MODELLING RECYCLING AND MATERIAL EFFICIENCY TRENDS IN THE EUROPEAN STEEL INDUSTRY

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Andrea Herbst, Fraunhofer ISI; Tobias Fleiter, Fraunhofer ISI; Eberhard Jochem, Fraunhofer ISI/IREES GmbH

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STRUCTURE

- Motivation
- Steel production routes and scrap availability
- Modelling changes in recycling and production
- Results

MOTIVATION

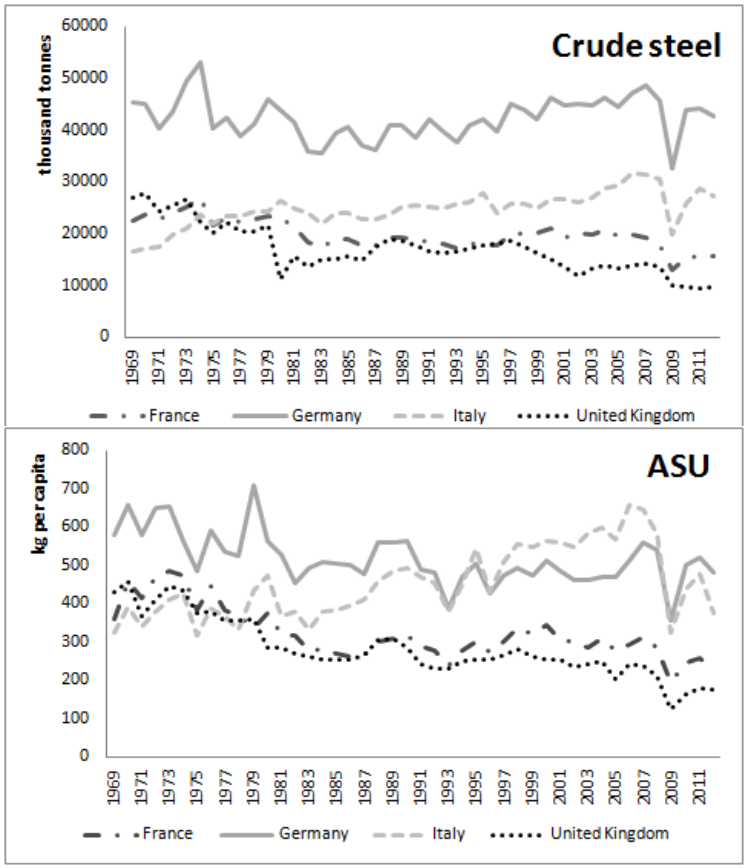
Industrial production projections

Reduced energy demand and CO^2 emissions

STEEL PRODUCTION ROUTES AND SCRAP AVAILABILITY

Final basic product, distinguishing primary and recycle chains of production

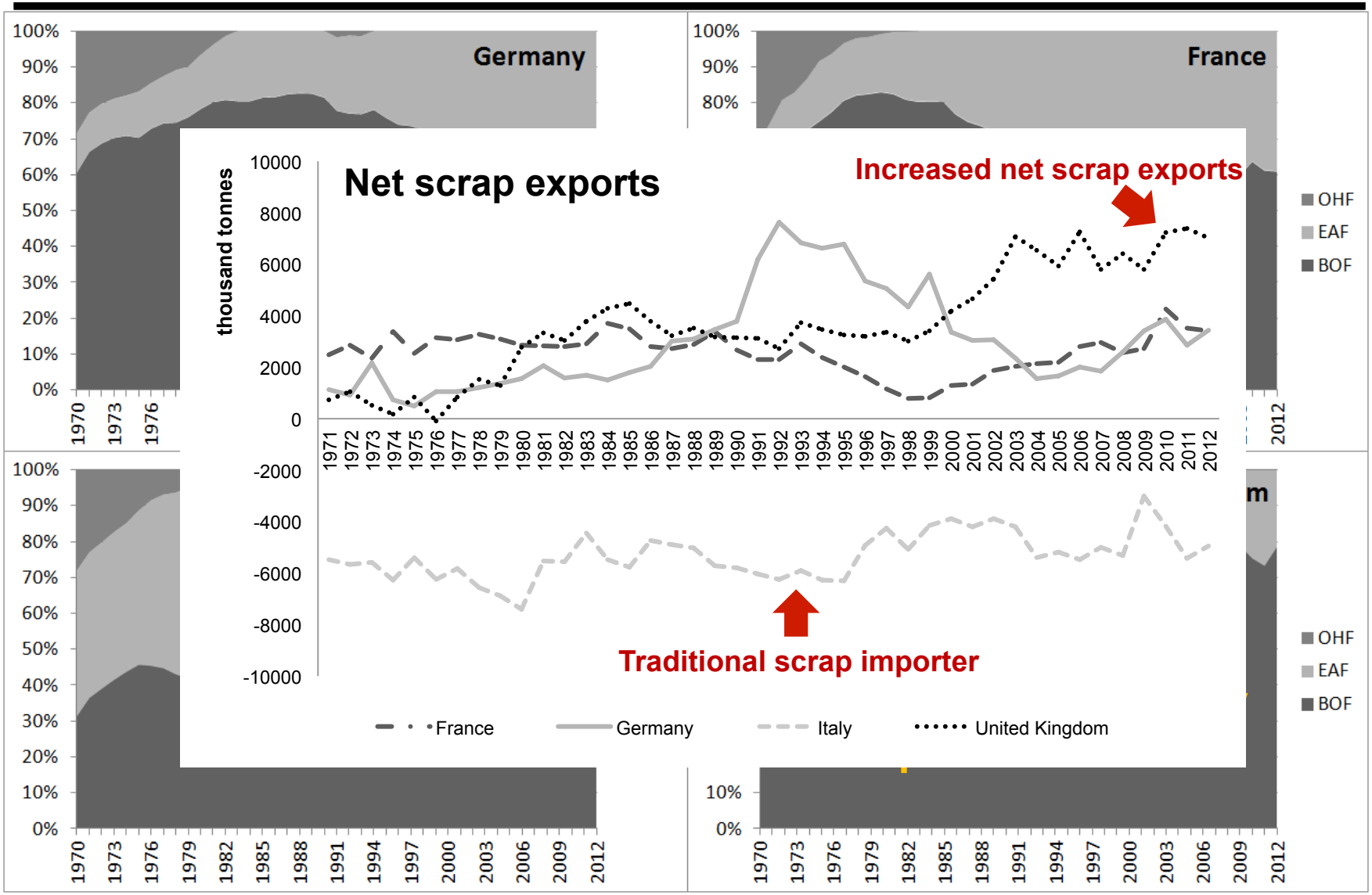
Steel production and apparent steel use (1970-2011)



Source: (IISI 1998), Fleiter et al. (2013)

Source: World Steel Association (worldsteel) (2013)

STEEL PRODUCTION ROUTES AND SCRAP AVAILABILITY

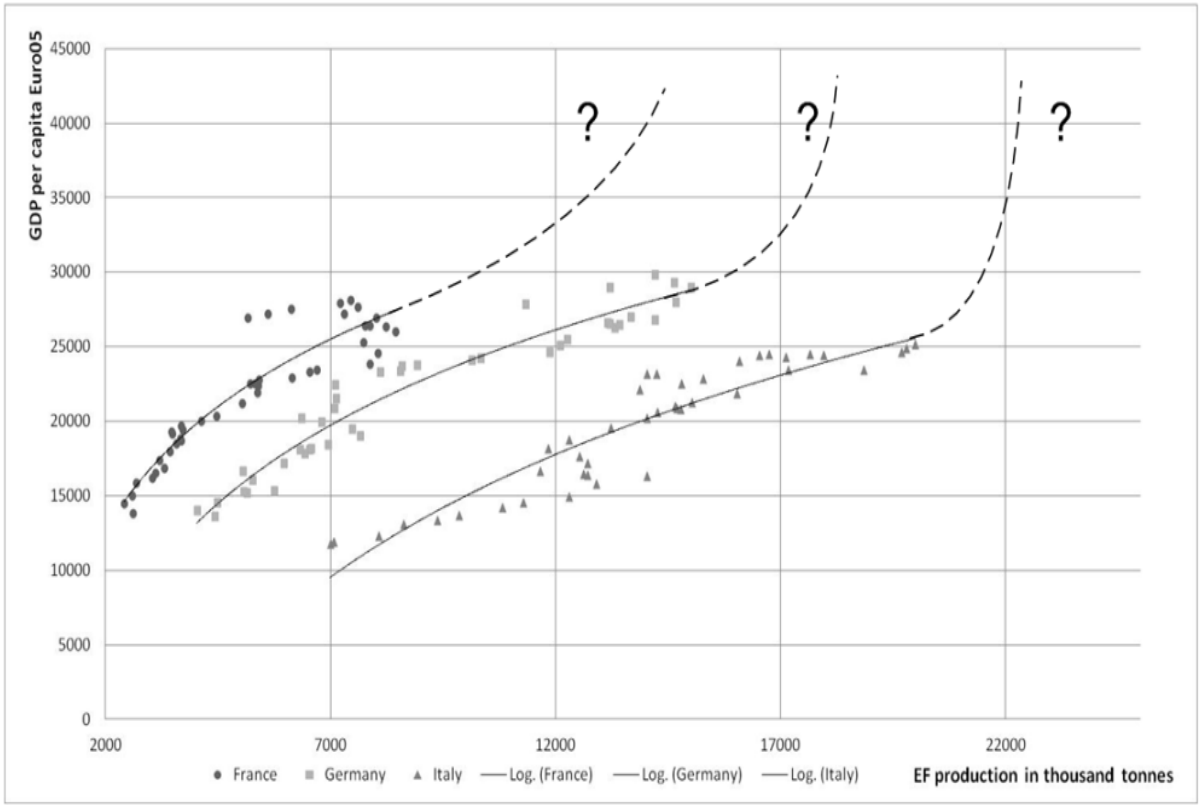


Source: World Steel Association (worldsteel) (2013)

STEEL PRODUCTION ROUTES AND SCRAP AVAILABILITY

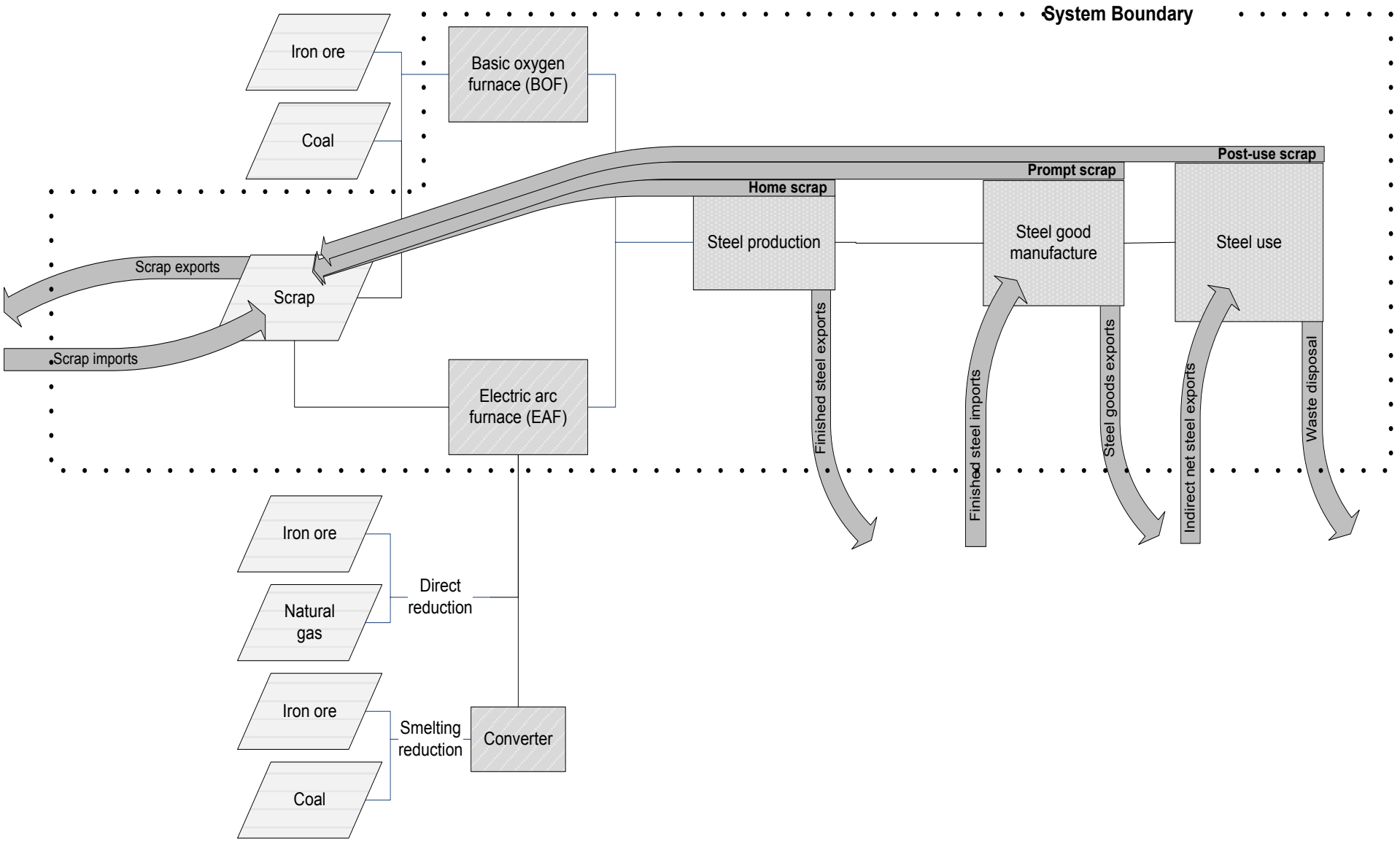
Whether/when secondary production might stagnate someday despite further GDP per capita growth depends on:

- **Domestic scrap arising**
  - Limits
  - Dynamics of future infrastructures
- **Scrap trade**
  - Dynamics of future trade between countries
- **Scrap quality**
  - Purity of scrap and waste
  - Costs of seperation and purification processes



Source: The World Bank (2012); World Steel Association (worldsteel) (2013b)

MODELLING CHANGES IN RECYCLING AND PRODUCTION



MODELLING CHANGES IN RECYCLING AND PRODUCTION

- **System boundaries and assumptions:**

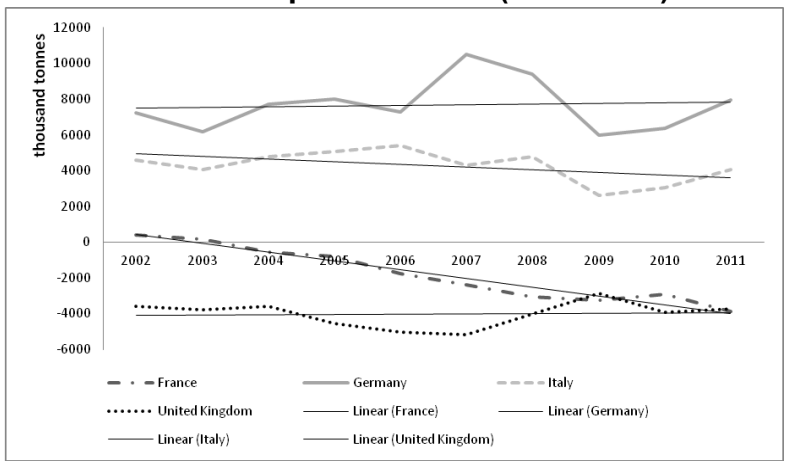
I. Additional **decoupling** (to its historic trends) of apparent steel use (ASU) in tonnes and economic value of the steel demanding branches

II. **Home scrap** of blast oxygen and electric arc furnace route steelworks is recycled immediately **on site**

III. "***Prompt scrap ratio*** = *prompt scrap / steel input to manufacture*" adapted as **constant 15%** from Michaelis and Jackson (2000, p.136)

IV. „***Indirect net steel exports***" (*IndNX*) (World Steel Association (worldsteel), 2013b) remain **constant** on the level of the year 2010

Indirect net exports of steel (2002-2011)



Source: Data from World Steel Association (worldsteel) (2013b)

MODELLING CHANGES IN RECYCLING AND PRODUCTION

- **System boundaries and assumptions:**

V. Chosen **average life cycle** (*alc*) of steel containing products after literature analysis: **20 years**

VI. „***post-use recycled steel scrap rate*** *(r)*“ (Michaelis and Jackson, 2000a, p. 136f): set to **83%** in 2010 and assumed to increase linearly up to **90%** (Worldsteel Association (worldsteel), 2010; also cited in UNEP, 2013, p.47)

VII. **Net exports of steel scrap trade** assumed to remain **constant** on the level of the year 2010 over the models projection horizon

VIII. **EAF-production-scrap ratio** (λ) is assumed to stay the same **as in 2010**
As the model is not fully calibrated value for the year 2010 below 1 (see assumption I)

IX. **Ratio of crude steel production to apparent steel use** (μ) is assumed to move **linearly towards 1** from the level of the year 2010

MODELLING CHANGES IN RECYCLING AND PRODUCTION

- **Regression Methodology:**

1) Pooled **regression analysis** for the identification of a behavioural equation for the development of the **apparent steel use** of a country, average time-dummy coefficient base on 2007

$$ASU_{t,j} = \beta_0 + \beta_j \times VA_{t,j} + \varepsilon_{t,i}$$

$$\ln ASU_{t,i} = \beta_0 + \beta_1 \times \ln bm.va_{t,i} + \beta_2 \times \ln veh.va_{t,i} + \beta_3 \times \ln eng.va_{t,i} + \beta_4 \times \ln constr.va + CD + TD + \varepsilon_{t,i}$$

Data availability:

I. average length of time-series **1974-2007**

II. **Data in metric tonnes for 23 countries :**
Worldsteel Association, Steel Statistical Yearbooks 2013 to 1987

III. **Value added data for 23 countries:**
EU-KLEMS database, University of Groningen
transformed in Euro 2005 using market exchange rates

MODELLING CHANGES IN RECYCLING AND PRODUCTION

- **Material Flow Methodology:**

2) Assuming a **trend to higher gross value added** (see assumption I) multiplication with the **structural change ratio *α***

$$asu_{t,i} = \alpha_t \times ASU_{t,i}$$

3) **Available and recovered amount of prompt scrap** ($Scrap_{prompt}$) within year *t* for country *i* via **prompt scrap ratio *δ*** (assumption II and III)

$$Scrap_{prompt\,t,i} = \delta \times asu_{t,i}$$

Adapted from Michaelis and Jackson (2000a, p.136)

4) Definition **true steel use** of a country *i* in year *t*

$$TSU_{t,i} = asu_{t,i} - IndNX_{t,i}$$

Taken from Worldsteel Association (worldsteel) (2012), *IndNX* assumed to remain constant (assumption IV)

MODELLING CHANGES IN RECYCLING AND PRODUCTION

- **Material Flow Methodology:**

5) Amount of **post-use/end-of-life scrap** ($Scrap_{eol}$)

$$Scrap_{eol\,t,i} = r \times TSU_{t-alc,i}$$

Adapted **"*use phase*" model** from Michaelis and Jackson (2000a, p.136f) (assumption V & VI) -> no finalized modelling of steel stocks

6) **Total domestic scrap availability** for EAF steel production (assumption II)

$$Scrap_{dom\,t,i} = Scrap_{prompt\,t,i} + Scrap_{eol\,t,i}$$

7) **Total available amount of scrap** (assumption VII)

$$Scrap_{total\,t,i} = Scrap_{dom\,t,i} - ScrapNX_{t,i}$$

MODELLING CHANGES IN RECYCLING AND PRODUCTION

- **Material Flow Methodology:**

8) Steel produced via the **electric arc furnace route** ($PROD_{EAF}$) (assumption VIII)

$$PROD_{EAF\,t,i} = Scrap_{total\,t,i} \times \lambda$$

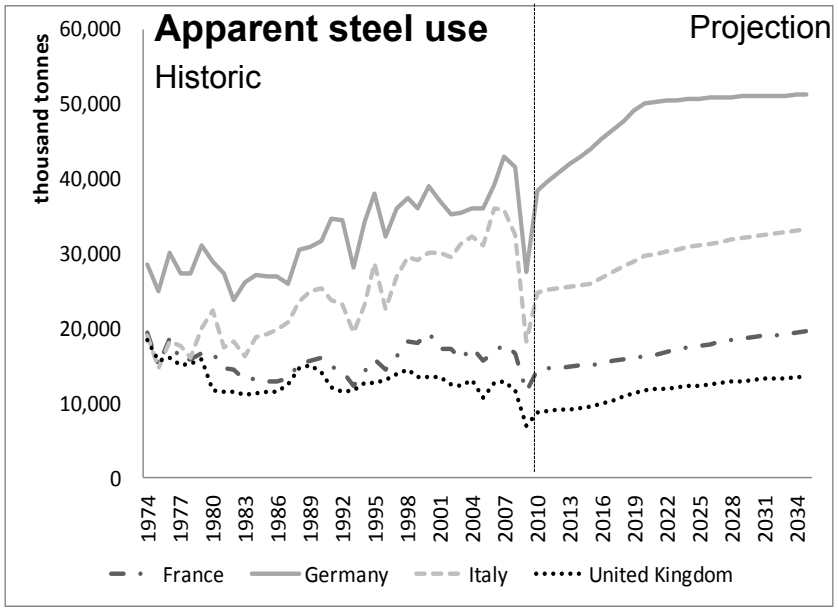
9) **Crude steel** production ($PROD_{CRUDE}$) (assumption IX)

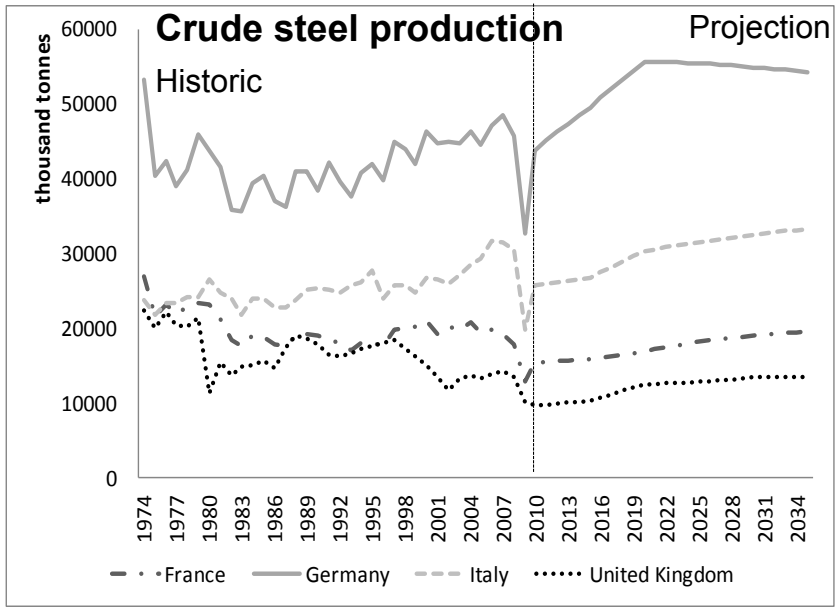
$$PROD_{CRUDE\,t,i} = ASU_{t,i} \times \mu$$

10) Steel production via blast **oxygen furnace route** ($PROD_{BOF}$)

$$PROD_{BOF\,t,i} = PROD_{CRUDE\,t,i} - PROD_{EAF\,t,i}$$

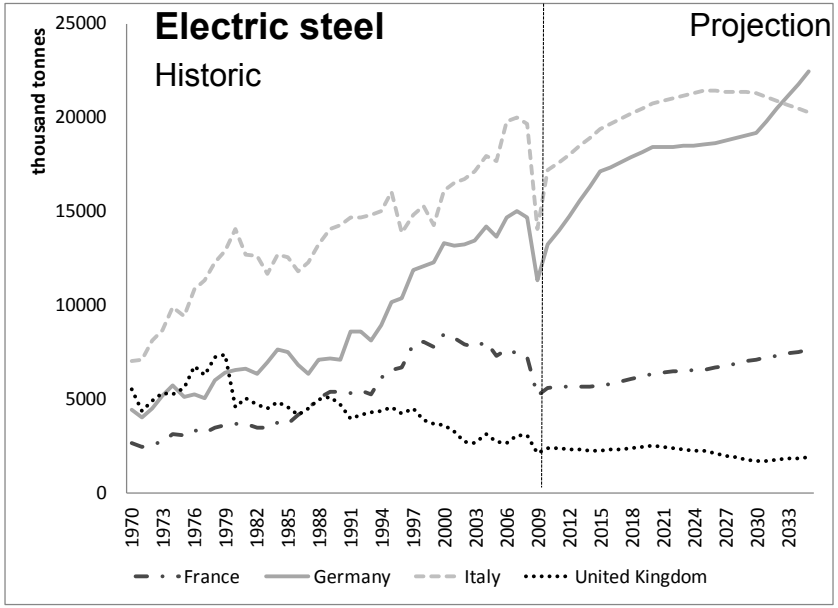
RESULTS

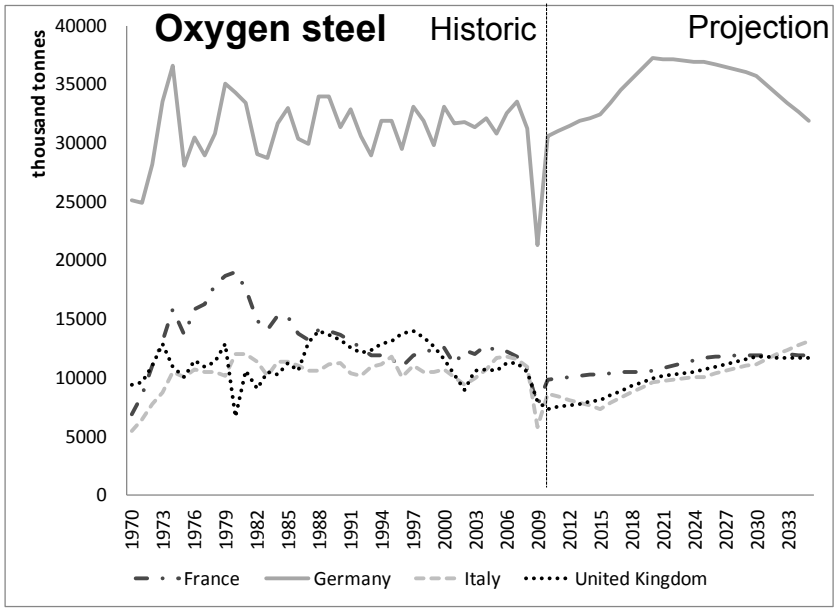




- **Increasing ASU** and **crude steel production** in Germany, Italy, France and the United Kingdom until 2020
- **Stagnation/decrease** after 2020 in **Germany**, **United Kingdom**
- **Major driver of ASU** underlying economic development of steel demanding branches: **construction, vehicle construction, engineering, basic metals**
  (Source: Macroeconomic model ASTRA; Krail et al. 2013)

RESULTS





- Results reflect **growth in steel demanding sectors**, combined with assumptions of an **increasing post-use recycling rate**
- **Electric steel production** follows rather **different pathways**:
  stagnation/decrease in Italy after 2025; France little increases; United Kingdom continues historic trends; TSU dominates German results
- Results for electric steel had to be interpolated in 5-years steps, due to economic fluctuations in the past which are reflected in the TSU (t-20) of the countries

CONCLUSIONS AND OUTLOOK

- Western European countries exhibit **trends towards secondary production**
- **Unlimited growth** in secondary production **cannot be expected** and will depend on dynamics of **future infrastructures** and **scrap trade** as well as future **material strategies**
- The shown **methodology** describes an approach to transparently **translate macro-economic information** of the major steel demanding industries into projections of future **steel use** and **steel production** in physical **tonnes** on process level under consideration of **structural change** and **recycling** using various **adjusting screws** for scenario analysis:
  - structural change ratio,
  - prompt scrap ratio, recycling rate, EAF-production scrap ratio,
  - and trade in indirect steel and scrap (netto exports), etc.
- **Model improvements planned:**

  improved parameter calibration over countries and scenarios, include the dynamic modelling of steel stocks, improved modelling of trade in steel scrap

MODELLING RECYCLING AND MATERIAL EFFICIENCY TRENDS IN THE EUROPEAN STEEL INDUSTRY

Thank you for your attention!

Andrea Herbst
Competence Center Energy Technology and Energy Systems
Fraunhofer Institute for Systems and Innovation Research ISI
Breslauer Straße 48, 76139 Karlsruhe, Germany
Tel.: +49 (0) 721 6809 -439

Institute for Resource Efficiency and Energy Strategies
Schönfeldstraße 8, 76131 Karlsruhe, Germany
Tel.: +49 (0) 721 915 2636 -30

E-Mail: andrea.herbst@isi.fraunhofer.de