

# Economic dynamic modeling of climate policy in Poland

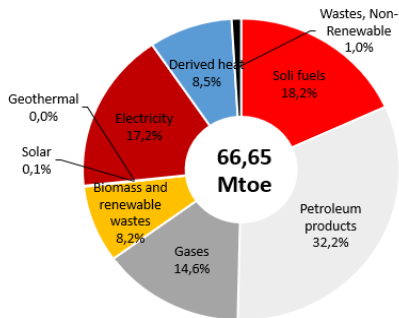
Emilia Lewczuk University of Warsaw  
Olga Kiuila University of Warsaw

sponsored by the National Science Center, Poland

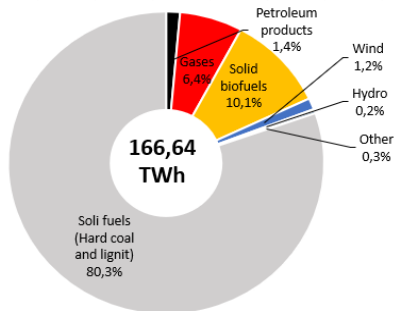
September 26, 2019

# The structure of energy carriers in Poland

Final energy consumption [Mtoe]



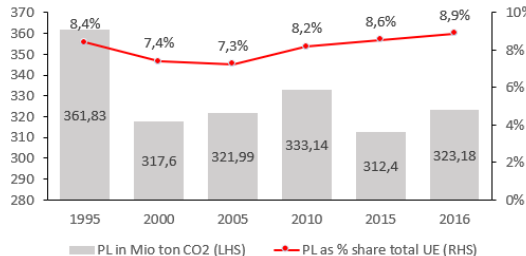
Gross electricity generation [TWh]



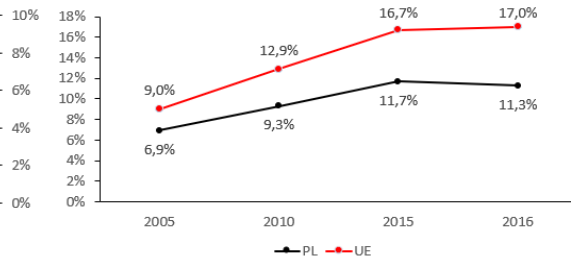
- Large dependence on coal from own deposits
- Large dependence on imports (25 perc.)
- Low share of renewable energy in gross final energy consumption
- Combustion of carbon-rich fossil fuel
- large CO<sub>2</sub> emission intensity - 0.9 vs 0.3 [kg CO<sub>2</sub> / EUR of GDP] for Poland vs EU

# Climate policy goals

## CO2 emission



## Share renewable energy in electricity production



# Model Overview 1

- Main elements:
  - fully dynamic model (based on Ramsey growth theory)
  - neoclassical CGE model (based on Walras theory)
  - bottom-up part for electricity production
  - small open economy calibrated to 2007
- 21 sectors:
  - 3 natural resources sectors (COAL, GAS, OIL) - they do not contribute to capital stock
  - 1 motor fuels sector
  - 3 energy sectors (ELEprod, ELEdist, HEAT)
  - 6 transportation sectors (CAR, VEH, CARserv, passenger and freight transport, other)
  - 8 other sectors

## Model Overview 2

- 5 actors types:
  - Representative HOUSEHOLD maximizes life-time utility from consumption and leisure s.t. lifetime budget constraint. They (i) rent labour to producers and (ii) sell capital to investors.
  - 21 PRODUCERS minimize annual costs of production using primary factors and intermediate inputs. Single product per producer.
  - Representative INVESTOR (i) transforms regular goods into future capital goods and (ii) supply current capital goods to producers (capital service).
  - Representative FOREIGNER (i) purchases exported products from Poland, (ii) provides imported goods to Poland, and (iii) supply fixed foreign savings.
  - GOVERNMENT (i) collects taxes, (ii) distributes revenues to firms and households, and (iii) covers current account deficit s.t. life-time balanced budget.

## Model Overview 3

- Bottom-up part
  - Decomposition of ELEprod. into 7 technologies (energy carriers)
    - coal, gas, oil, biomass, hydro, wind, other
    - capital, labor, and other inputs adjusted appropriately
  - Energy linkage:
    - electricity is supplied to a single distribution sector ELEdist. (monopson) which sells it to other agents
    - electricity enters production functions in industrial sectors directly (production factor) and indirectly (transport and building services)
    - electricity enters utility function through services: housing (directly), transport (directly), transportation service (indirectly)
    - energy balance per period

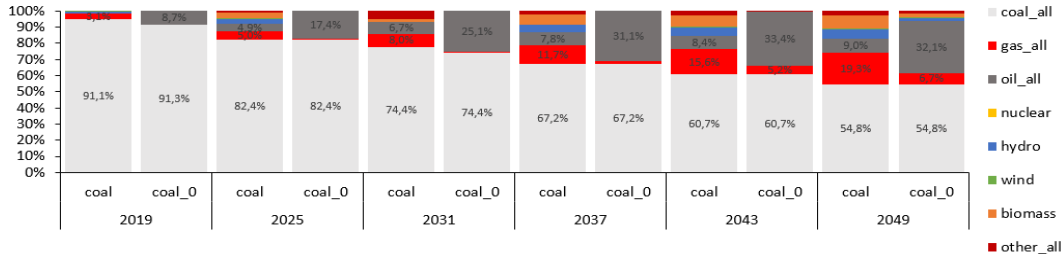
## Scenario description

The name of the scenario	Including CO2taxes	The limitations for coal electricity production	Free use of other energy resources	Other energy mix restrictions
<b>BAU</b>	YES	No limits (coal = 91%)	YES	NO
<b>coal</b>	YES	Fixed at 2019 level	YES	NO
<b>coal_0</b>	NO	Fixed at 2019 level	YES	NO
<b>mix_biomass</b>	YES	Exogenous decrease in 2024 and 2030	NO	Exogenous increase of biomass-based electricity to rich 18% in 2030
<b>mix_wind</b>	YES	Exogenous decrease in 2024 and 2030	NO	Exogenous increase of biomass-based electricity to rich 18% in 2030

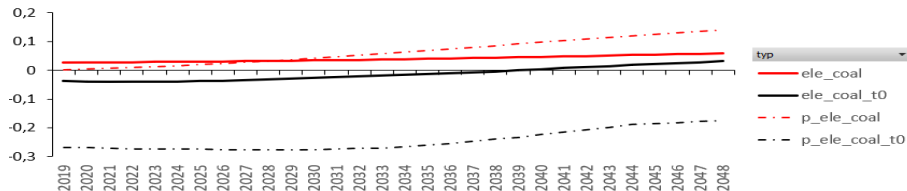
- annual economic growth is 1%
- CO2 tax is 18 EUR/t
- equal yield constraint for public budget (except scenario coal\_0)
- benchmark energy mix for ELEprod: 91% coal, 3% gas, 2% oil, 2% biomass, 1% hydro, 0.3% wind, and 0.9% other

# Electricity market results

## Energy mix



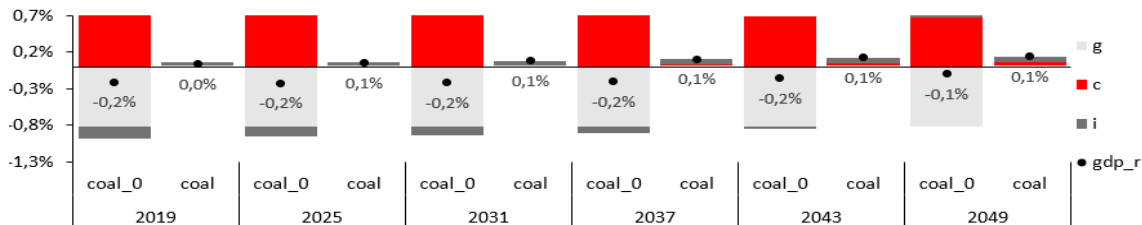
## Electricity production and price index (% changes wrt. BAU)



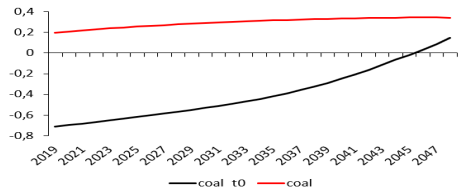


# Macroeconomics results

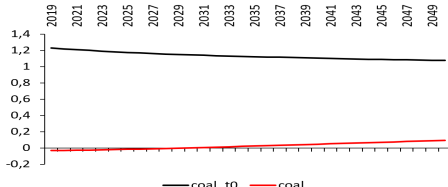
Real GDP, private and public consumption, investments (% changes wrt. BAU)



Investments (% changes wrt. BAU)

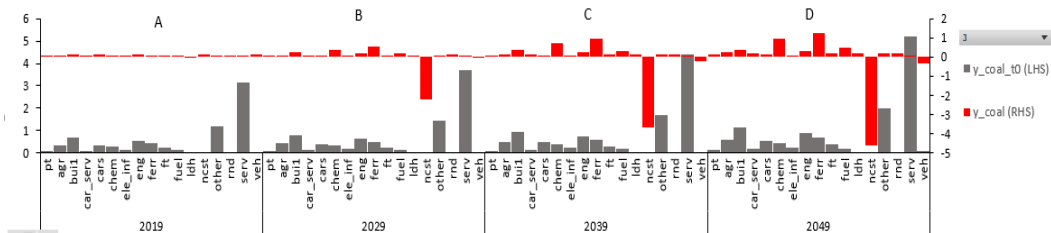


Private consumption (% changes wrt. BAU)

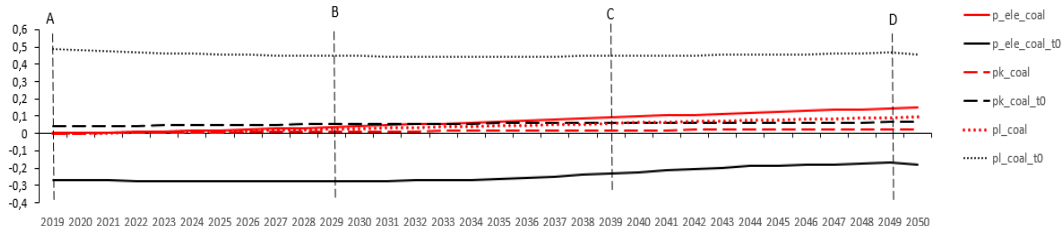


# Industries results

## Industries production (% changes wrt. BAU)



## Primary factors price index (% changes wrt. BAU)

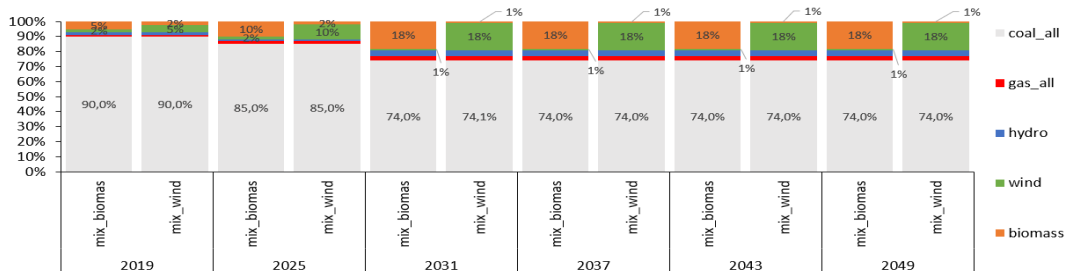


## Scenario description (renewables)

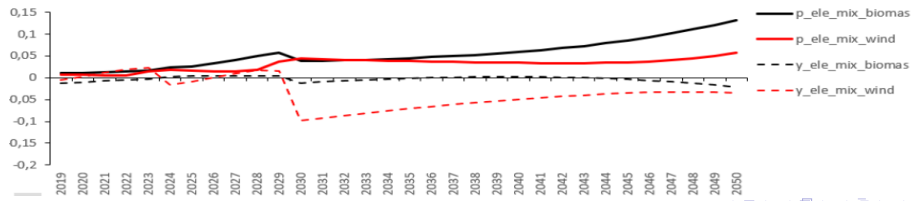
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# Electricity market results

## Energy mix

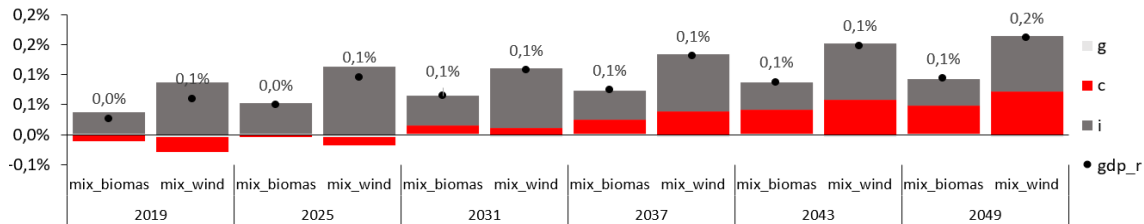


## Electricity production and price index (% changes wrt. BAU)

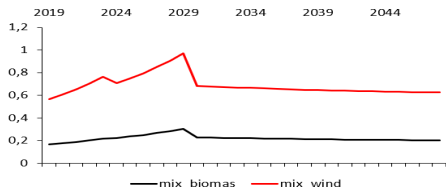


# Macroeconomics results

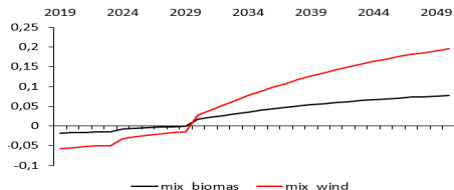
Real GDP, private and public consumption, investments (% changes wrt. BAU)



Investments (% changes wrt. BAU)

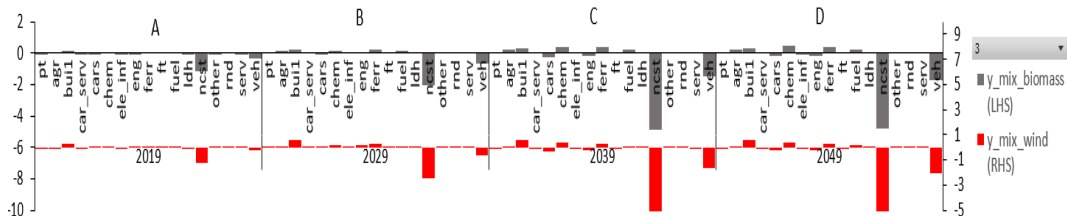


Private consumption (% changes wrt. BAU)

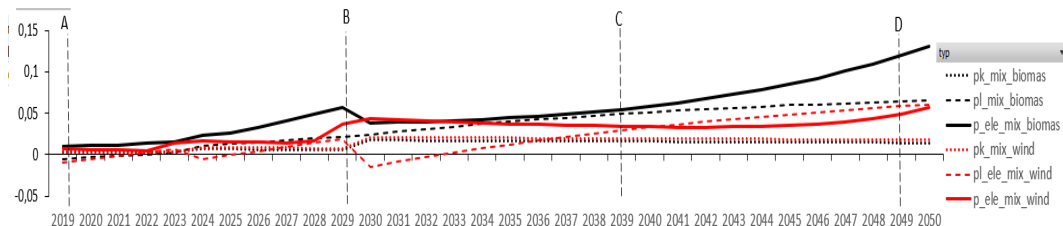


# Industries results

Industries production (percents changes vs. BAU)



Primary factors price index (percents changes vs. BAU)



# Conclusions

- Positive economic growth is possible with realistic energy mix, but it will not offer considerable emission reduction required by the European Commission. In the short time horizon, the best renewable energy sources should be indicated by less capital-intensive technologies (like biomass). In a long time horizon, more capital-intensive technologies (like wind turbines) will be better choice for economic growth.
- Carbon tax plays crucial role in optimal energy mix targets, since its elimination *ceteris paribus* implies negative economic growth.
- Besides power generation, reforms in transportation sector might be also an option. Our results suggest that 50% reduction in tax rate on retail electricity will require to increase tax rate on retail motor fuels by 60% in order to keep equal yield constraint for the public budget.
- Decarbonisation of the economy can be achieved directly through CO<sub>2</sub> emission limits. Gradual emission reduction up to 30% in 2050 wrt. BAU scenario has negative effect on GDP no matter equal yield constraint distribution (lump-sum, labor, capital, VAT). The least negative result offers labor tax recycling. If in addition we will implement the reasonable energy mix the effect will be even worse. The only solution is considerable technological progress.