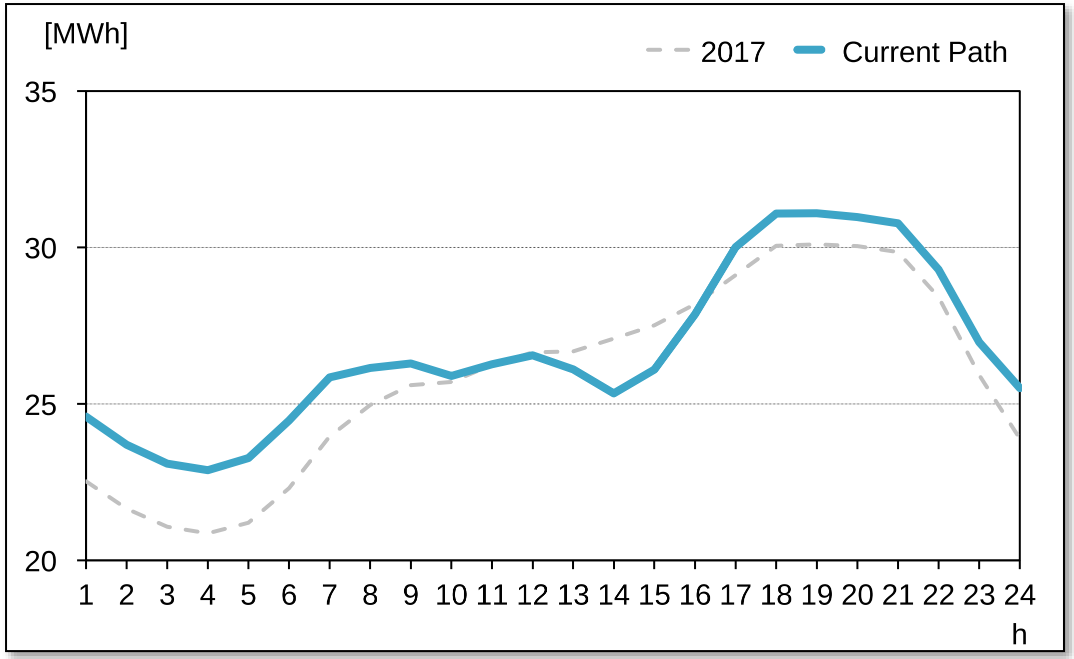
- No PV decline due to continuous strong policy support
- Battery storage deployment remains low until 2030.
- The electricity grid serves as a free-of-charge and unlimited storage.

### Scenario 3: 2018 Policy Off

- Shutdown of support policies triggers an immediate collapse of PV market.
- PV market recovers with declining global panel prices.
- Uptake of battery storage as they increase self-consumption of PV electricity and thus make use of excess electricity

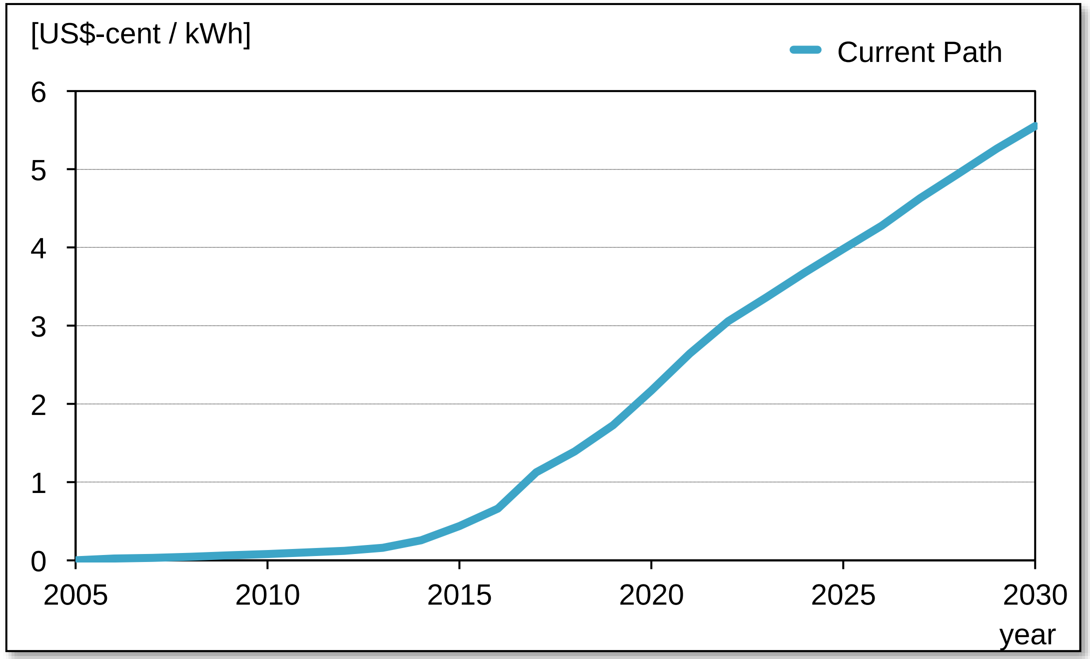
# … and on the two integration challenges

1




## Challenge 1: Need for fast-ramping generation capacity

- *Current Path*: High shares of solar power require fast-ramping generation capacity during sunset. However, the uptake of battery storage holds it at bay.




## Challenge 2: Retail Electricity Prices

- *Current Path*: Solar power and battery storage cause an increase in retail electricity prices. Many households self-consume a large share of their generated electricity. In turn, costs for the electricity grid are split over less electricity sales.

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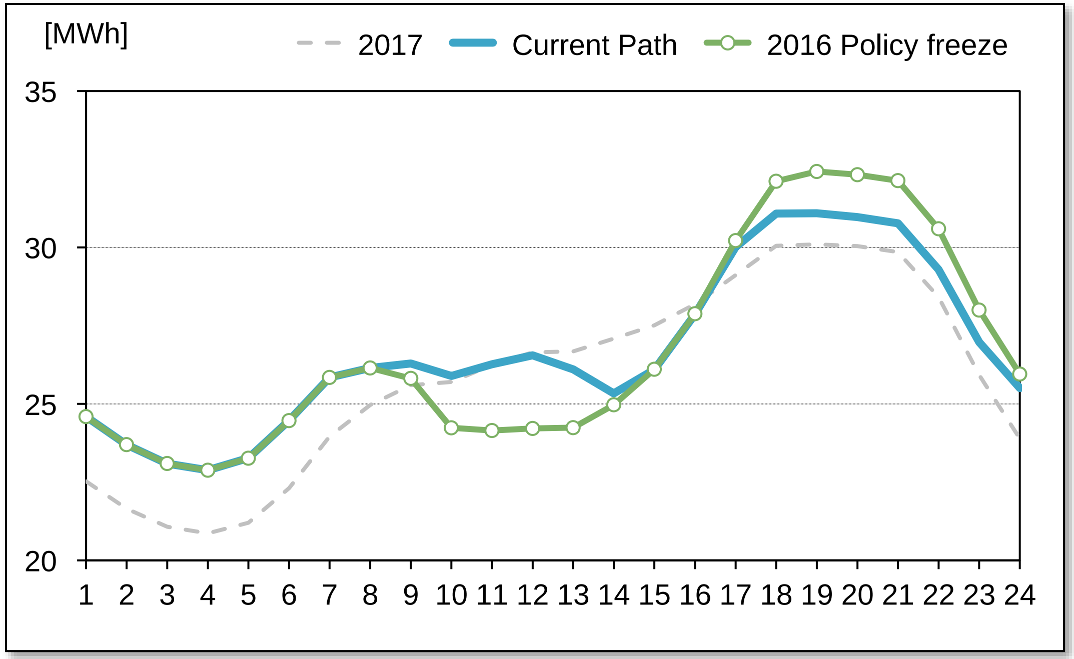
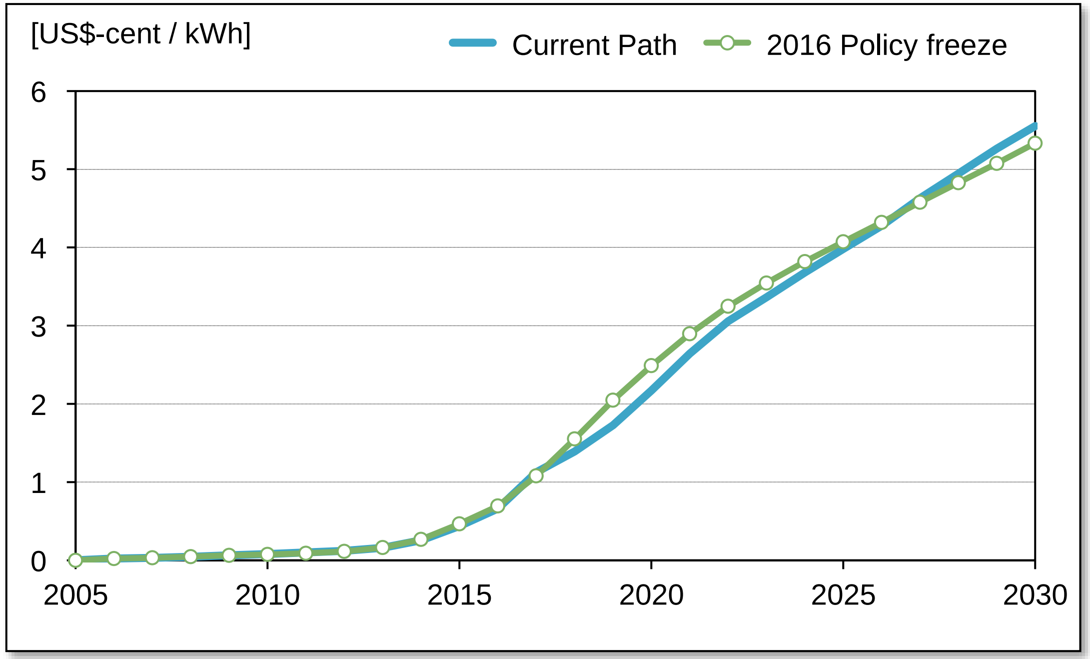
# … and on the two integration challenges




## Challenge 1: Need for fast-ramping generation capacity

- *Current Path*: High shares of solar power require fast-ramping generation capacity during sunset. However, the uptake of battery storage holds it at bay.
- *2016 Policy Freeze*: Vast demand for fast-ramping capacity due to the lack of battery storage. Demand curve exhibits a pronounced “duck curve”, including a “belly” around midday and a “neck” in the evening.

## Challenge 2: Retail Electricity Prices

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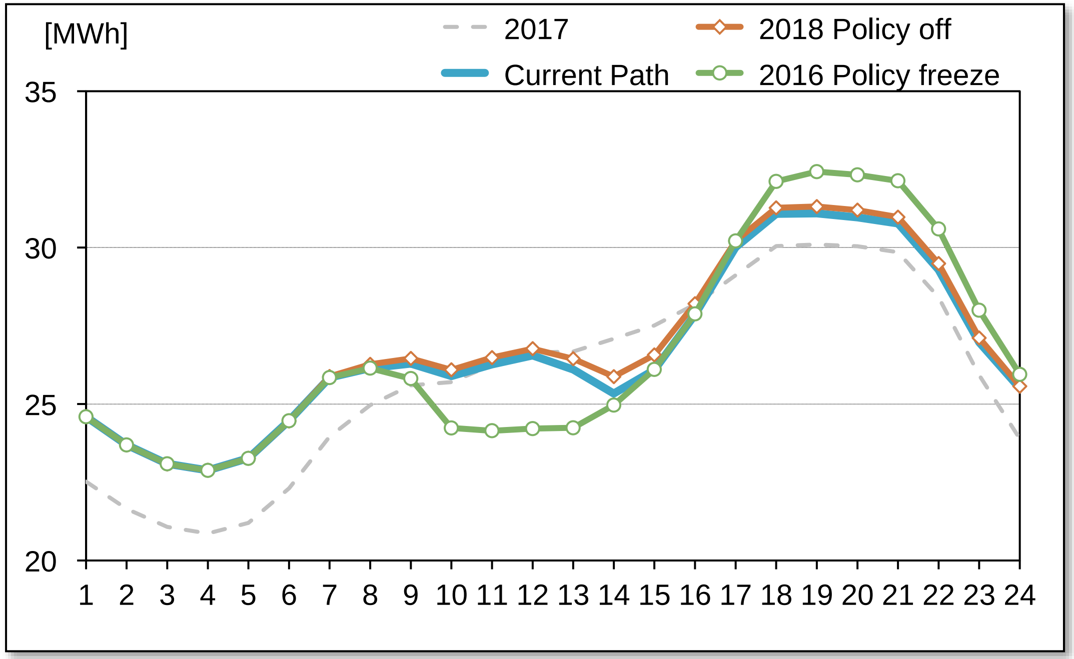


## Challenge 1: Need for fast-ramping generation capacity

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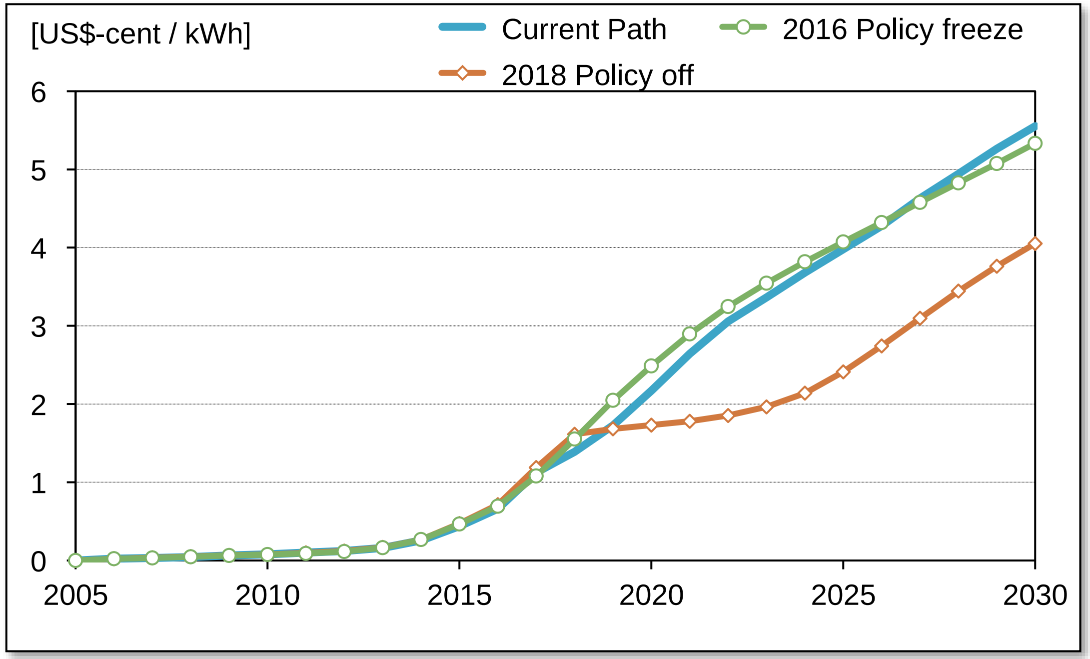



## Challenge 2: Retail Electricity Prices

- *Current Path*: Solar power and battery storage cause an increase in retail electricity prices. Many households self-consume a large share of their generated electricity. In turn, costs for the electricity grid are split over less electricity sales
- *2016 Policy Freeze*: Similar to current path.
- *2018 Policy Off:* Electricity price increase is mitigated. Support policies are phased out and the PV market collapses. However, with the battery storage uptake and solar market recovery, retail prices increase substantially by 2030.

# Summary of Articles

1

## Addressing integration challenges of high shares of residential solar photovoltaics with battery storage and smart policy designs

M. Schwarz, J. Ossenbrink, C. Knoeri, V.H. Hoffmann

- Policy change in 2017 essential for the further diffusion and system integration of both technologies
- Under Policy status quo, electricity prices exceed the household's willingness to pay for renewable energy
- The immediate shutdown of policies cause a PV market crash
- There is a need for an alternative policy path

Published in *Environmental Research Letters*

2

## Can electricity pricing leverage electric vehicles and battery storage to integrate high shares of solar photovoltaics?

M. Schwarz, Q. Auzepy, C. Knoeri

- Electric vehicles can also support the integration of solar power as their immense charging load likely reduces retail electricity prices
- They can mitigate the need for fast-ramping capacity when price signals steer charging to sunny hours and public charging stations are available.

Published in *Applied Energy*

3

## Innovative designs of building energy codes for building decarbonization and their implementation challenges

M. Schwarz, C. Nakhle, C. Knoeri

- Many countries fail to make use of their full regulatory power due to implementation challenges.
- We outline these challenges and how policymakers can learn valuable lessons from front-runners
- Applying these learnings policy effectiveness and acceptance

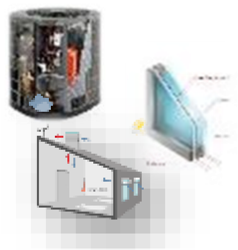
Published in *Journal of Cleaner Production*

4

## Put the pedal to the metal – How policies can accelerate the diffusion of energy-efficient building technologies

M. Schwarz, C. Knoeri

- Policies typically have a substantial impact on technology diffusion, however, to a varying degree
- In most cases, a substantial impact only occurs when multiple policies are combined.
- One policy instrument can also affect multiple technologies directly or indirectly via unintended side effects



Working paper for submission *Research Policy*

# Policy Implications

- Policies are more effective and efficient when combined in a so-called policy mix.
- Policies targeting one technology often have unintended side effects on other technologies.
- Policies can support technology diffusion not only by targeting investors' economic consideration but also during other steps of their decision-making.
- Policies should support the system integration of mature renewable energy technologies with complementary technologies and sector coupling.

# Thank you for your attention!

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