DEFINE - Electricity Market Modeling for Germany

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Overview

- Question: What is the interaction between the electricity system and electric vehicles in the future?
- Important aspects:
  - How much and when is electricity needed?
    - → Power plant dispatch and fuel use will be affected
  - CO_2-Emissions of additional electricity?
  - Do EVs introduce additional flexibility into the system
    - potentially less Renewables curtailment
  - Fuel mix of Plug-In Hybrids

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Model

We have developed a cost-minimizing power plant dispatch model with a special representation of EVs in the model

- Scope: Electricity spot market of Germany
- 8760 hours, representing 1 year with
  - Electricity load time series
  - Renewable time series (Solar, Wind Onshore and Offshore, hydro)
- Power plant portfolio
  - realistic inter-temporal constraints (ramping, minimum capacity, minimum downtime)
  - Heat productions constraints (depending on power plant characteristics, the temperature and time of day)
- Storage dispatch (pumped hydro, compressed air)

→ Mixed Integer Linear Problem (MILP)

We have developed a cost-minimizing power plant dispatch model with a special representation of EVs in the model

- EVs act as an additional load
- 28 Load profiles
- EVs and PHEVs (with option to use conventional fuel)

Two charging options considered:

Decentral uncoordinated	Coordinated
Charging occurs when a car is connected to the grid and the battery is not full. • As fast as possible • No consideration of capacity shortage etc.	The timing of the charging activities is coordinated • Electricity price is considered • Result is system cost optimal timing

Further Data inputs into the model:

- 2 Time steps are analyzed: 2020 and 2030
  - power plant portfolio, development of renewable capacity, fuel- and CO_2-prices based on official government scenarios (reference scenarios B 2023 and B 2033 adjusted to fit to 2020, 2030): German Grid Development Plan (NEP) (50Hertz et al., 2013)

- Reference Year for time series patterns: 2012
  - Few electric vehicles in use (4.451 in January 2012 (Kraftfahrt-Bundesamt, 2012))
  - Load time series based on ENTSO-E (2013)
  - Renewable time series from TSO data

Fahrzeugnutzung in der Strommarktmodellierung - Nutzungsprofile

- Grundlage der Ableitung: MiD 2008
  - Repräsentativ für Deutschland
  - Verkehrsverhalten des Jahres 2008
- Differenzierung der Nutzung nach Größenklasse und Raumstruktur
  - Pkw – klein, mittel, groß
  - Kernstadt, Umland
- 28 Nutzungsprofile – Kombination von Tagesfahrprofilen
  - Fahrleistung/Energieverbrauch
  - Standorte/Ladeleistung
  - Standzeiten/Ladezeiten

We derive 11 calculations based on the DEFINE scenarios and the charging options :

Scenario and Year	No EVs	Scenario BAU		Scenario EM+	
		Uncoordinated charging	Coordinated charging	Uncoordinated charging	Coordinated charging
2010	x				
2020	x	x	x	x	x
2030	x	x	x	x	x

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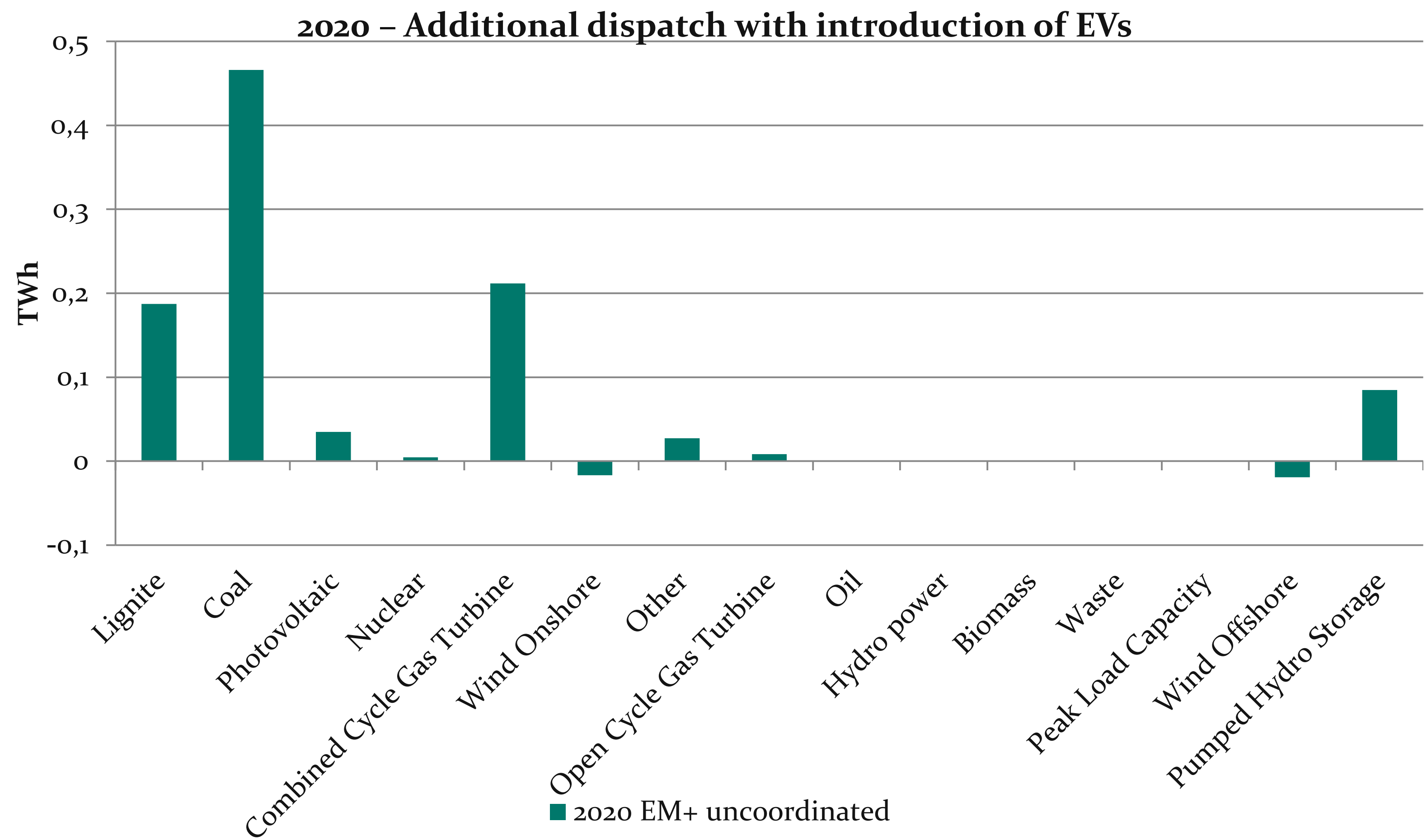
Results

- Additional energy need is small

Load increase	BAU	EM+
2020	+0.13%	+0.16%
2030	+1.23%	+1.60%

- Capacity needed can be large
  - Maximum charging capacity in EM^+ 2030:
    - 16.1 GW in the uncoordinated case
      - peak increases the already existing evening load peak
    - 13.1 GW in the coordinated case
      - Peak occurs at nighttime

- Additional energy is mainly provided by coal & gas plants



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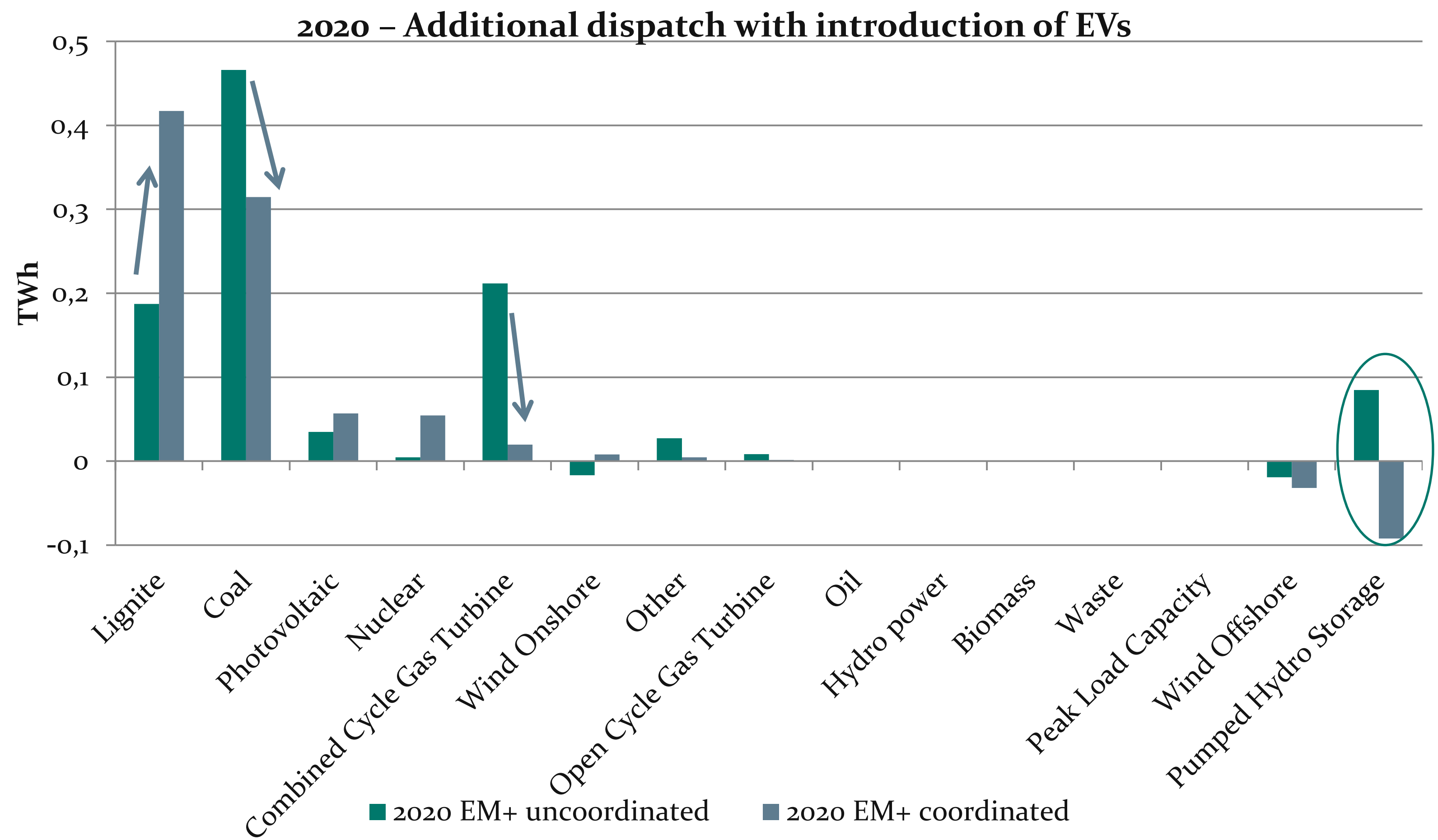
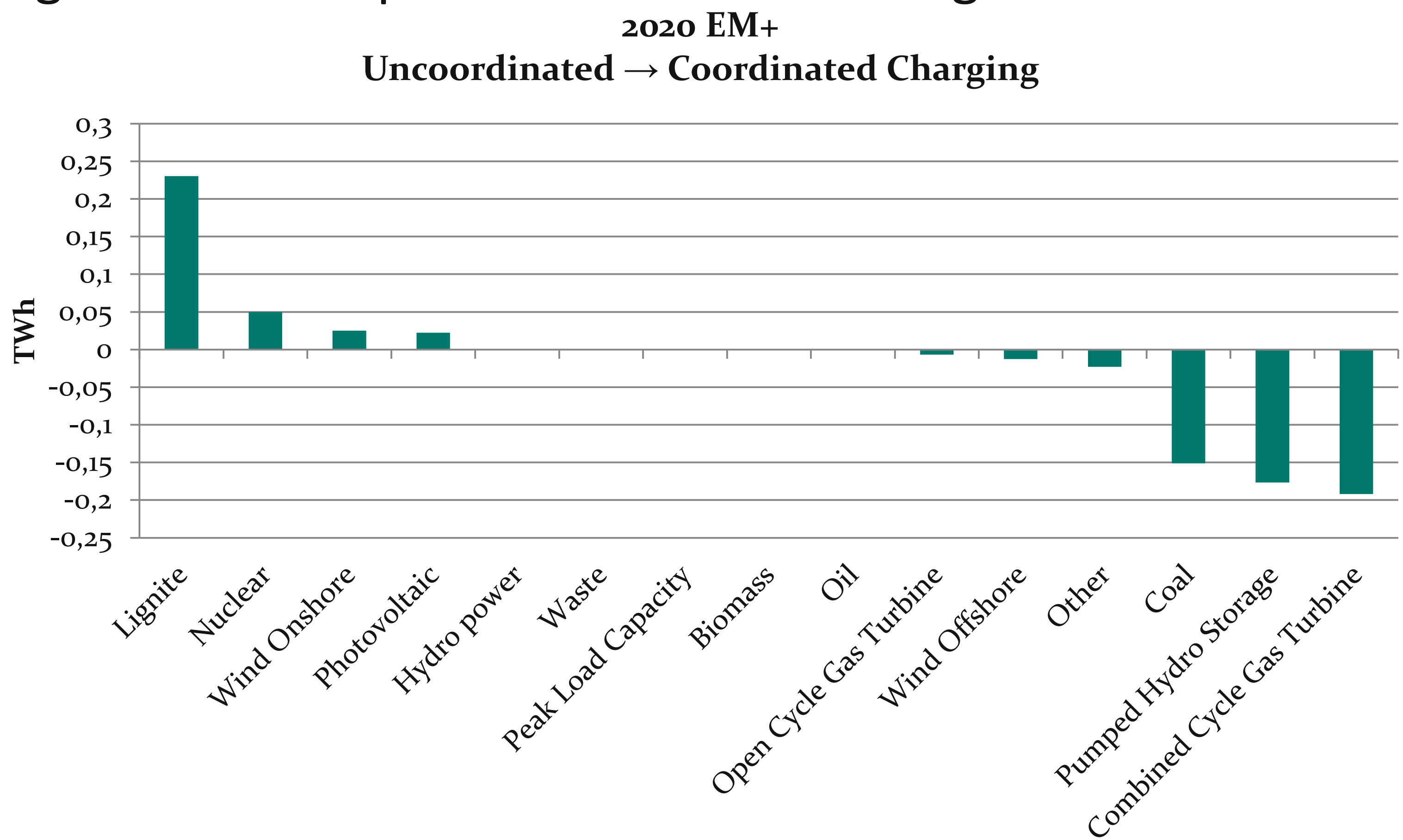
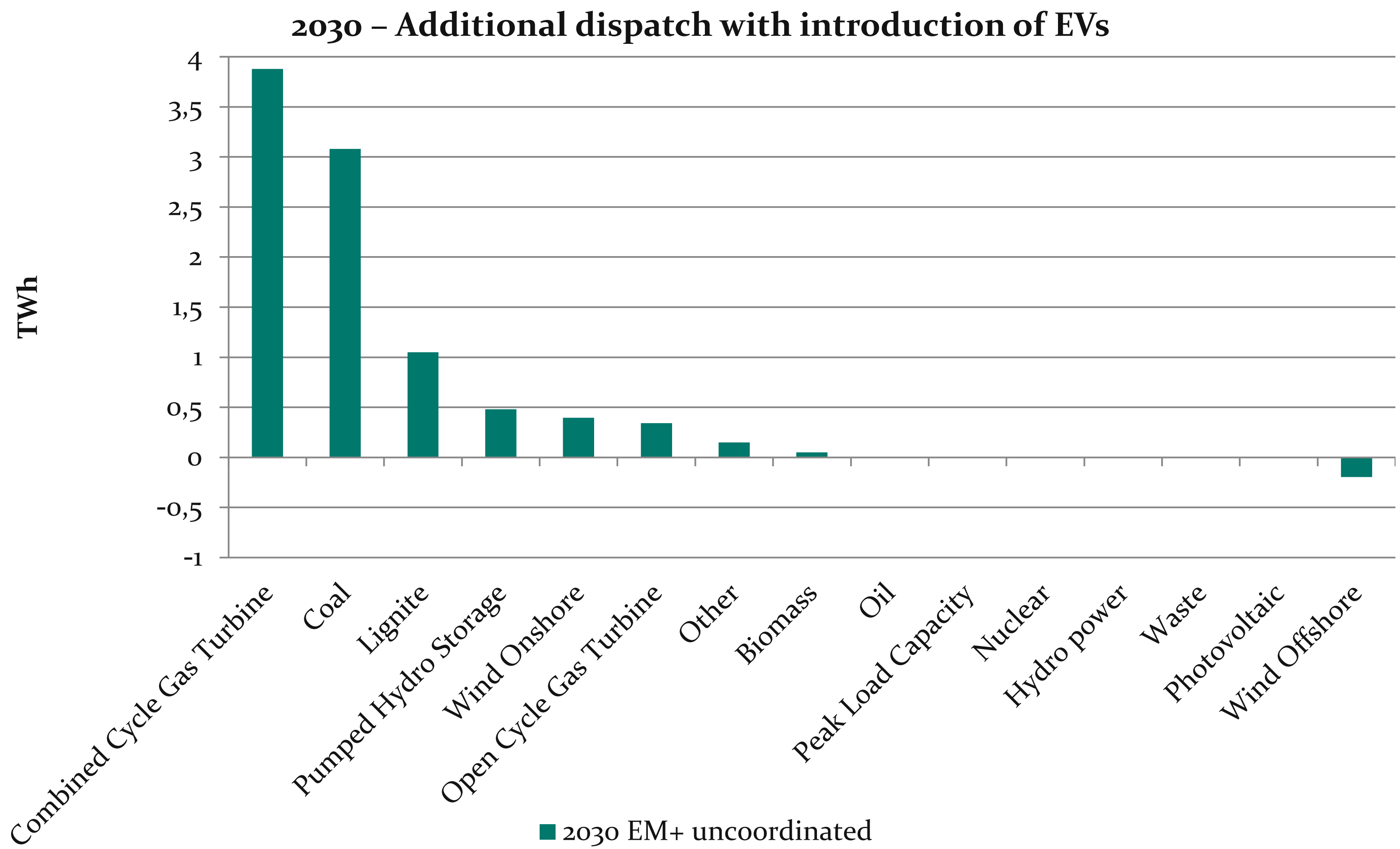


- Flexibility introduced by coordination shifts to cheaper generation dispatch and reduces storage demand



3 Results 2030 - Addditional load is mainly provided conventional power plants

- For 2030 similar results can be observed



3 Results 2030 - Coordinated charging provides flexibility in the electrictiy system

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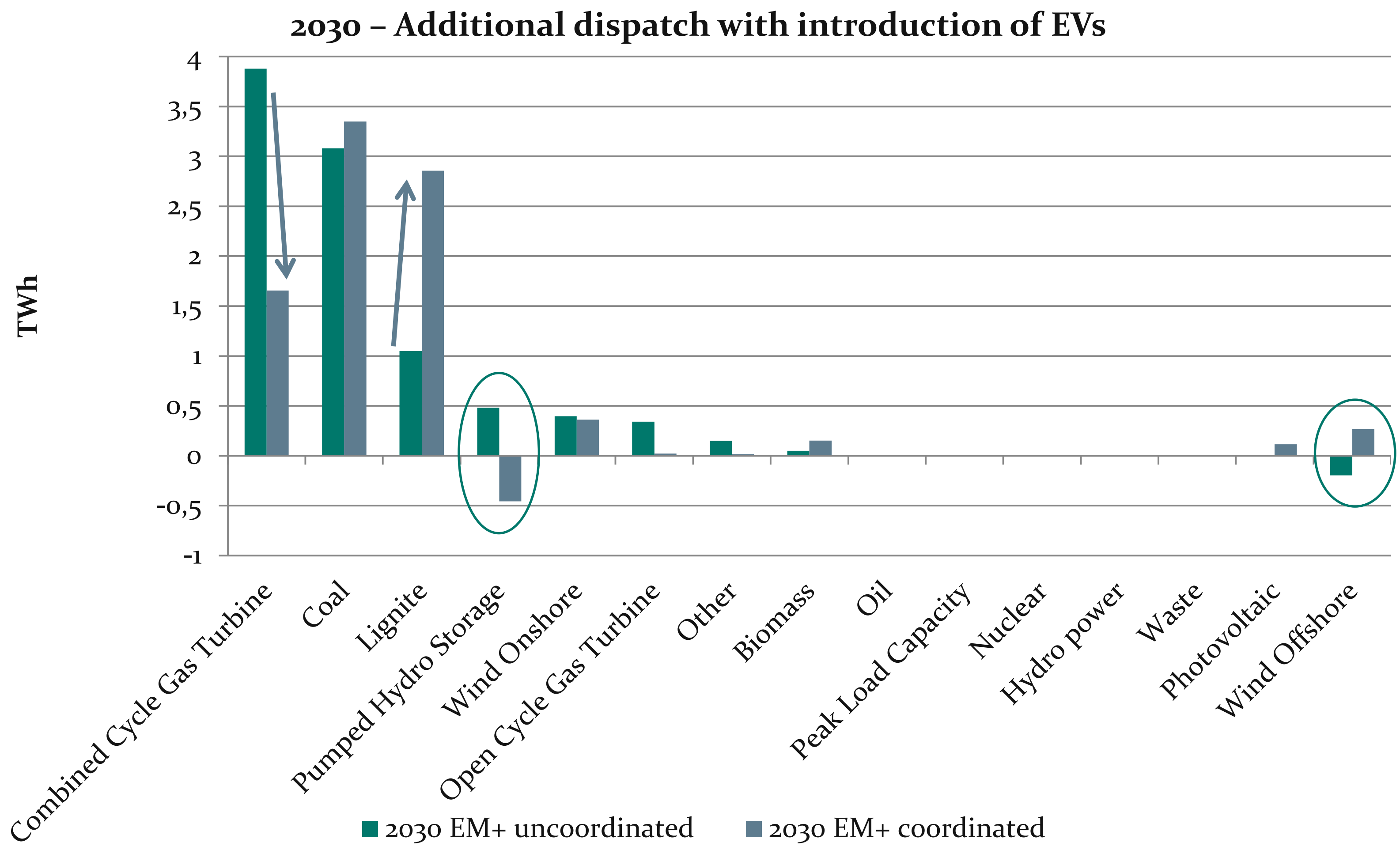
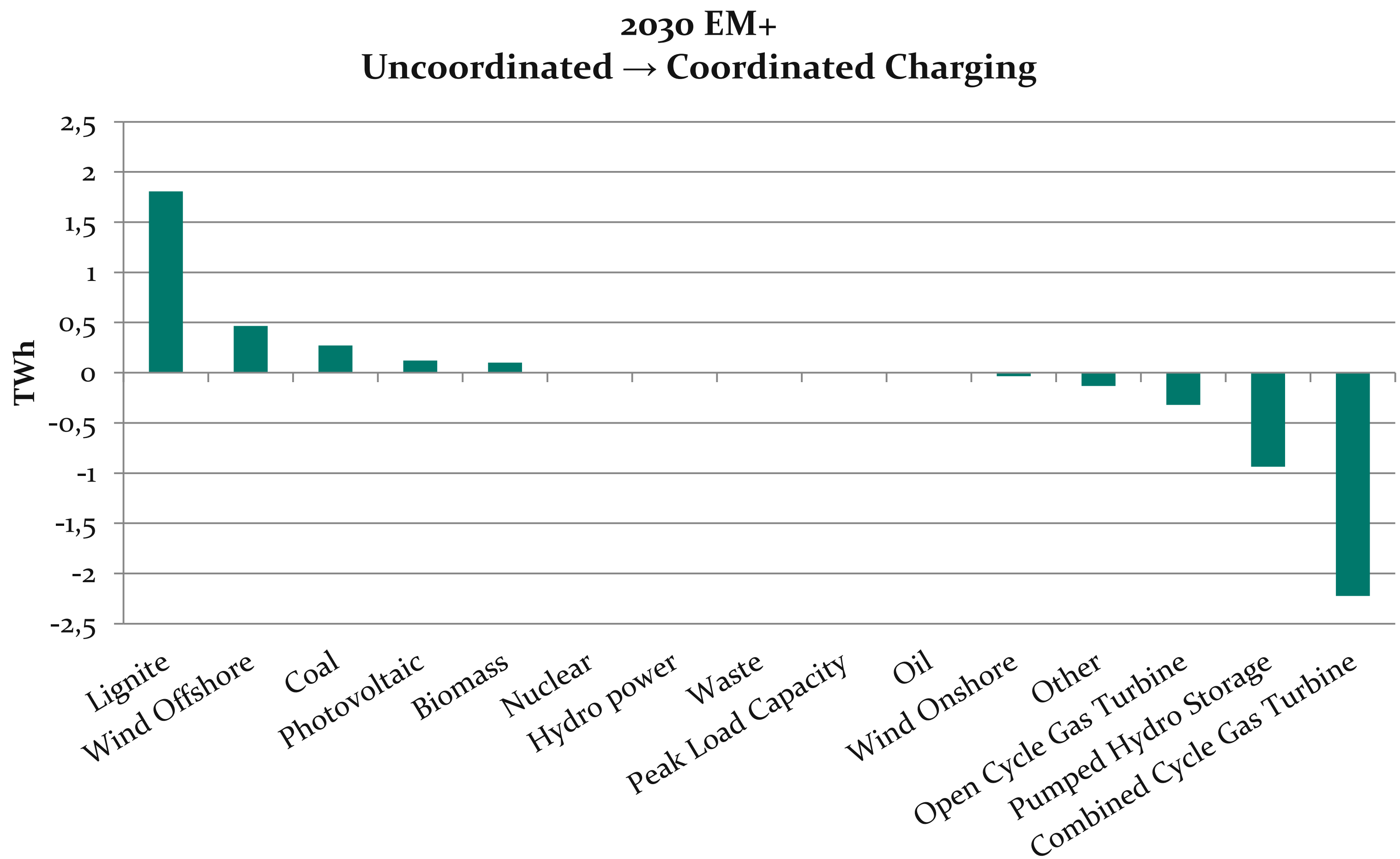


- Coordinated charging provides flexibility



DEFINE Development of an Evaluation Framework for the Introduction of Electromobility
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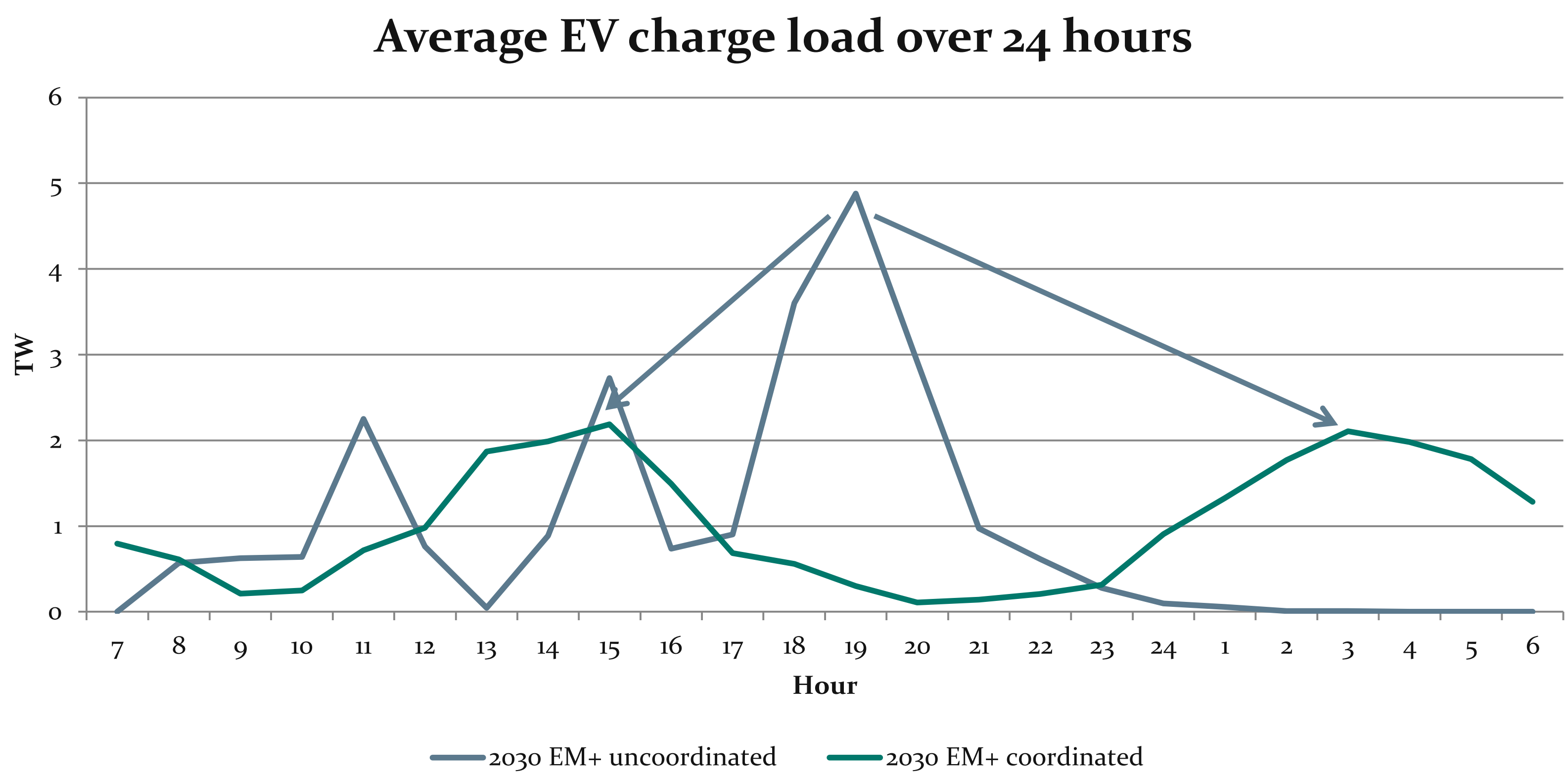
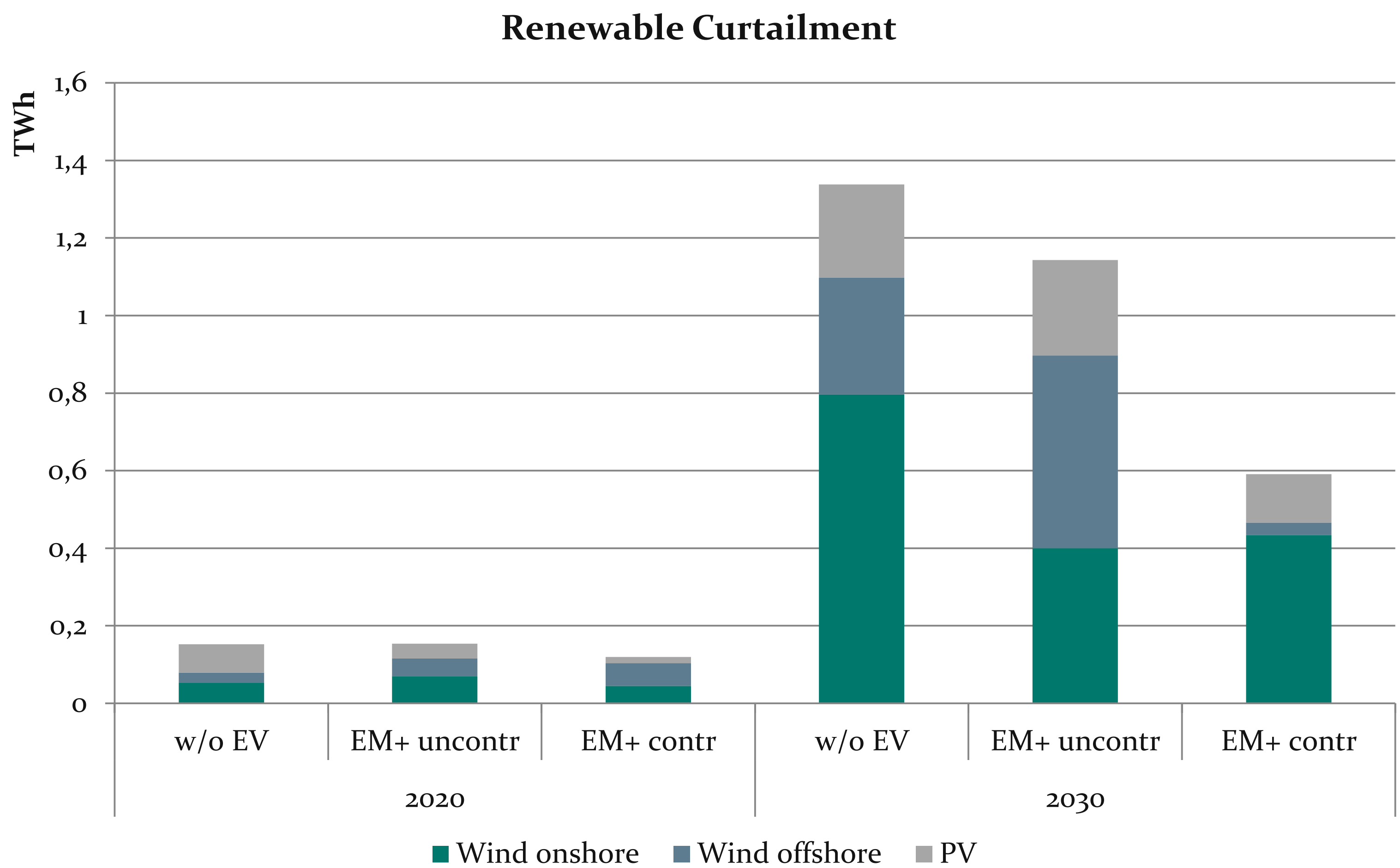
Coordination shifts loading activities towards

- Hours with solar availability
- Hours with low load (night)



Less Renewable Curtailment with controlled charging

- In 2030: Renewable Curtailment with EVs lower



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Conclusion

- Policy makers should make sure that electric vehicles are recharged in a controlled way
  - Avoiding a high peak system load.
  - Capacity adequacy concerns are already salient, even without the prospect of additional capacity needed to charge the EVs.
- Controlled charging leads to lower costs of vehicle loading compared to uncontrolled charging.
  - But: high CO_2-intensity of charging electricity in Germany.
  - This result is driven by the assumed power plant mix.
- Controlled charging will lead to little additional renewable integration
  - Policy makers should not overestimate these potentials.
- Possible measures:
  - Incentives for vehicle owners (e.g., cheaper tariffs at off-peak hours, access to real-time prices)
  - Regulation (requiring controlled charging infrastructure)

Vielen Dank für Ihre Aufmerksamkeit.

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