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# **A CGE Analysis of Energy Policies Considering Labor Market Imperfections and Technology Specifications**

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## Outline

1. Employment, Environment and Energy Policy
2. Basic Model Structure
3. Disaggregating Labor by Qualification
4. Modeling Imperfect Labor Markets
5. Modeling Generation Technologies
6. Exemplary Application
7. Conclusion and Prospects

## Motivation: Employment, Environment, Energy

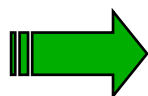
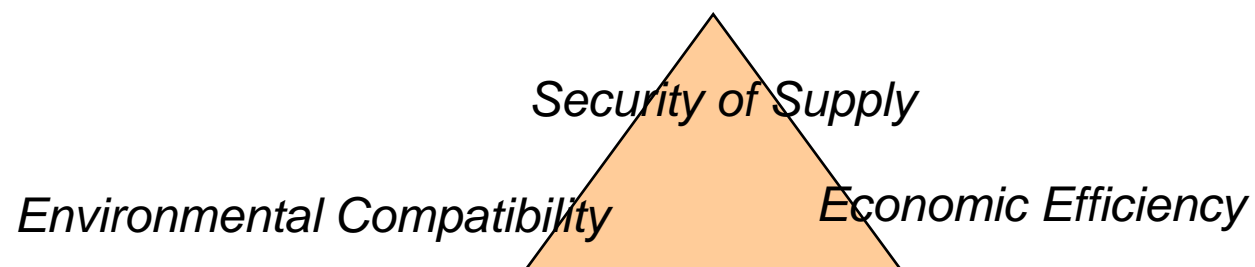
### Sustainability

ecology

economy

social

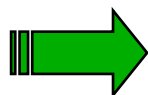
### Energy Policy



Energy policy strongly determines sustainable development

Energy policy is technology related

Modeling necessity: Technological detail → **Technology specifications**

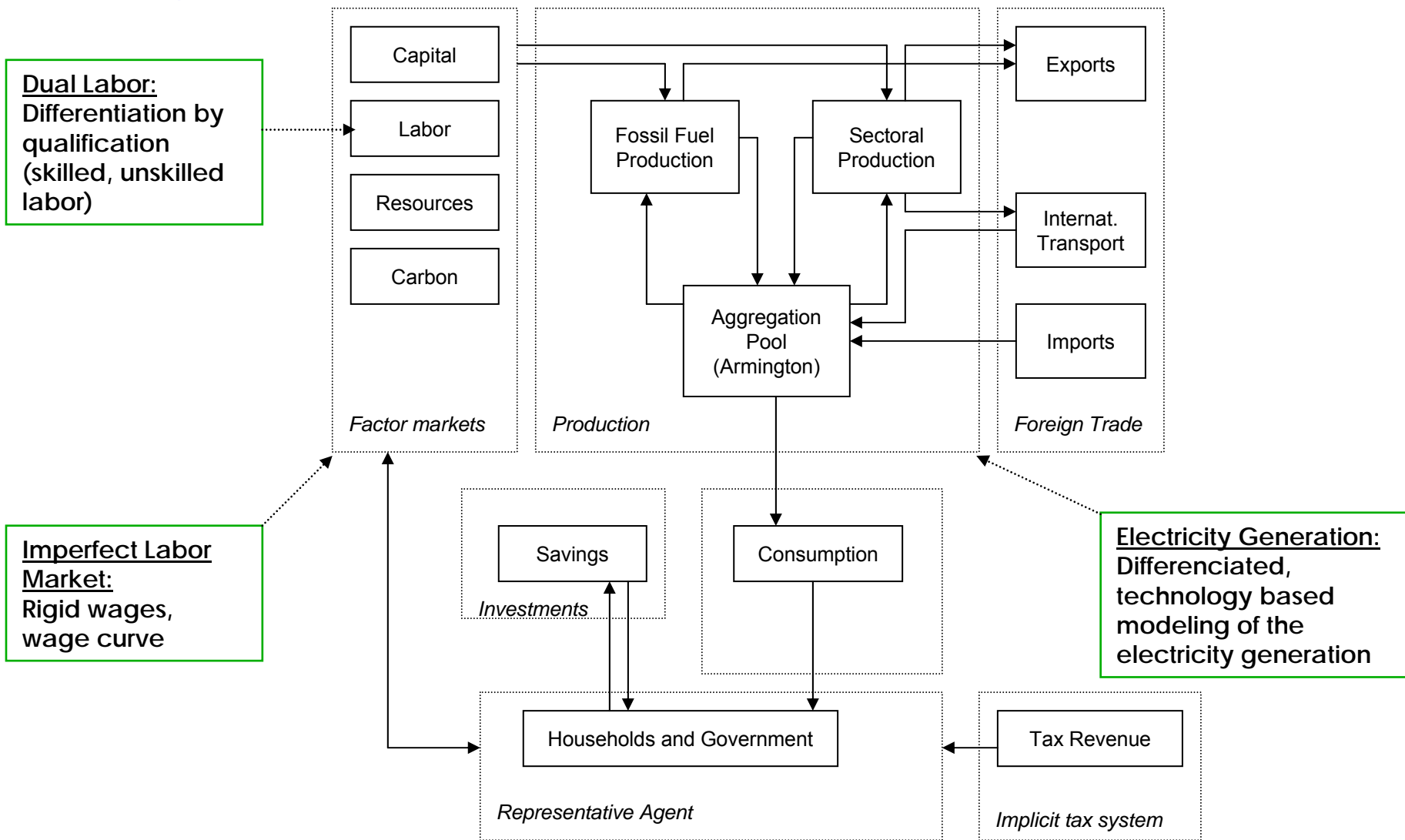


Unemployment is part of social facet of sustainability

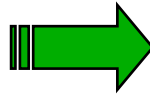
Employment is affected by economic efficiency of energy policy

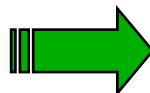
Modeling necessity: Labor market detail → **Labor specifications**

# Modeling the Circular Flow Economy




## Selected Model Characteristics

 Data base: GTAP 6 (2005), Base year 2001

 Regions: 10 (DEU, OEU, NEU, EAB, RUS, RAB, REJ, OPE, CHI, ROW)

 Sectors: 13 industry and service sectors

Energy		Non-energy	
Coal	COL	Chemical, plastic products	CHM
Natural Gas	GAS	Machinery and equipment	MAC
Crude Oil	CRU	Construction	BUIL
Petroleum	OIL	Transport Industries	TRN
Electricity	ELE	Agriculture and forestry	AGR
		Paper products and printing	PPP
		Iron and steel	I_S
		Other goods and manufactures	Y

 Dynamics: Recursive-dynamic, 5 year steps, time horizon 2030.  
Growth drivers: Labor productivity, investments, technological progress (AEEI)

## Heterogeneous Labor

Skilled – unskilled differentiation based on occupational categories. GTAP6 provides data on labor by occupation.

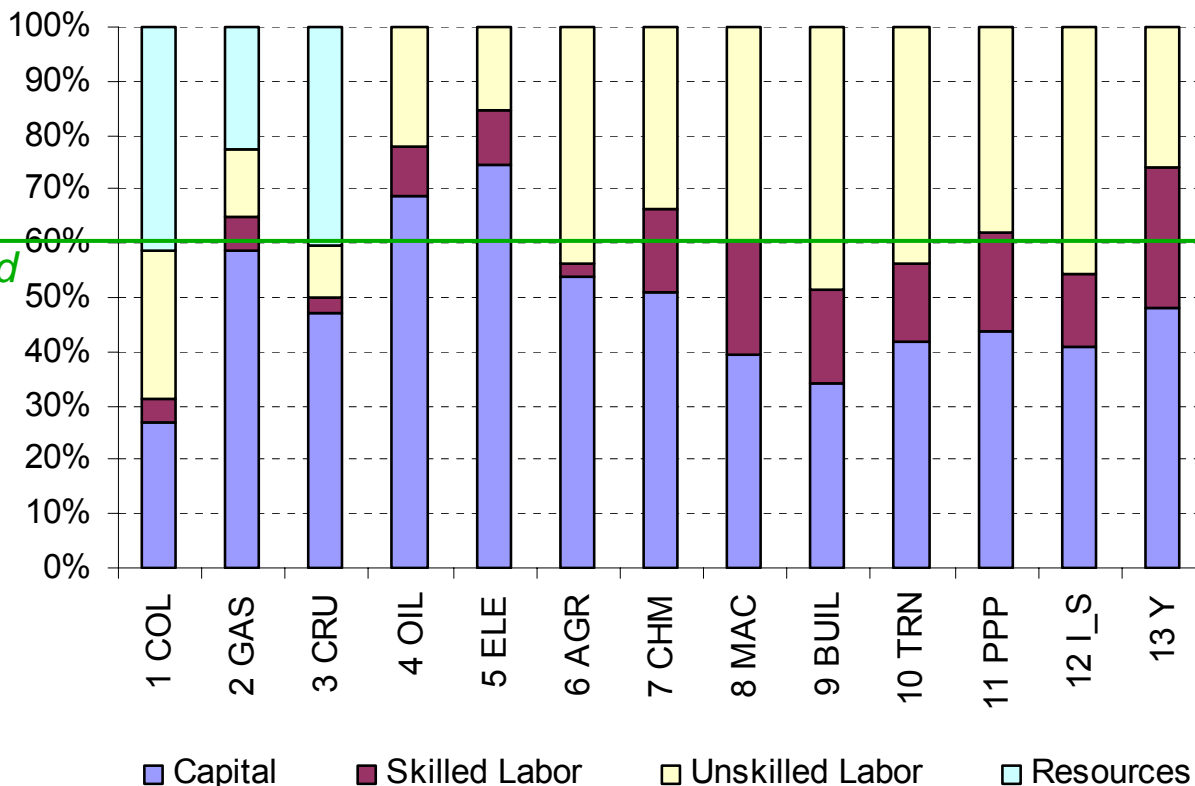
Modification of *Value Added* in CES production nesting structure

1. Single Primary Factor Nest
2. Direct Labor Substitutability
3. Capital Skill Complementarity

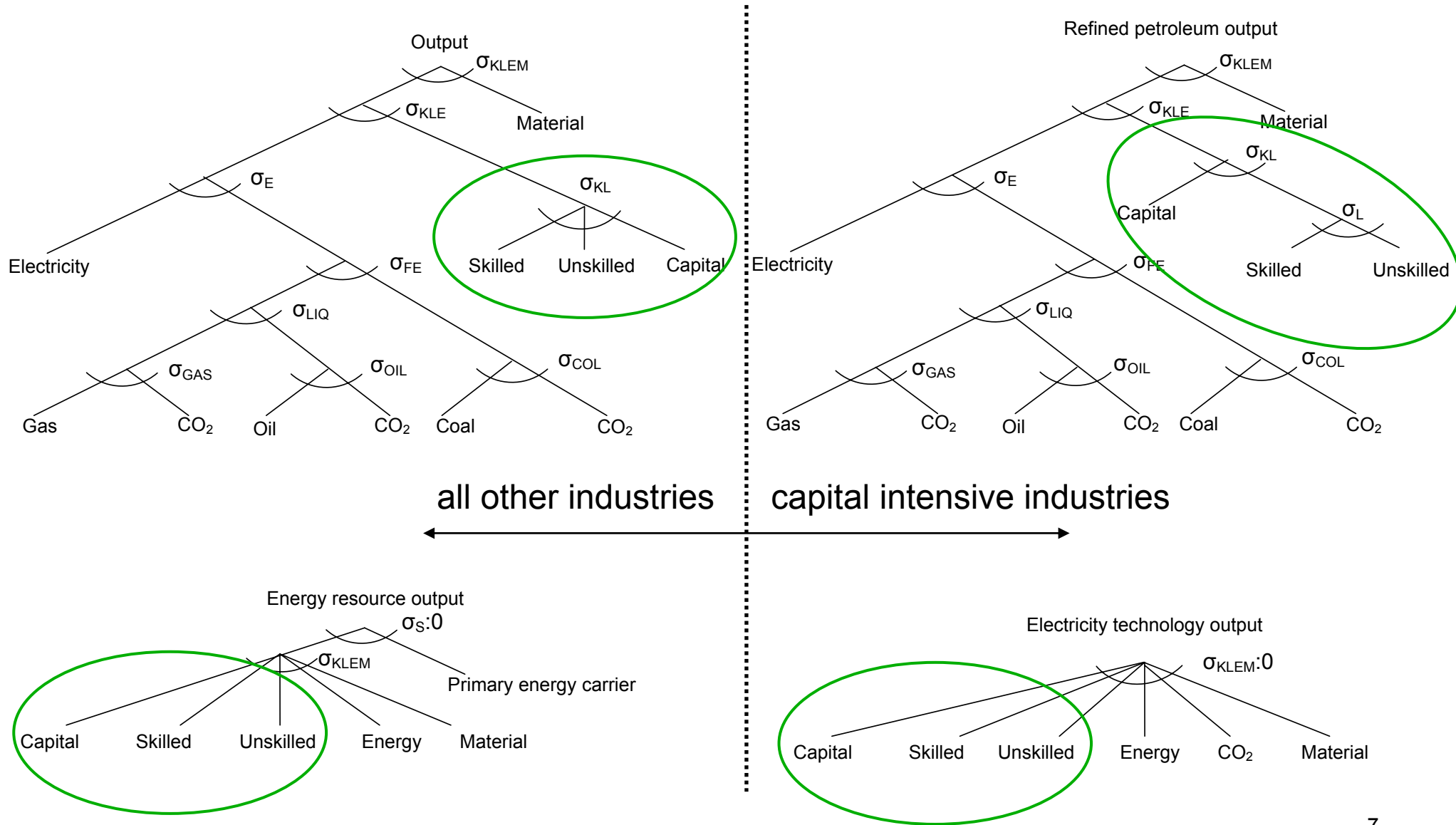
*capital intensity threshold*

Assumption:

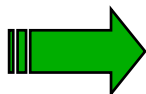
Capital intensity of an industry determines separability and degree of substitutability and hence nesting structure



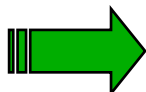
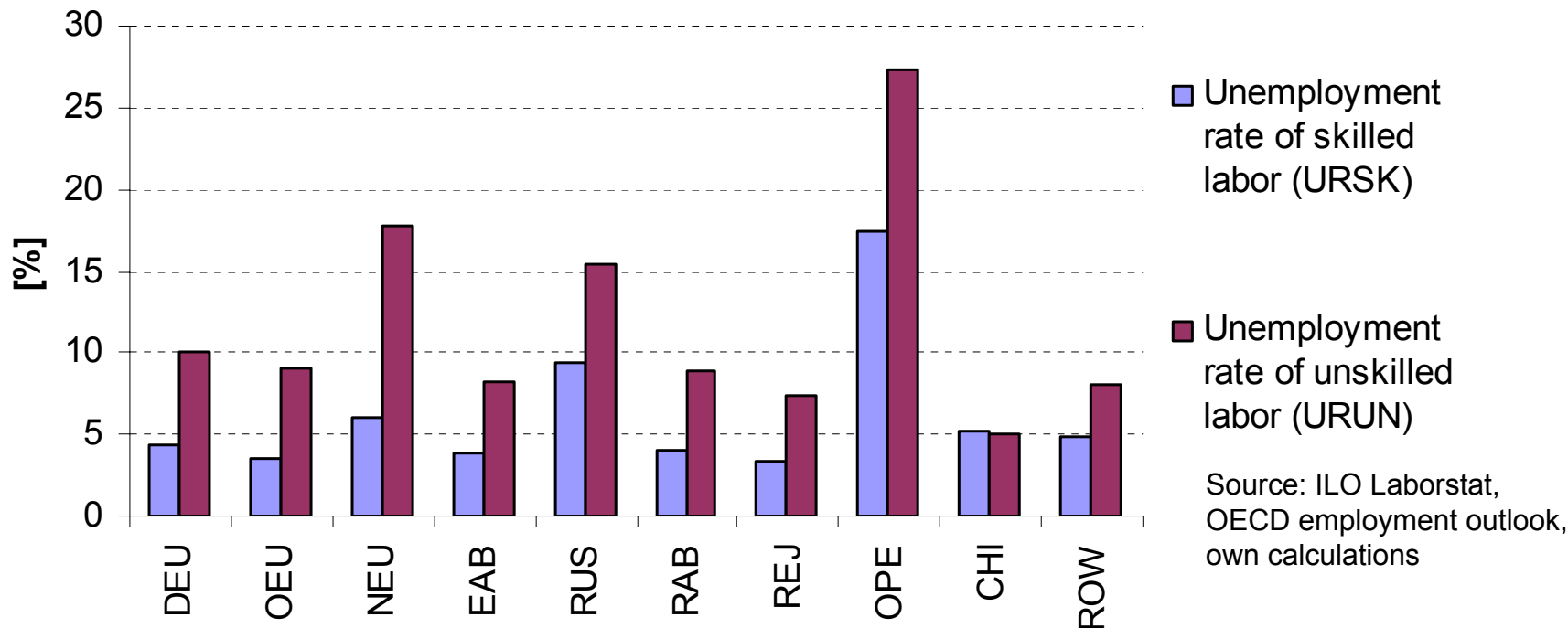
# Production Functions with Heterogeneous Labor



# Modeling Unemployment

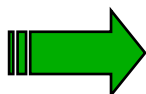


Reality: Labor markets are not cleared



Model: Equilibrium condition market clearance

$$supply - demand \geq 0, p \geq 0, p^T (supply - demand) = 0$$

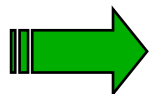


Implications:

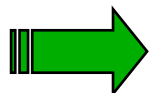
1. Take into account unemployment in BMK  $LS^* = (1 + UR)LS$
2. Suspend axiom of flexible prices



## Modeling Unemployment: Minimum Wage



Arrow-Debreu economy: Real wage equals marginal productivity



Downward rigid wages induce classical unemployment if wage > productivity

*Example:*

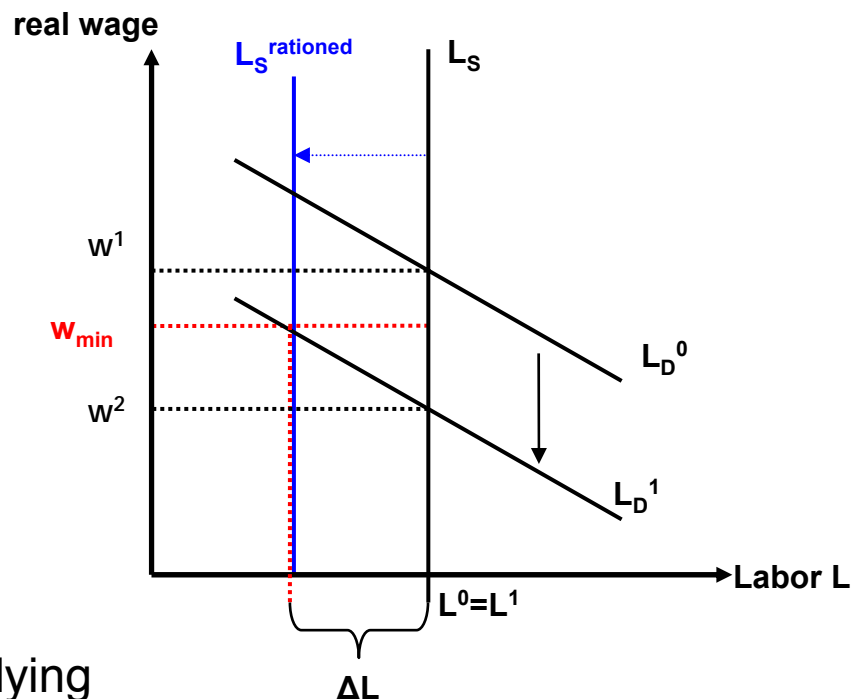
*Green tax reduces labor productivity*

Modeling:

- Wage equation  
setting real wage constant

$$\frac{w_r}{P_r} \geq w_r^{min}$$

- Rationed equilibrium realized by applying endogenously computed rationing multiplier (unemployment rate) on  $LS^*$   
 $supplyUR - demand \geq 0, \bar{p} \geq 0, \bar{p}^T (supplyUR - demand) = 0$



Hypothesis: Relevant for unskilled labor

## Modeling Unemployment: Wage Curve

➡ Negative relationship real wage and local unemployment rate (Blanchflower, Oswald 1995)

➡ Microeconomic rationale: Efficiency wage, union bargaining

➡ Labor supply curve substituted by wage curve which follows empiric observation

➡ Modeling:  
 • Wage equation

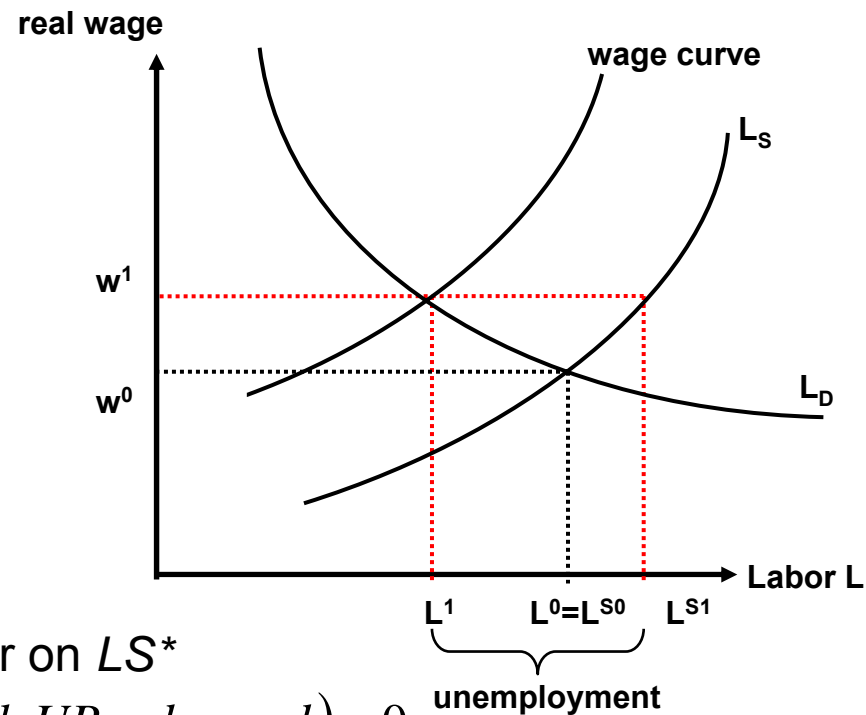
$$\frac{w_r}{P_r} = f(ur_r)$$

$$\ln\left(\frac{w}{P}\right) = \beta \ln ur + z; \left(\frac{w}{P}\right) = ur^\beta$$

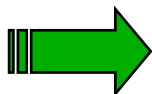
• Rationed equilibrium realized by applying endogenously computed rationing multiplier on  $LS^*$

$$supplyUR - demand \geq 0, p(UR) \geq 0, p_{(UR)}^T (supplyUR - demand) = 0$$

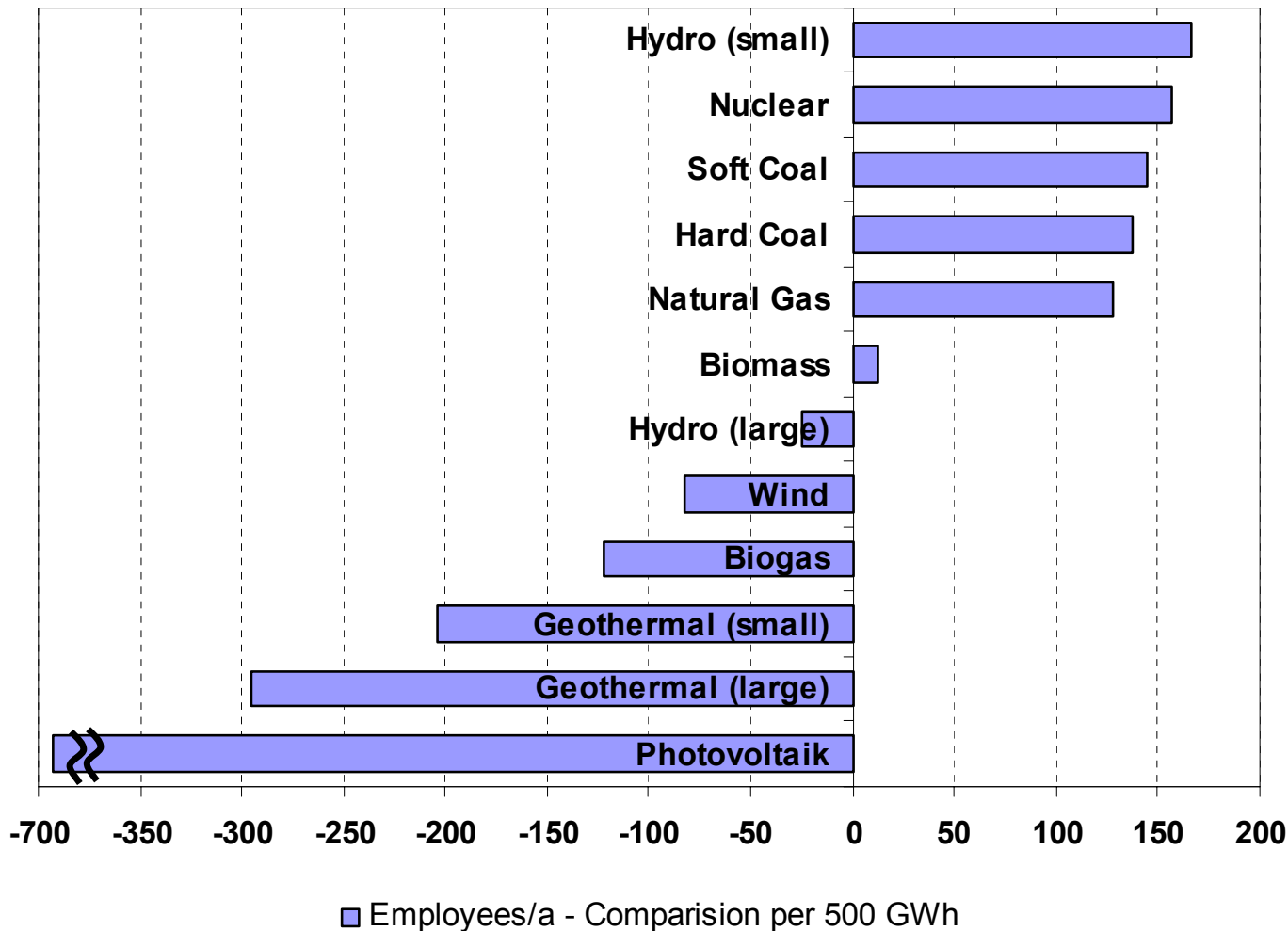
➡ Hypothesis: Relevant for skilled labor



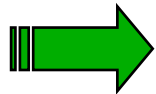
# Generation Technology Descriptions



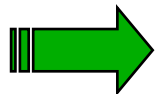
Employment impacts dependent on choice of generation technologies



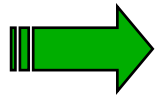
## Generation Technology Descriptions



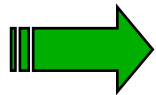
Detailed implementation of electricity generation sector for all regions.



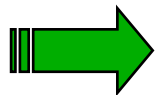
Electricity is produced with 10 generation technologies within 3 load segments.



Every generation technology is implemented with a CES production function with inputs of capital, skilled labor, unskilled labor, energy, and materials. CO<sub>2</sub> allowances are an additional input when fossil fuels are used.

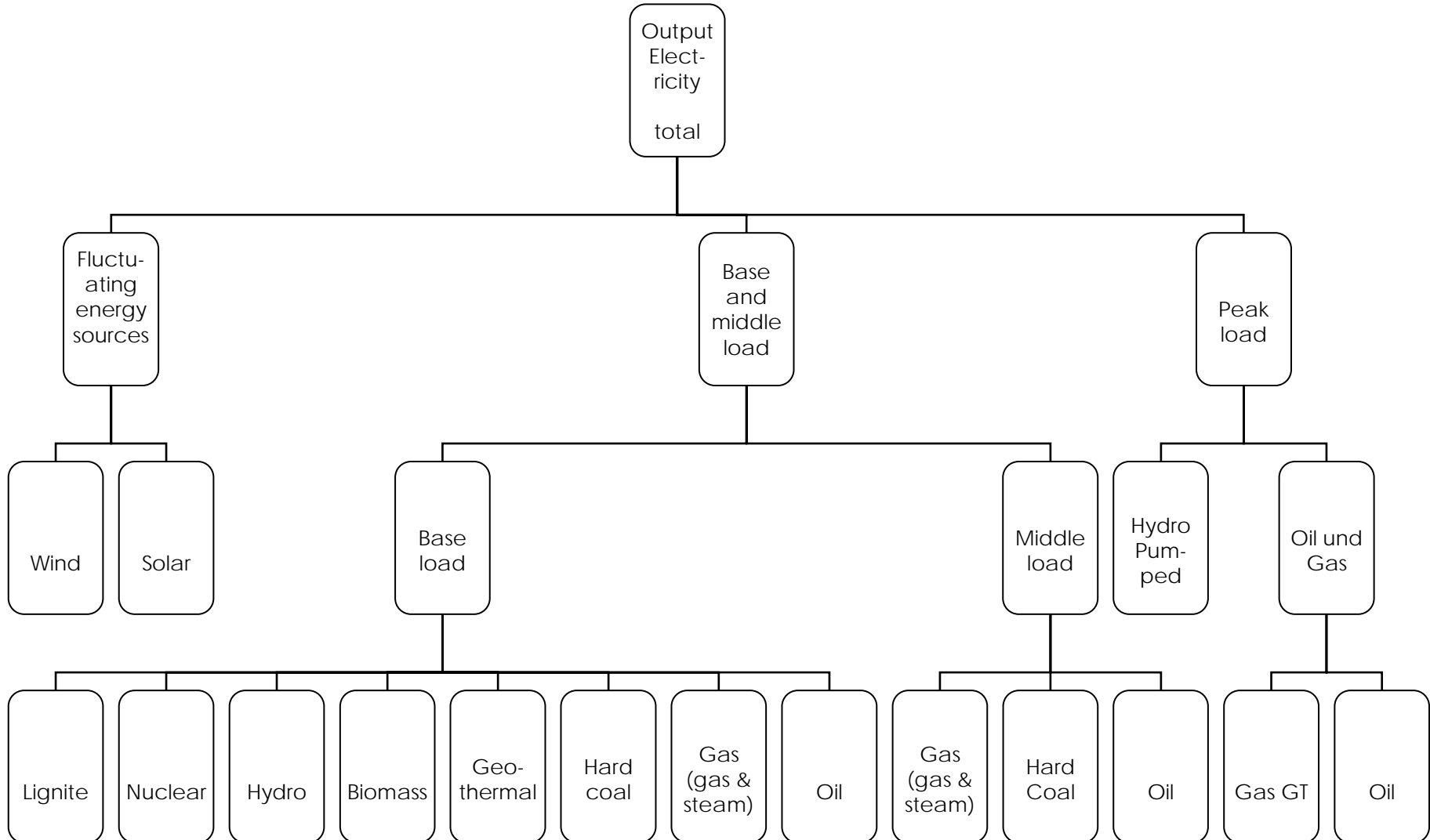


GTAP data is complemented by information from IEA energy balances (generation costs). Regionally differentiated cost shares are computed.

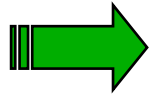


Output of all generation technologies is aggregated in a production function satisfying the demand of electricity.

# Aggregating Generation Technologies to a Power Plant System

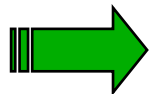


## Model Application: Subsidy on CO<sub>2</sub> Free Generation Technologies



Energy policy framework:

- Climate protection regime “Kyoto-Forever“  
Effective trade with CO<sub>2</sub> allowances for all ratifying Annex-B countries.
- Nuclear phase out in Germany
- Potential (capacity projections) for lignite, biomass and hydro power bounds generation through these technologies



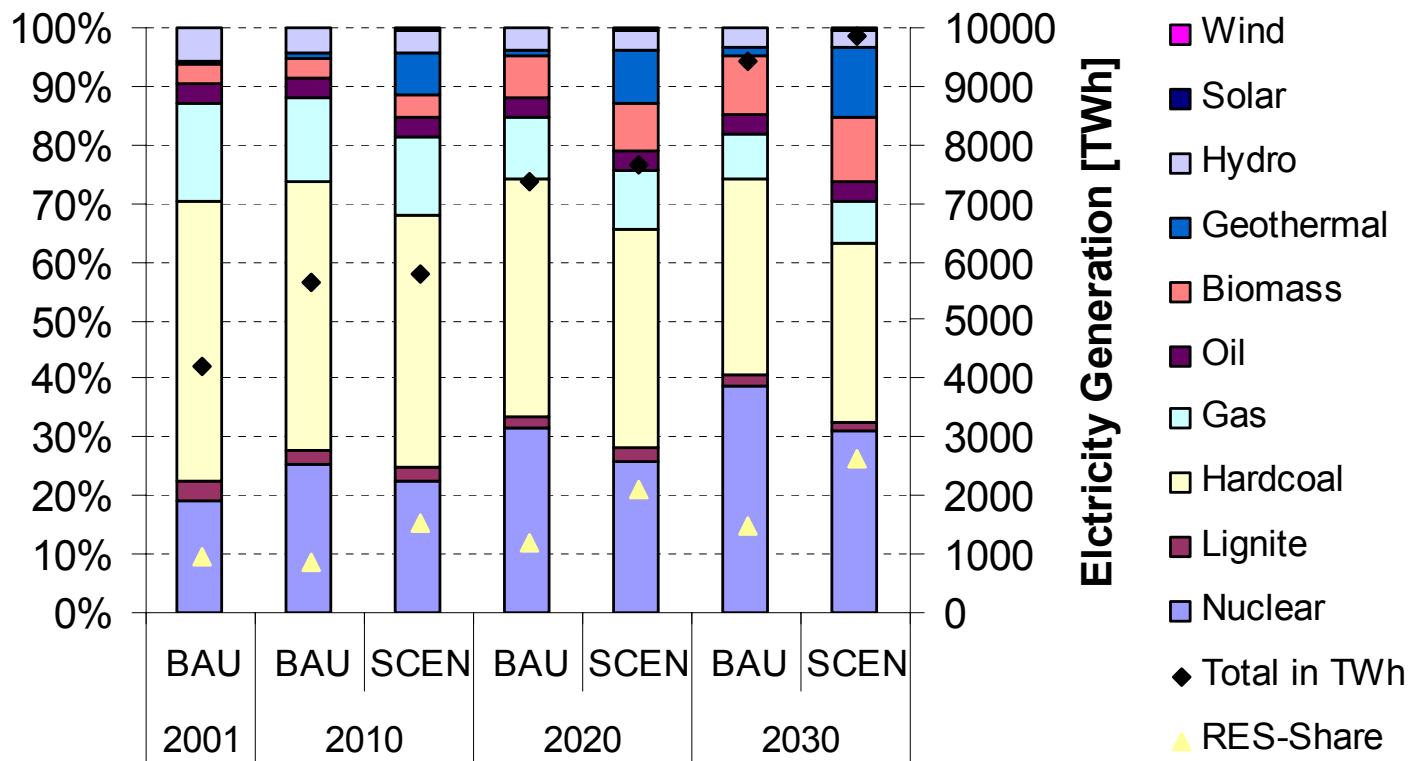
Comparing BAU and SCEN with Subsidies on CO<sub>2</sub> free technologies (except nuclear power)

	BAU	SCEN	Policy Relevance
Annex-B	Kyoto	Kyoto + Tech	Kyoto Protocol + EU Strategy Paper “ <i>Winning the Battle...</i> “
REJ, CHI	-	Tech	Asia-Pacific Partnership on Clean Development and Climate
Others	-	-	

## Model Application: Impacts on Power Plant Systems (REJ)

### Technology dimension:

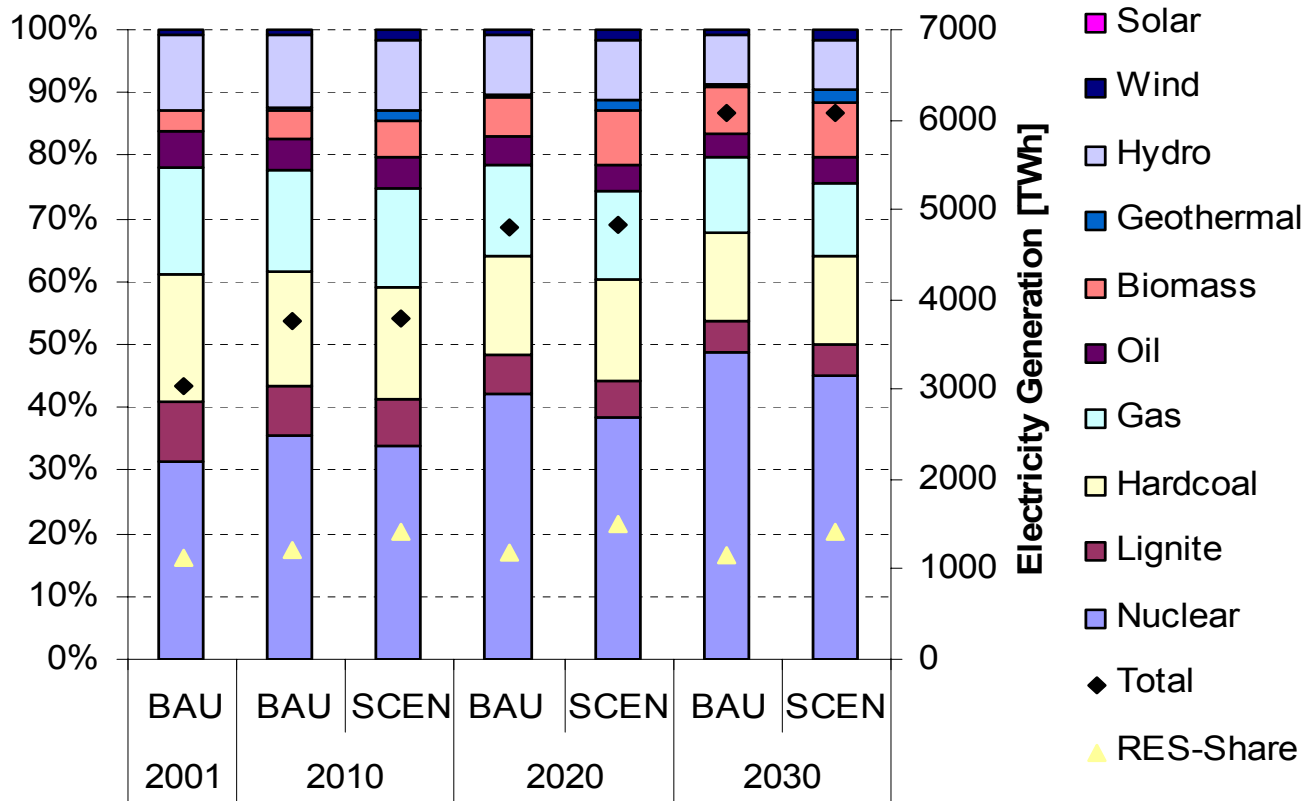
- Subsidies alter technologies' comparative advantages and directly affect national power plant systems
- Share of renewable energy sources (RES) in generation mix rises (substitution effect)
- Total electricity production increases (scale effect)



# Model Application: Impacts on Power Plant Systems (EU-25)

## Technology dimension:

- Substitution effect less strong in EU-25 than in REJ
- Wind and solar technologies increase only slightly due to substitution elasticities
- Increase is bounded by technology potential on hydro and biomass
- Scale effect is dampened if emission caps are effective

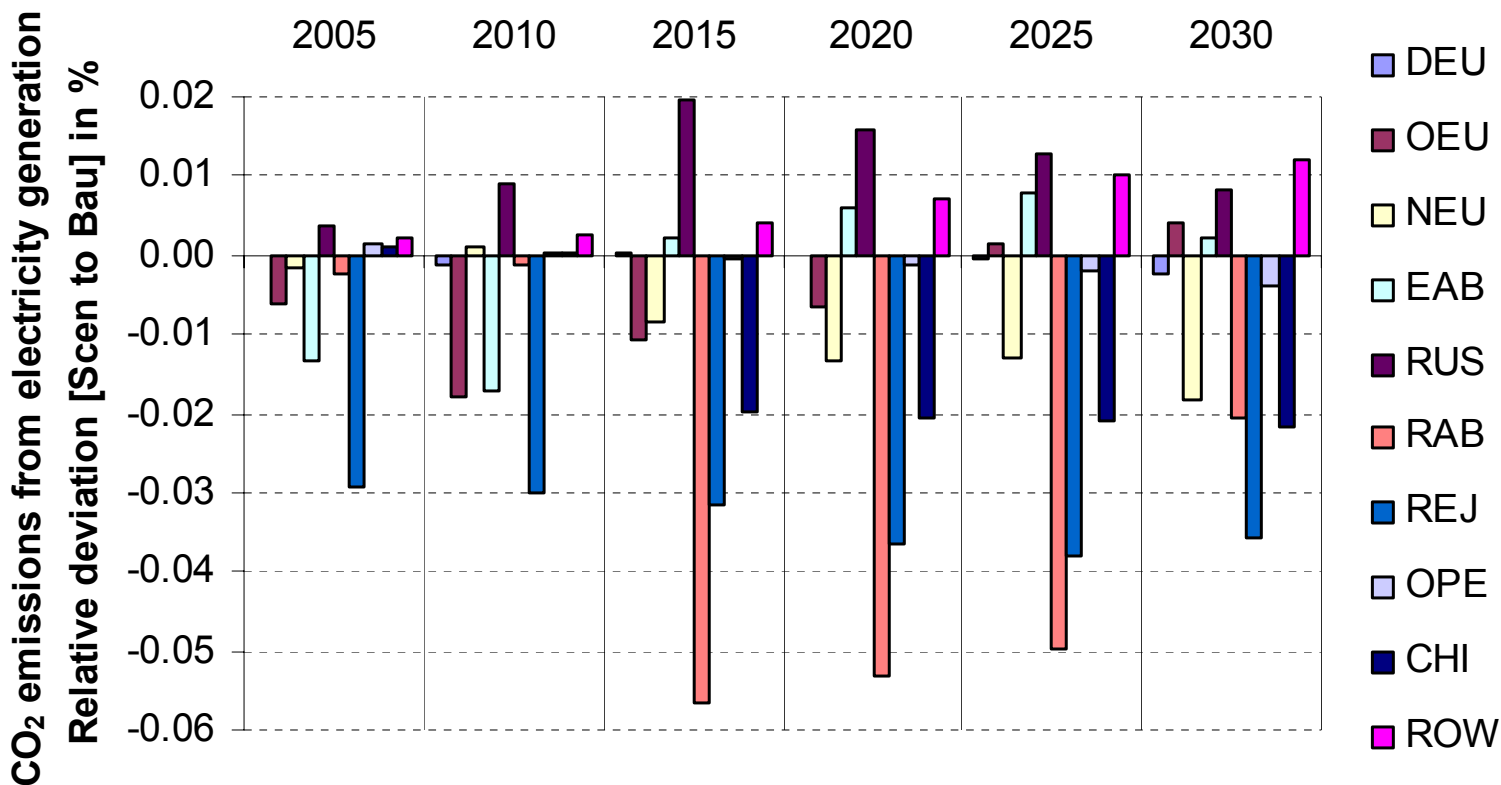




# Model Application: Changes in CO<sub>2</sub> Emissions from Generation

## Ecological dimension:

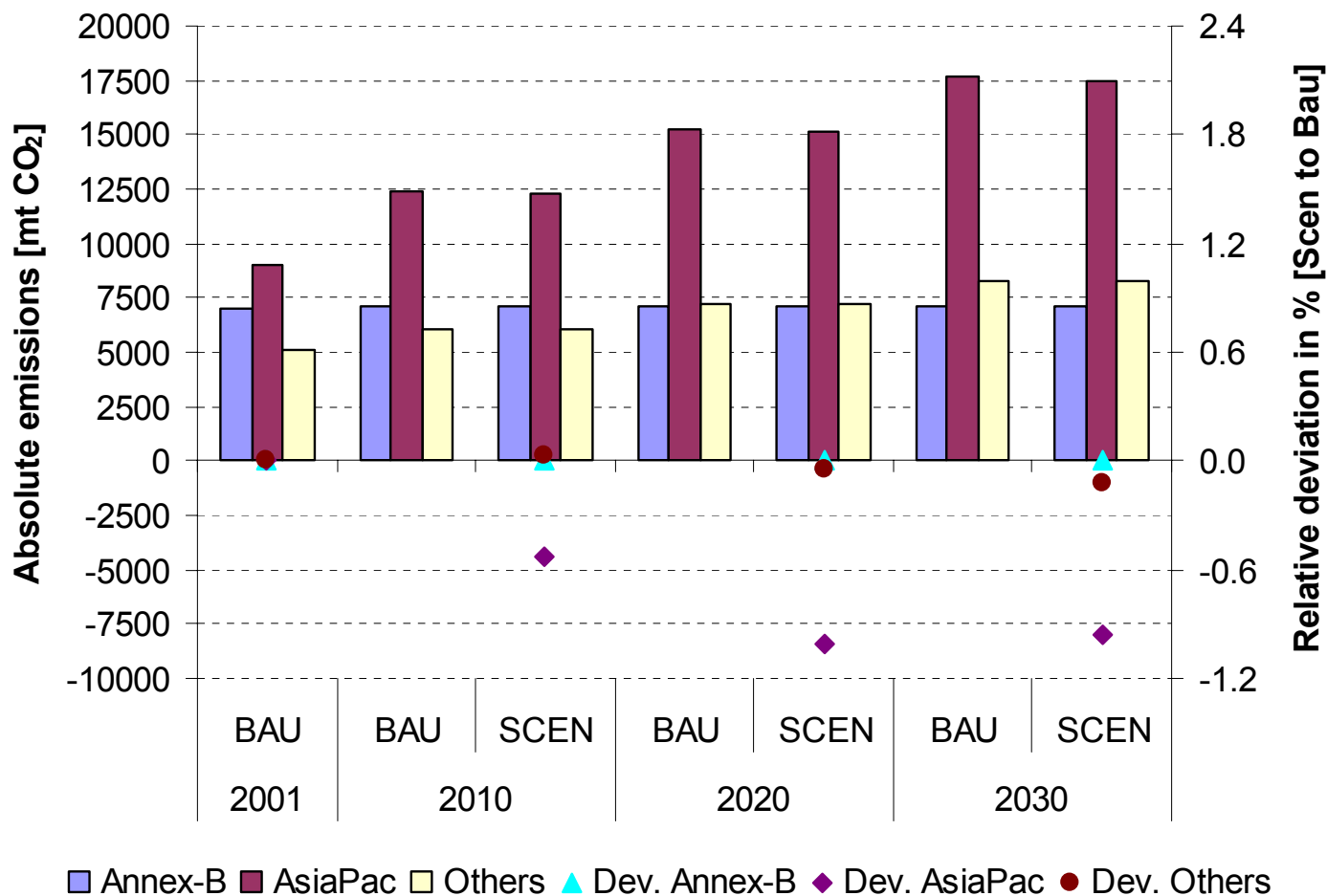
- Composition of power plant system triggers changes in CO<sub>2</sub> emissions



## Model Application: Changes in CO<sub>2</sub> Emissions

### Ecologic dimension:

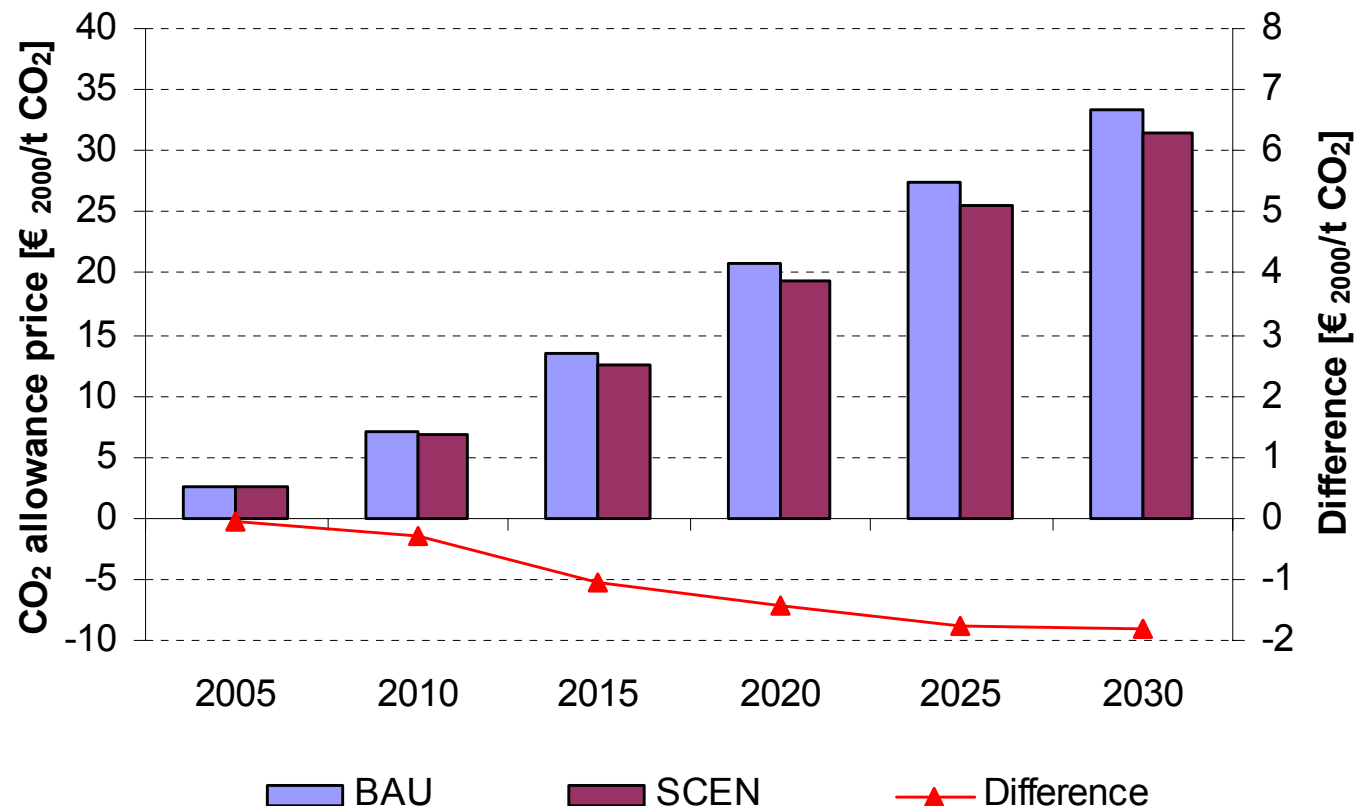
- CO<sub>2</sub> free technology subsidies can decrease GHG emissions
- For Annex-B countries emission cap is still effective



## Model Application: CO<sub>2</sub> Allowance Price Development

### Economic dimension:

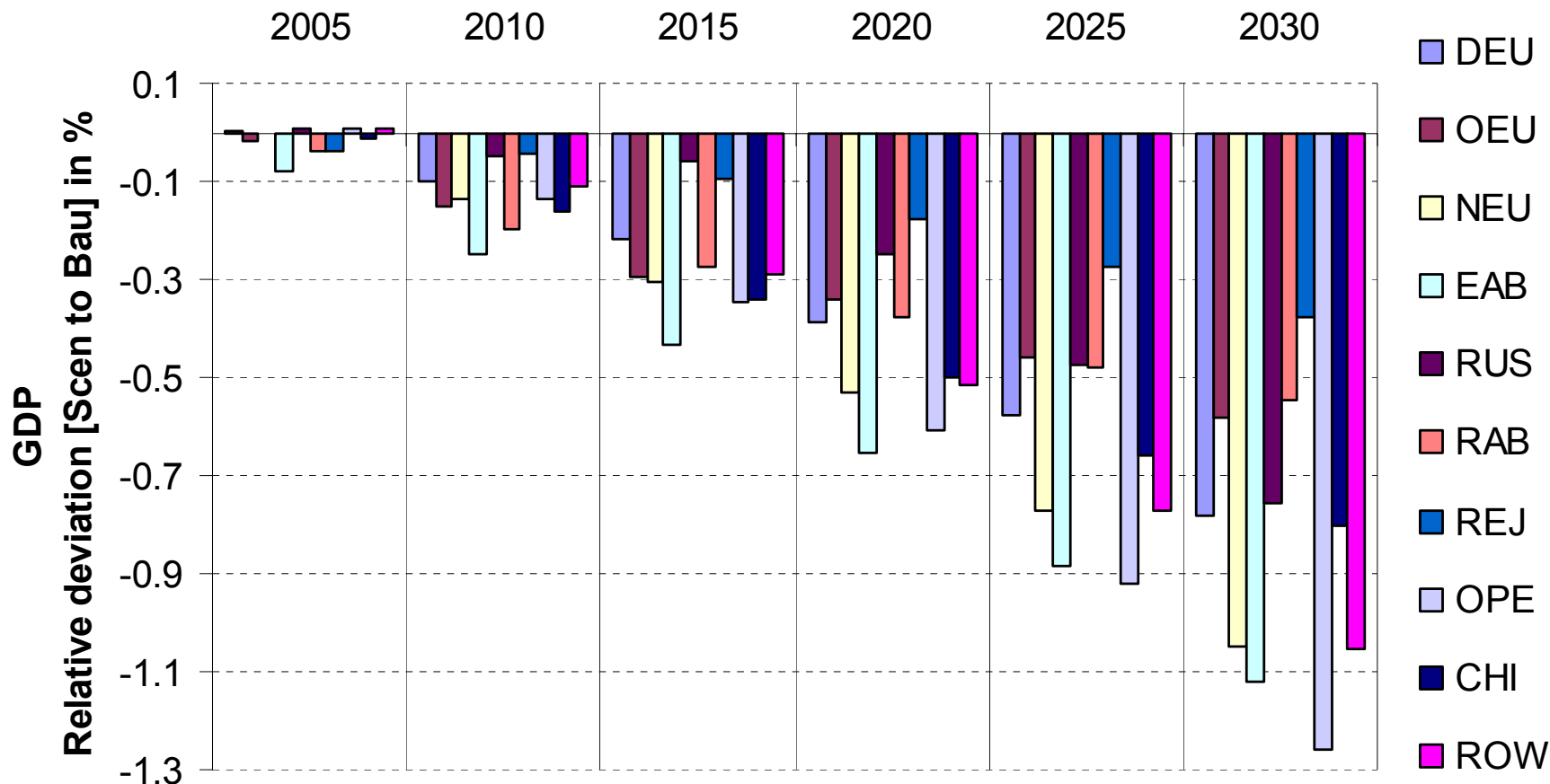
- Technology application effects demand for allowances, price effect
- CO<sub>2</sub> free technology subsidies decrease CO<sub>2</sub> price on international allowance market
- In addition GDP growth effects have an impact on allowance demand



## Model Application: Changes in GDP

### Economic dimension:

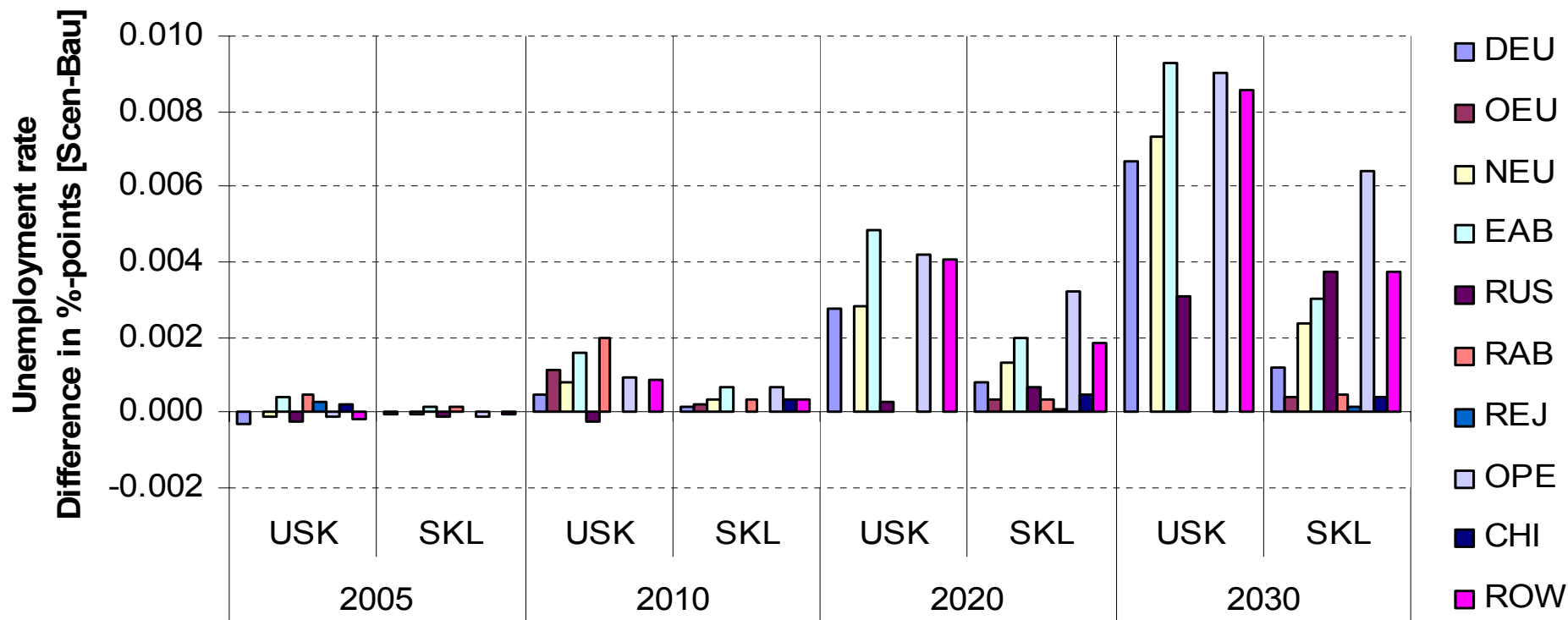
- Technology subsidies induce significant negative GDP impact
- ROW and OPE are also suffer growth losses (international trade feed backs)



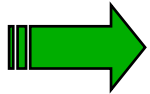
## Model Application: Changes in Unemployment Rate

### Social dimension/ Unemployment:

Negative GDP impacts and application of less labor intensive generation technologies increase unemployment rates. Deviations are slightly smaller for the skilled.

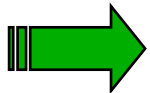


## Conclusions and Prospects



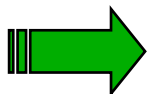
Model extensions:

- *Labor market*
- *Electricity supply*



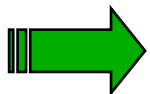
Preliminary results from exemplary application:

- *Subsidies on CO<sub>2</sub> free generation technologies may distort objective triangle of energy policy and do not automatically lead to a more sustainable development*
- *Long term associated labor effects are considerable small but tend to be negative*



Possible further model extensions related to labor markets:

- *Union wage bargaining*
- *Labor leisure decision*



Possible further model extensions related to energy policies:

- *Elasticities of substitutions in the power plant system*
- *Handling of not competitive generation technologies (renewable energy sources)*
- *Sectoral emission trading scheme (EU-ETS)*
- *Imperfect energy conversion markets with price mark-ups*

**Thank you for your attention!**

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