Low Carbon Ukraine

Policy advice on low-carbon policies for Ukraine

Policy Briefing #2

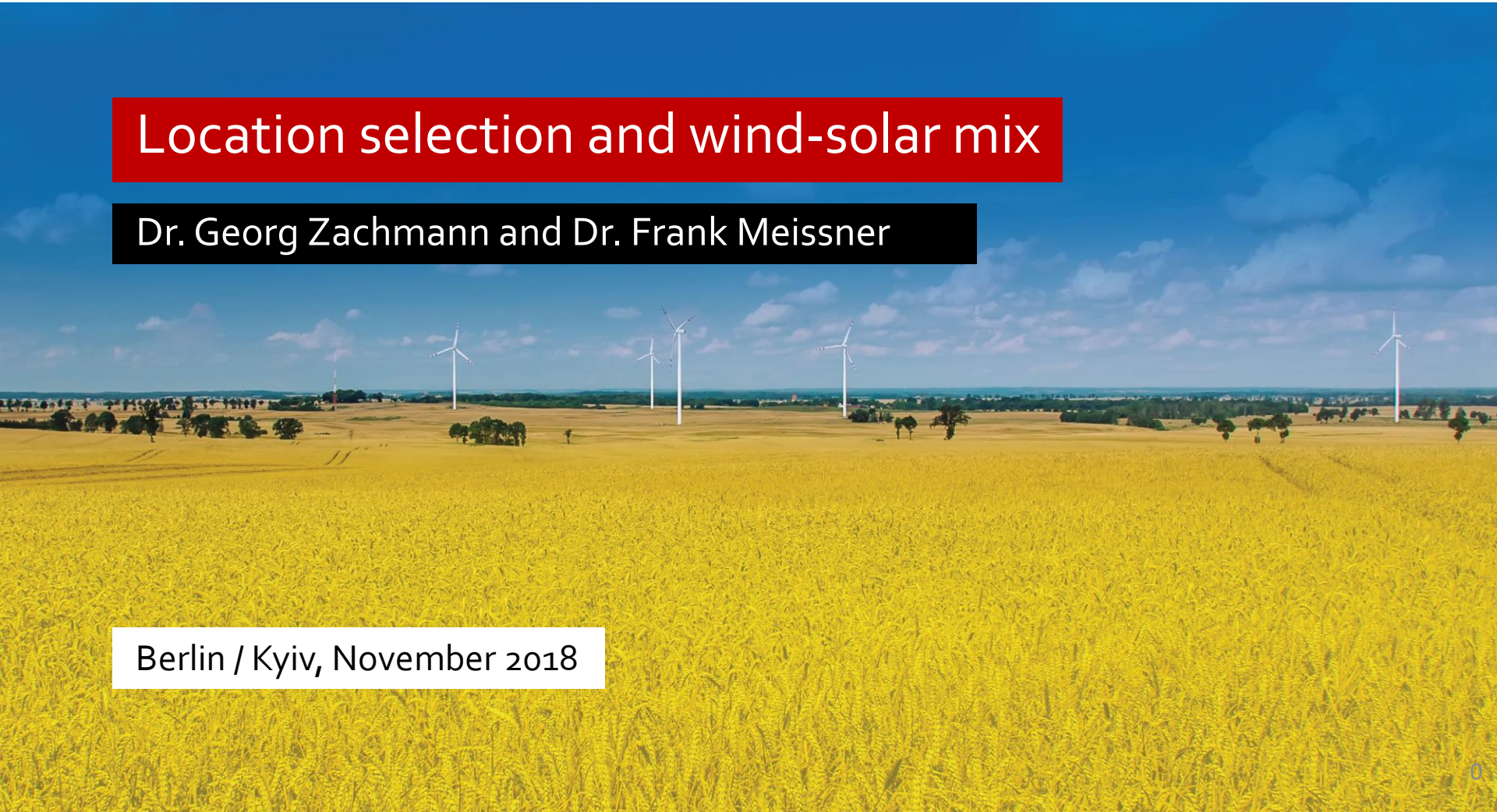
Supported by:

Federal Ministry for the Environment, Nature Conservation and Nuclear Safety

based on a decision of the German Bundestag

Location selection and wind-solar mix

Dr. Georg Zachmann and Dr. Frank Meissner



Berlin / Kyiv, November 2018

Low Carbon Ukraine

Key messages

- Wind and solar installations should be distributed over the country, and not only concentrated in the most sunny/windy locations

- Policy should strive for an optimal mix of wind and solar installations in order to reduce system cost

Low Carbon Ukraine

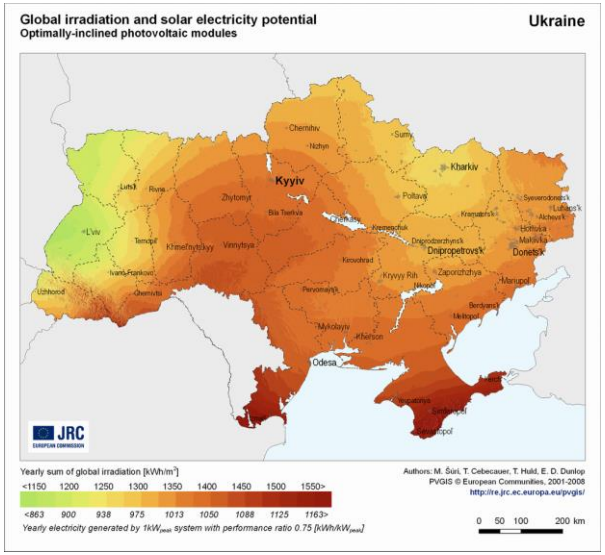
1. Optimal location selection

- Wind and solar power yields depend on fluctuating weather conditions
- Weather conditions – solar irradiation and wind – differ between regions
- Wind and solar day profiles typically differ

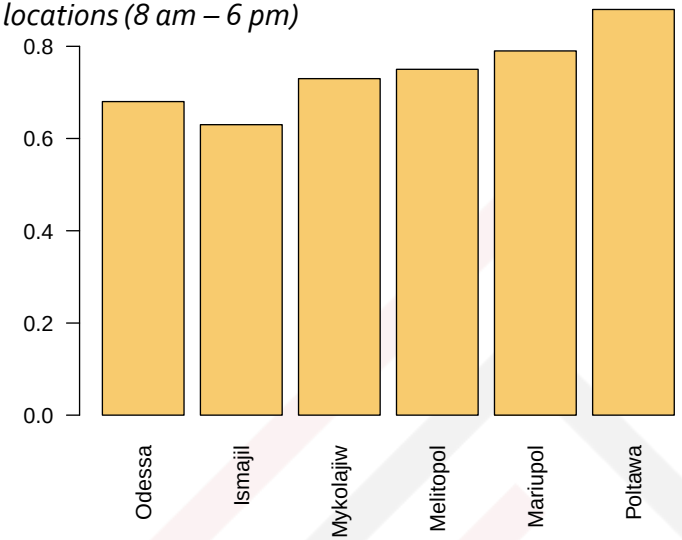
An optimal location selection enables a balancing within wind and solar generation across regions

Low Carbon Ukraine

1.1 Regional distribution of solar irradiation



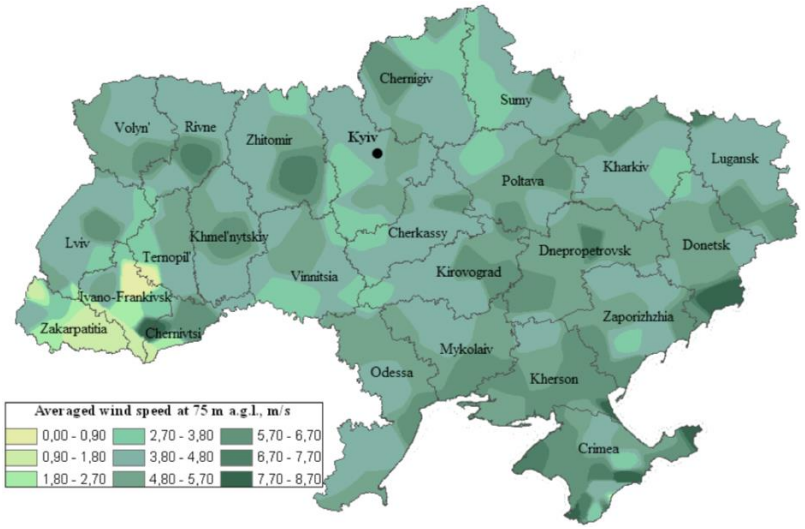
Correlation of solar irradiation between area Kharkiv and other locations (8 am – 6 pm)



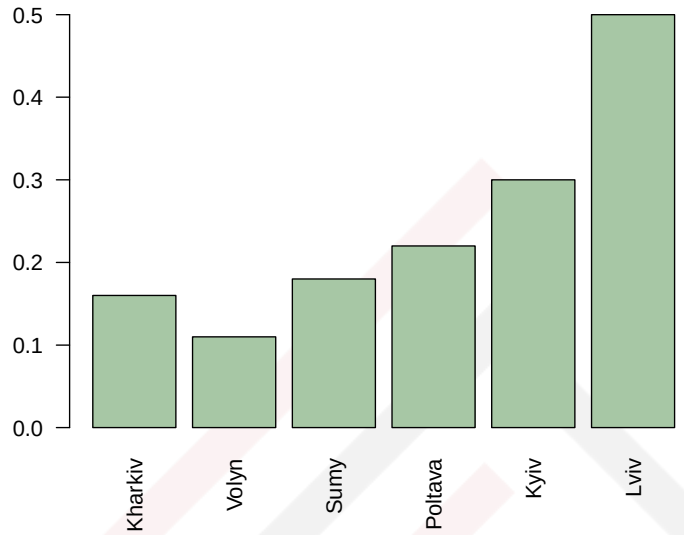
- Solar irradiation ranges between < 1.100 and >1.500 kW/m2
- Highest solar potential in south of Ukraine
- High correlations between regions - range 0.6 - 0.9 (8 am – 6 pm)
- High correlation hinder balancing between regional fluctuation PV-solar power generation

Low Carbon Ukraine

1.2 Regional distribution of wind speed



Correlation of wind speed between area Zakarpattia Oblast and other locations



- Average wind speed range from <1 up to 8.7 m/s
- Wind speed correlates less than solar irradiation between regions
- Correlations range between 0.11 [e.g. between Volyn and Zakarpattia] and 0.8 [e.g. between Poltava and Kirovohrad]
- Low correlation enables a balancing between regional wind power yields

Low Carbon Ukraine

1.3 Examples for an optimal location selection

Target

- Minimizing the curtailment losses through location selection
- Increasing the stability of the whole power system
- Minimizing the aggregated electricity generation costs

Constraints

- Installed capacity of wind and/or PV-solar
- Boundaries of conventional capacity electricity generation

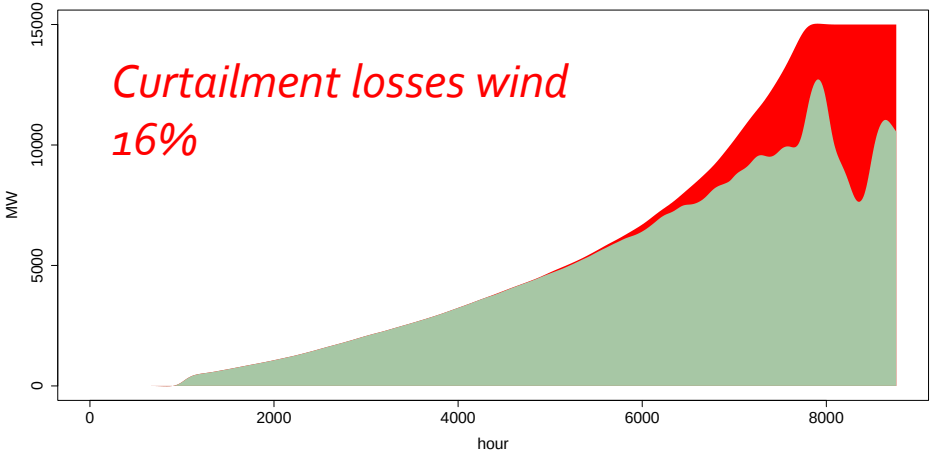
Model

Optimal dispatch model, Version 2.2

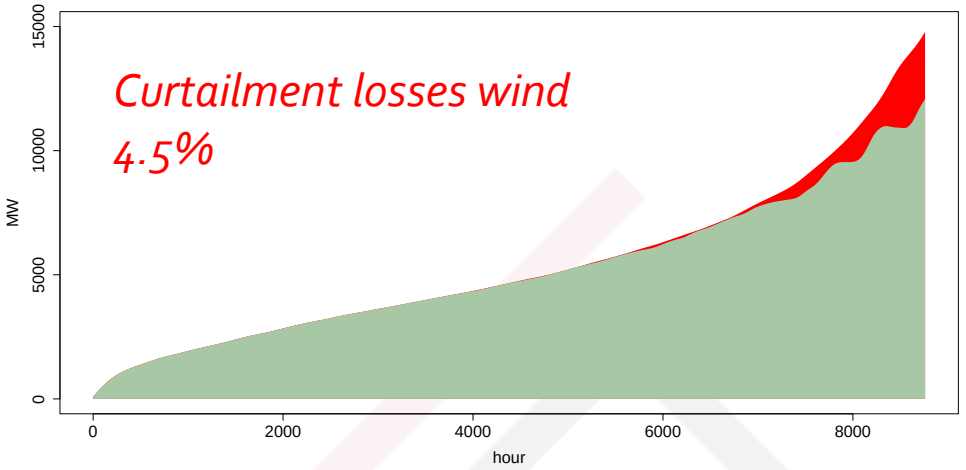
Low Carbon Ukraine

1.4 Examples for an optimal location selection

Installation at only **one** location



Even distribution of installations



Example: 15 GW wind, 0 GW PV-solar

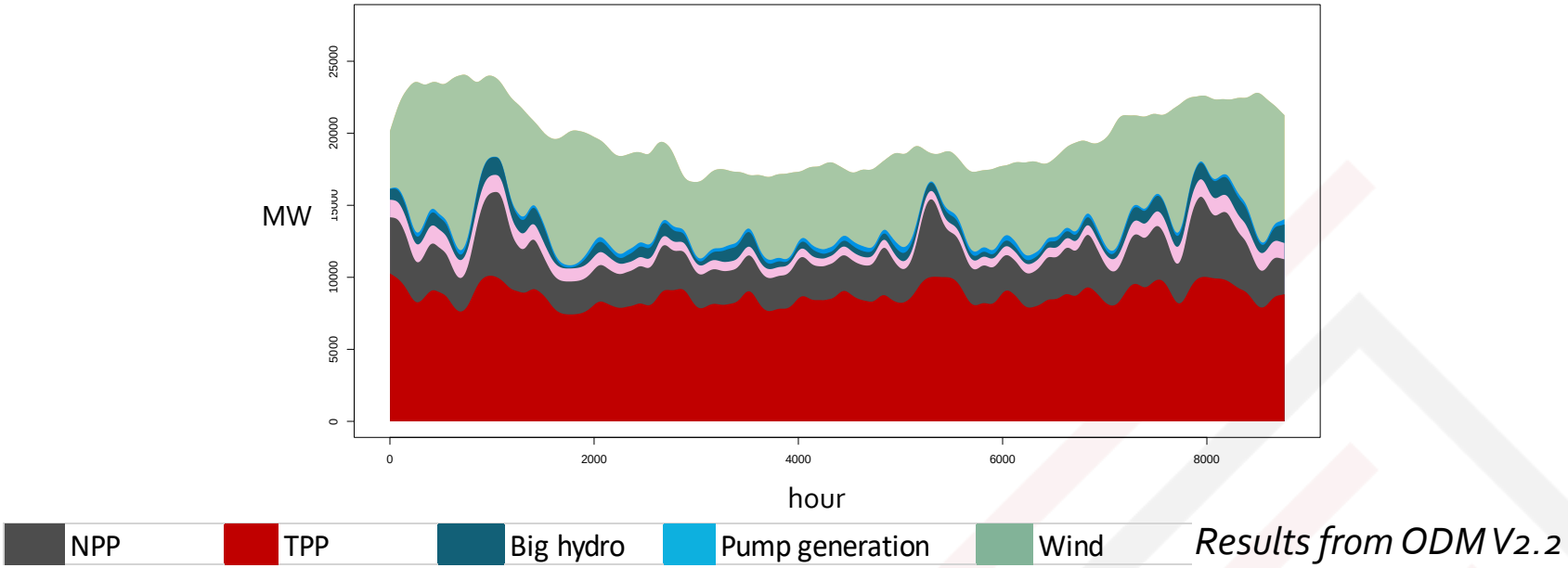
Results from ODM V2.2

Indicator	One location	Even distribution	Difference
Installed capacity	Wind: 15 GW PV-solar: 0 GW	Wind: 15 GW PV-solar: 0 GW	
Utilized RES	39 TWh	45 TWh	+ 6 TWh
GHG emission	44 Mt	38 Mt	- 6 Mt
Curtailment losses	16.5 %	4.5%	-12 percentage points

Low Carbon Ukraine

1.5 Optimal location selection

Electricity generation in 15 GW wind scenario – even distribution



Results from ODM V2.2

- An optimal location selection for wind (and solar) generation capacities increases the RES output, stabilizes the grid and reduces the need for other balancing options
- Optimal location will also have to take network topography into consideration [we plan to work on that]

2. Optimal wind-solar-mix

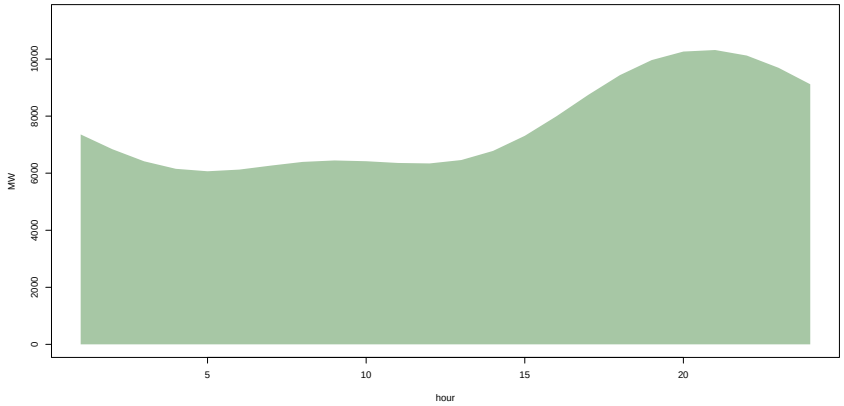
- CAPEX and OPEX of wind and solar differ
- Local value added of wind and solar differ
- Wind and solar power yields depend on fluctuating weather conditions
- Weather conditions – solar irradiation and wind – differ between regions
- Wind and solar day profiles typically differ

An optimal wind and solar mix helps reducing CAPEX and/or OPEX

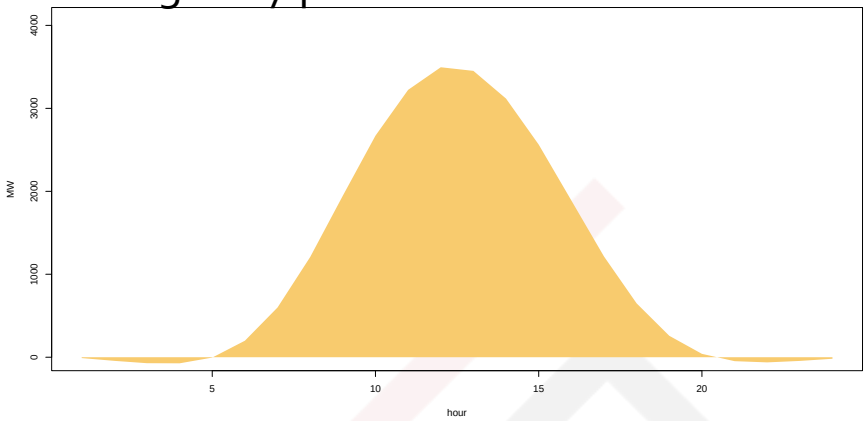
Low Carbon Ukraine

2.1 Day profiles of wind and solar

Average day profile wind



Average day profile PV-solar



- Average day profiles of wind and solar differ
- PV-solar has the peak around noon, average wind profile is quite flat
- With appropriate forecast: solar capacities can be used for covering increasing demand in the middle of the day and wind capacities for supplementing base load of fossil fuels
- **Wind and solar capacities can complement each other**
- The "optimal" wind-solar-mix depends on several determinants

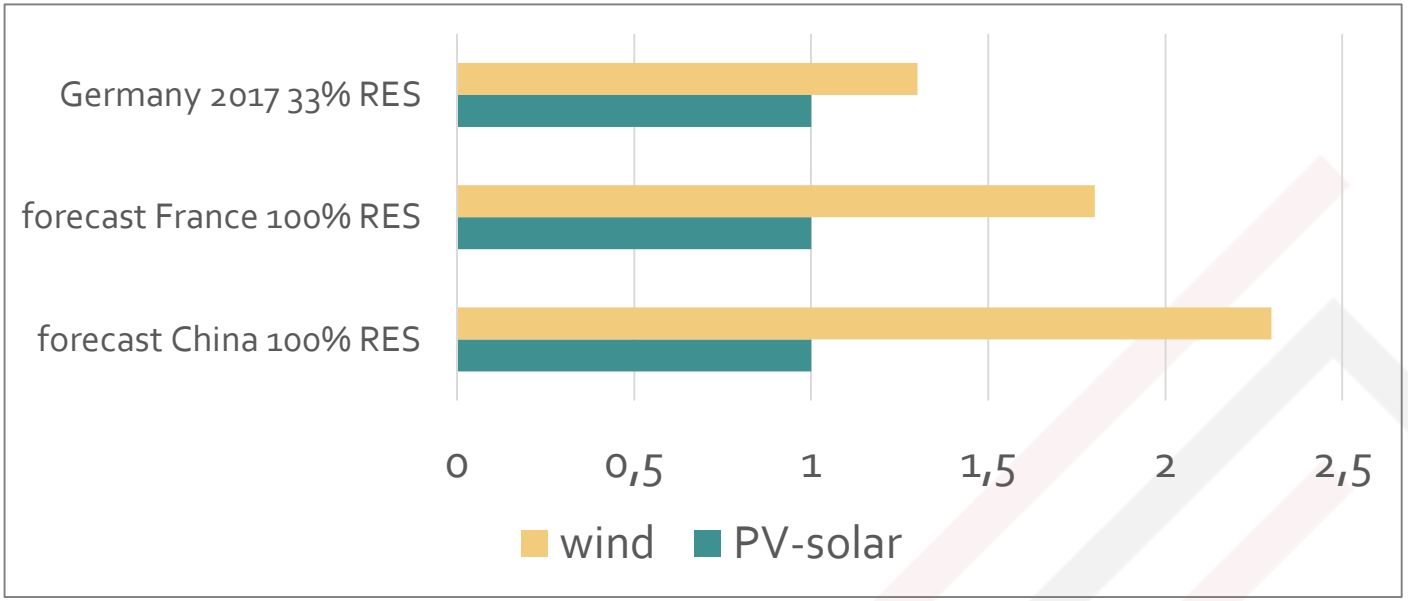
2.2 Determinants for an optimal wind-solar mix

- **Technological determinants:**
  - Electricity demand profile
  - Existing power plant park
  - Availability of storage capacities and int'l trade
  - Potential wind and solar yields
  - Detailed profile of wind-speed and solar-radiation
- **Economic determinants:**
  - Relative CAPEX of wind and PV-solar installations
- **Further determinants:**
  - Long-term RES targets
  - Various socio-economic and political targets

Low Carbon Ukraine

2.3 Examples from the literature

Wind-solar-mix (installed capacities) , discussed in literature



- In literature optimal wind:solar mix is in the range between 1.8 : 1 and 1.3 : 1
- Defining an optimal mix for Ukraine requires a specification of the target system e.g.:
  - Reducing CAPEX and increasing macroeconomic gains
  - Increasing RES share and decreasing power system costs

2.4 Mathematic optimisation of Ukraine's wind-solar mix

Target

- Minimizing the CAPEX for the aggregate of wind and solar
- Increasing the stability of the whole power system
- Minimizing the aggregated electricity generation costs

Constraints

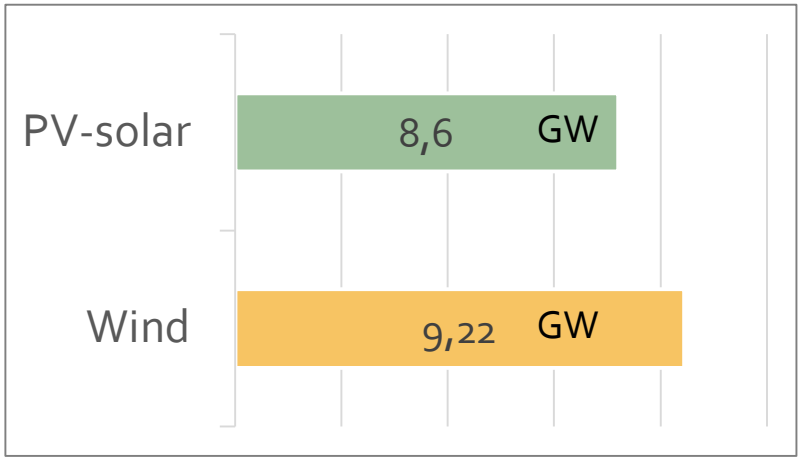
- Installed capacity of wind and/or solar
- Boundaries of conventional capacity electricity generation

Model

Optimal dispatch model, Version 2.3

Low Carbon Ukraine

2.5 An example on optimising Ukraine's wind-solar mix



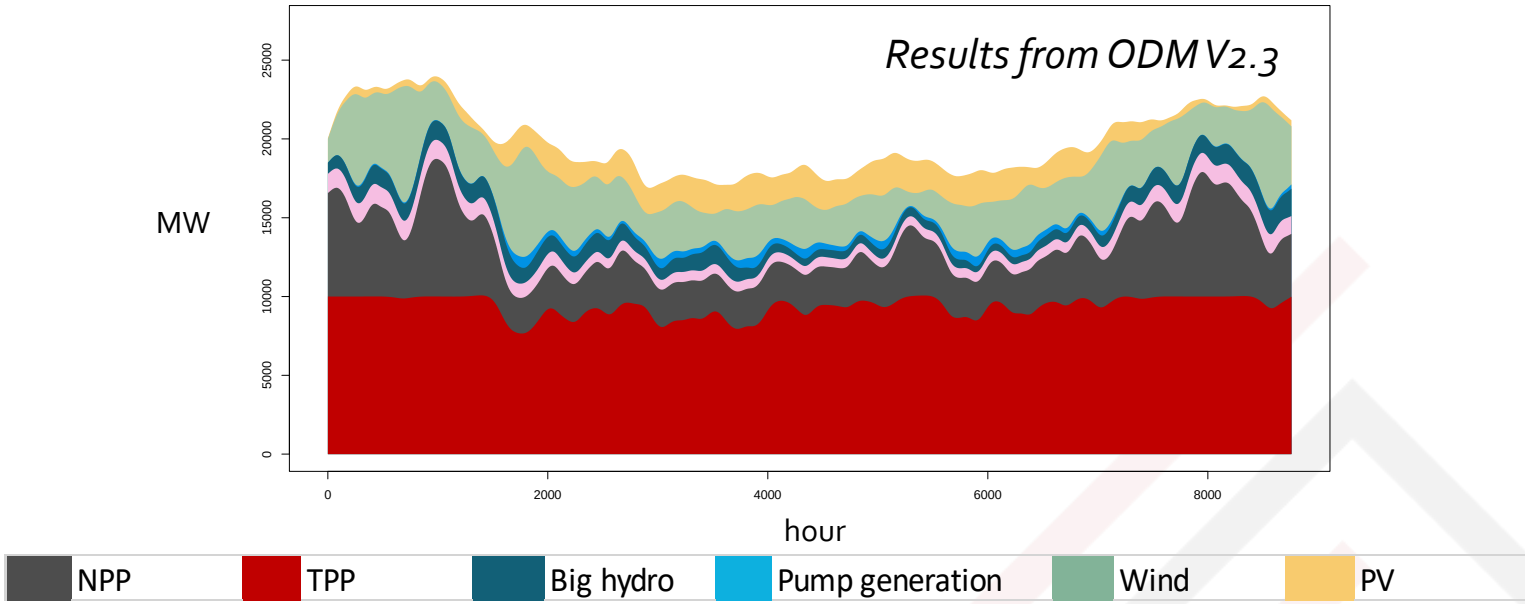
Results from ODM V2.3

Wind-solar mix is sensitive with respect To the relative wind/PV CAPEX and the relation of capacity factors

Constraints and parameters	
Electricity consumption	170 TWh
RES share	23%
Capex wind*	1,500 Euro/kW
Capex PV-solar*	600 Euro/kW

** Fraunhofer 2017 for Germany*

2.6 Optimal wind-solar-mix



- In our first approximation, the optimal wind-solar-mix in Ukraine would be in the order of **1 : 1.1**
- **Also in Ukraine a somewhat balanced mix of both technologies is advisable**
- Further research is needed to get robust results on the optimal mix

Low Carbon Ukraine

Policy advice on low-carbon policies for Ukraine

Supported by:

Federal Ministry
for the Environment, Nature Conservation
and Nuclear Safety

based on a decision of the German Bundestag

Implemented by:

Berlin Economics

Project Leader
Dr. Georg Zachmann
zachmann@berlin-economics.com

Consultant
Dr. Frank Meissner
meissner@berlin-economics.com

Tel.: 030 2064 34 64 – 0