

REEPS/Andong University Joint Workshop

# Modelling the interaction between energy, water and material consumption

E3ME

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# Overview

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- Energy-Water-Material Nexus
- E3ME
- Material modelling in E3ME

# NEXUS Definition

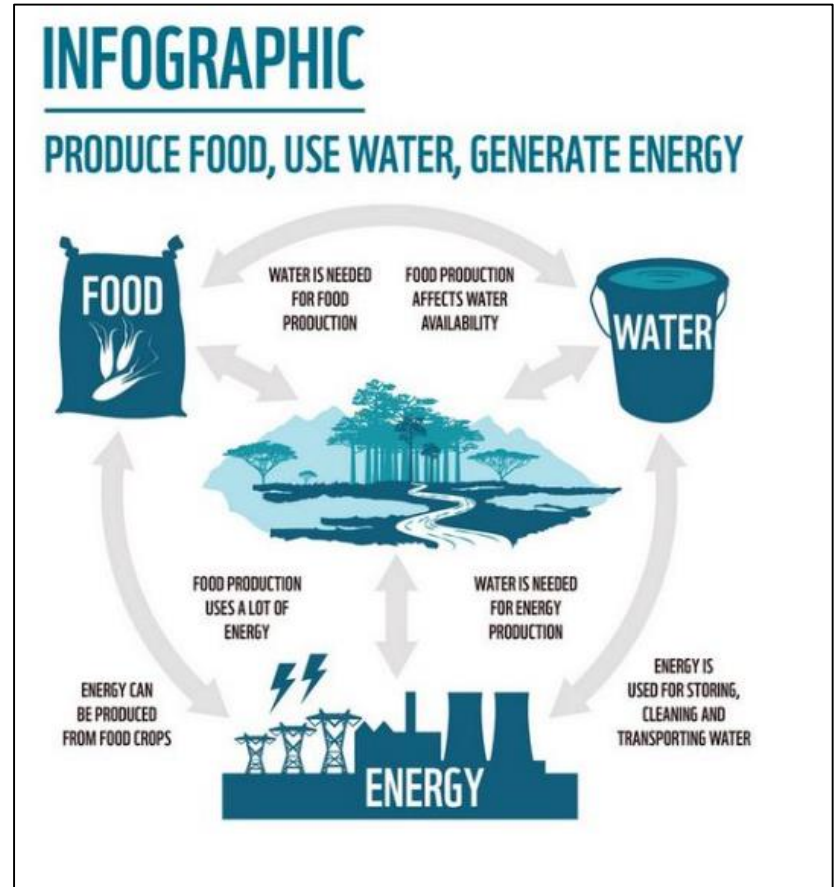
## nexus

/ˈnɛksəs/ 

*noun*

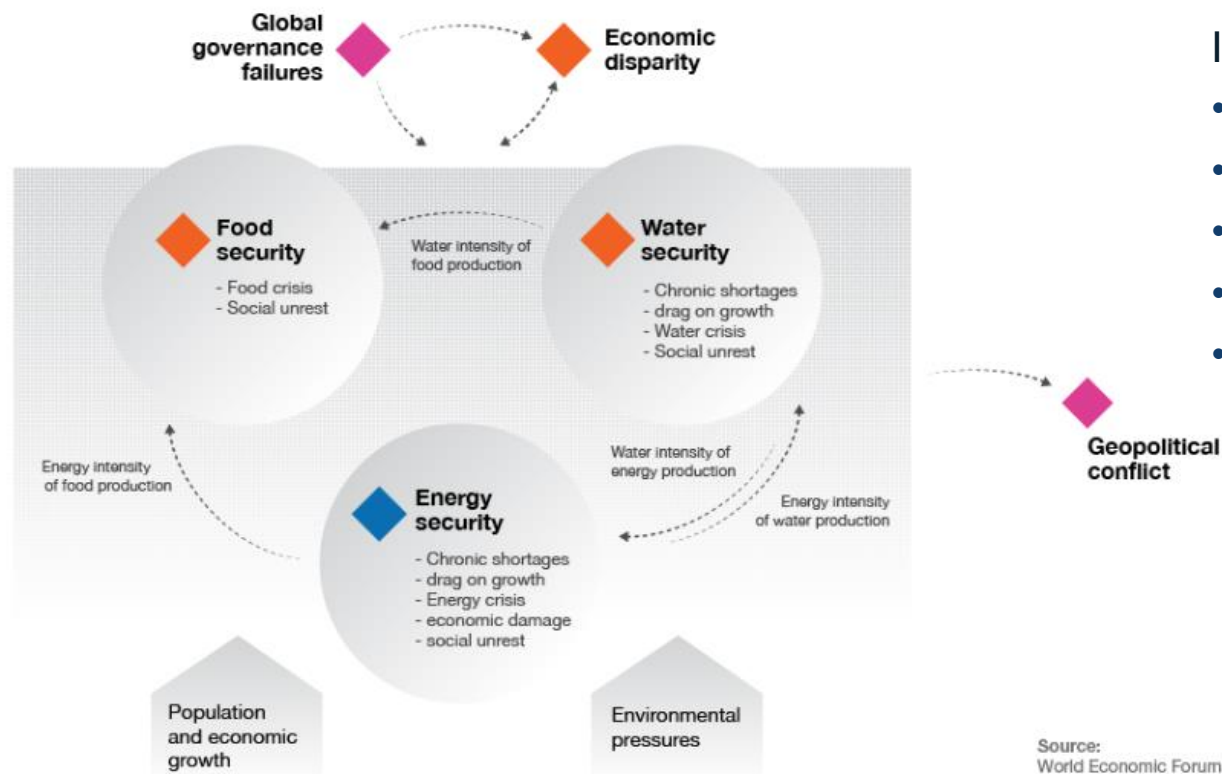
1. a connection or series of connections linking two or more things.  
"the nexus between industry and political power"
2. a central or focal point.  
"the nexus of any government in this country is No. 10"

\*interdependencies \*trade-offs



Source(s): Water Footprint

# The important issues



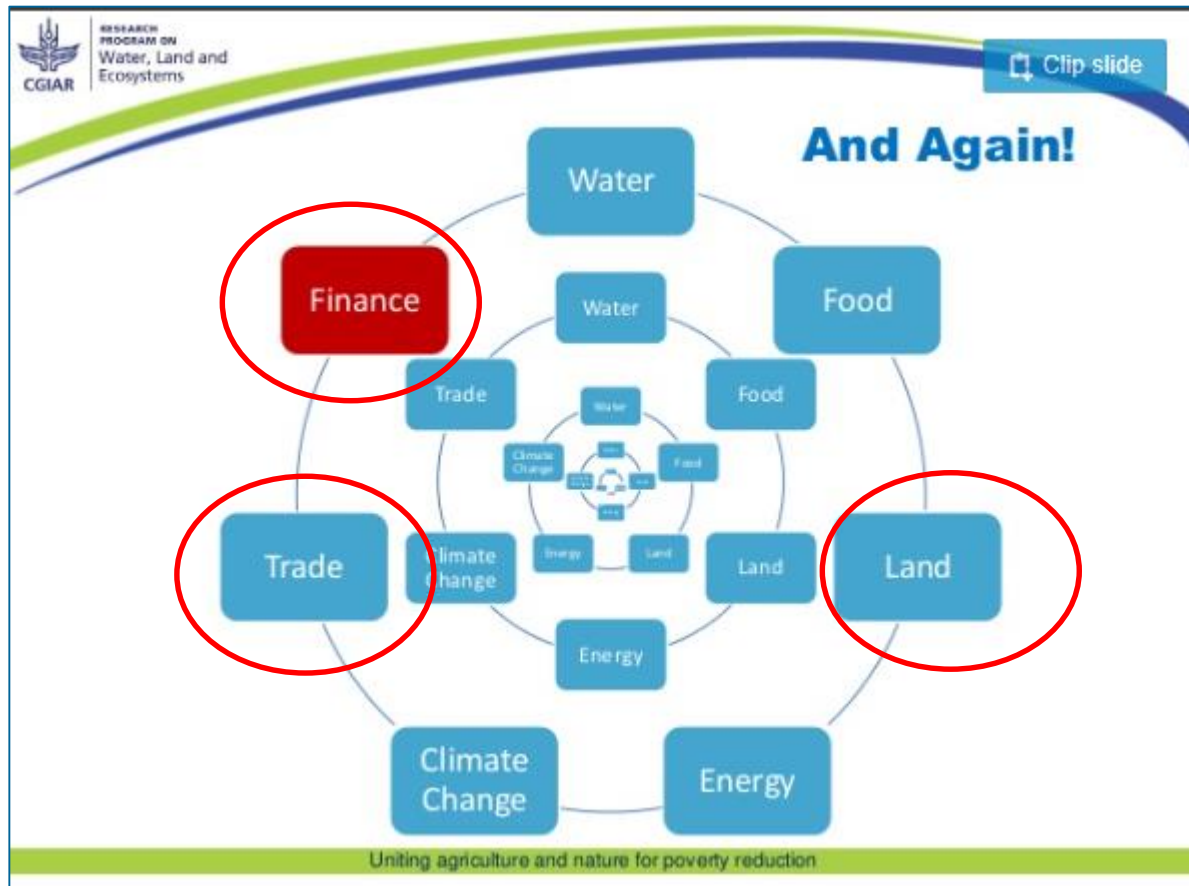
Issues:

- climate change
- increasing population
- poverty alleviation
- economic growth
- urbanisation

Source: World Economic Forum

\*\*need to look at all these issues in parallel as there are trade-offs between food, water, and energy

# In reality this is even more complex!



Source: CGIAR a global research partnership for a food-secure future

# E3ME and NEXUS

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- How do we capture the NEXUS in a model?
- E3ME has two-ways integrations between energy-environment and economy
- Recently expanded to have global raw material modelling
- Linkages to land-use model is under development
- Ongoing NEXUS research project for Brazil  
<https://www.camecon.com/news/brazil-food-water-energy-nexus/>

# Benefits of using E3ME

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- Fully integrated global tool with feedbacks between each modules and regions
  - relationships that would otherwise not captured if using bottom-up, sector or region-specific, or other simpler tools
  - contains detailed FTT technologies sub-modules for power generation, transport, and heating (land-use and industries are under development)
  - results automatically includes any rebounds effects
- E3ME and its submodules (FTTs) are simulation models with real world policies options
  - it doesn't rely on optimisation assumptions
- See model manual at [www.e3me.com](http://www.e3me.com)

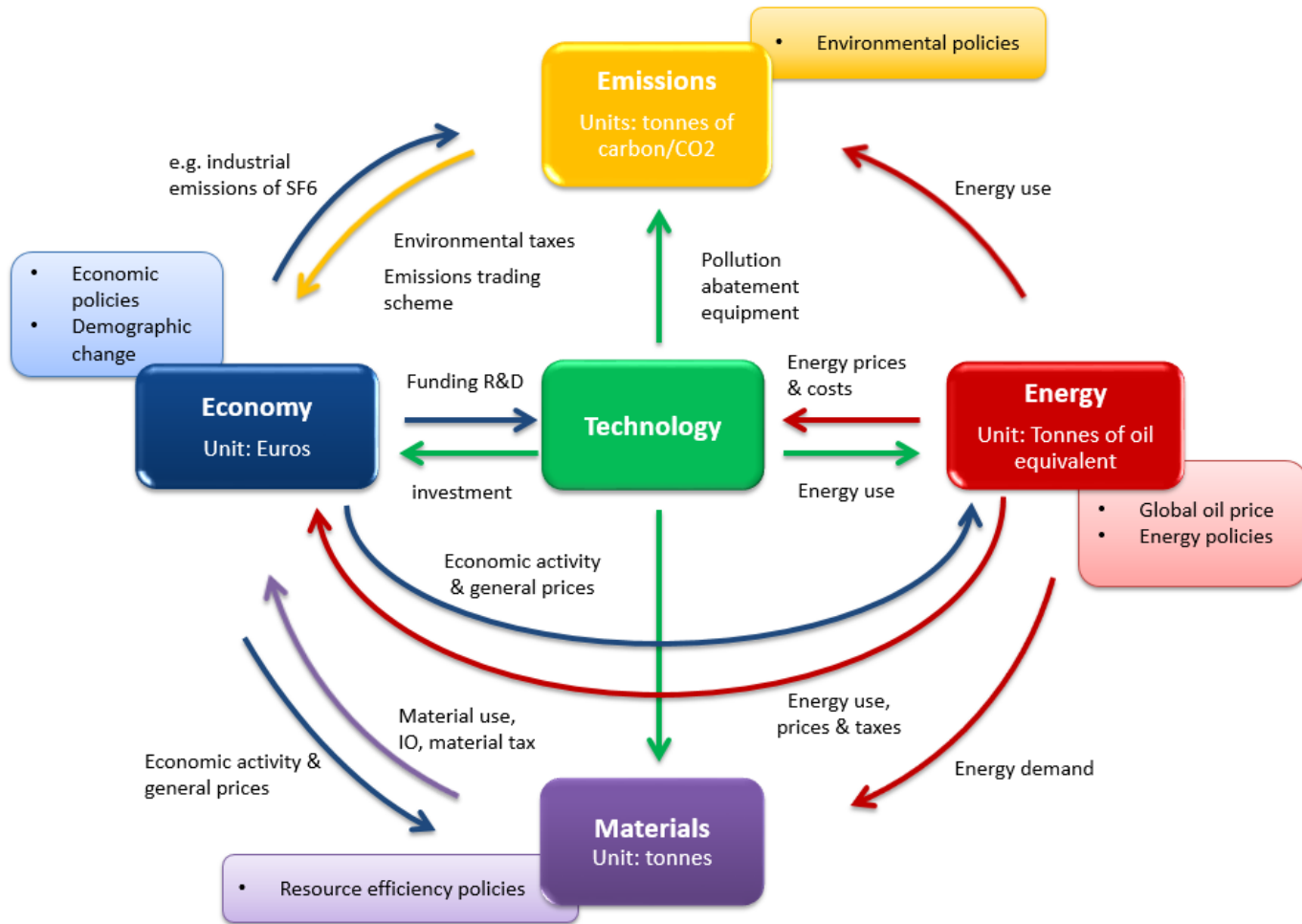
# Development of the material module in E3ME

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- Originally developed for the European Matisse research project <http://www.matisse-project.net/>
- Applied in the petrE project (Ekins et al, 2012) [http://www.petre.org.uk/pdf/ExtendingE3ME\\_to\\_Material\\_Flows.pdf](http://www.petre.org.uk/pdf/ExtendingE3ME_to_Material_Flows.pdf)
- Very few macroeconomic models currently include physical measures of material consumption
- Recent work for European Commission includes resource efficiency, material tax, ETR, and circular economy
- Now includes non-EU regions



# New in E3ME: Global material modelling



# Summary of material module in E3ME

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- Consist of econometrically estimated material demand equations for domestic material input (DMI)
- Material intensity allowed to change in response to price and other economic factors; rather than following a fixed input-output structure
- Provides two ways feedback to main economic framework
- Simpler treatment of other material flows variables available

# E3ME Material demand equations

Note: MUI refers to material 1 (Food). The equations below are applicable to materials 1-7.

Co-integrating long-term equation:

$$\begin{aligned} \text{LN}(\text{MUI}(\cdot)/\text{QR}(\cdot)) & \quad \text{[material intensity]} \\ = & \text{BMU1}(\cdot,8) \\ + & \text{BMU1}(\cdot,9) * \text{LN}(\text{QR}(\cdot)) \quad \text{[output by material users]} \\ + & \text{BMU1}(\cdot,10) * \text{LN}(\text{PMAT1}(\cdot)) \quad \text{[price of material]} \\ + & \text{BMU1}(\cdot,11) * \text{LN}(\text{KR}(\cdot)/\text{QR}(\cdot)) \quad \text{[investment ratio by material users]} \\ + & \text{BMU1}(\cdot,12) * \text{LN}(\text{YRD}(\cdot)/\text{QR}(\cdot)) \quad \text{[R\&D ratio by material users]} \\ + & \text{BMU1}(\cdot,13) * (\text{MUM1}(\cdot)/\text{MUD1}(\cdot)) \quad \text{[trade ratio: import/domestic consumption]} \\ + & \text{ECM} \quad \text{[error]} \end{aligned}$$

Dynamic equation:

$$\begin{aligned} \text{DLN}(\text{MUI}(\cdot)/\text{QR}(\cdot)) & \quad \text{[material intensity]} \\ = & \text{BMU1}(\cdot,1) \\ + & \text{BMU1}(\cdot,2) * \text{DLN}(\text{QR}(\cdot)) \quad \text{[output by material users]} \\ + & \text{BMU1}(\cdot,3) * \text{DLN}(\text{PMAT1}(\cdot)) \quad \text{[price of material]} \\ + & \text{BMU1}(\cdot,4) * \text{DLN}(\text{KR}(\cdot)/\text{QR}(\cdot)) \quad \text{[investment ratio by material users]} \\ + & \text{BMU1}(\cdot,5) * \text{DLN}(\text{YRD}(\cdot)/\text{QR}(\cdot)) \quad \text{[R\&D ratio by material users]} \\ + & \text{BMU1}(\cdot,6) * \text{D}(\text{MUM1}(\cdot)/\text{MUD1}(\cdot)) \quad \text{[trade ratio: import/domestic consumption]} \\ + & \text{BMU1}(\cdot,7) * \text{ECM}(-1) \quad \text{[lagged error correction]} \end{aligned}$$

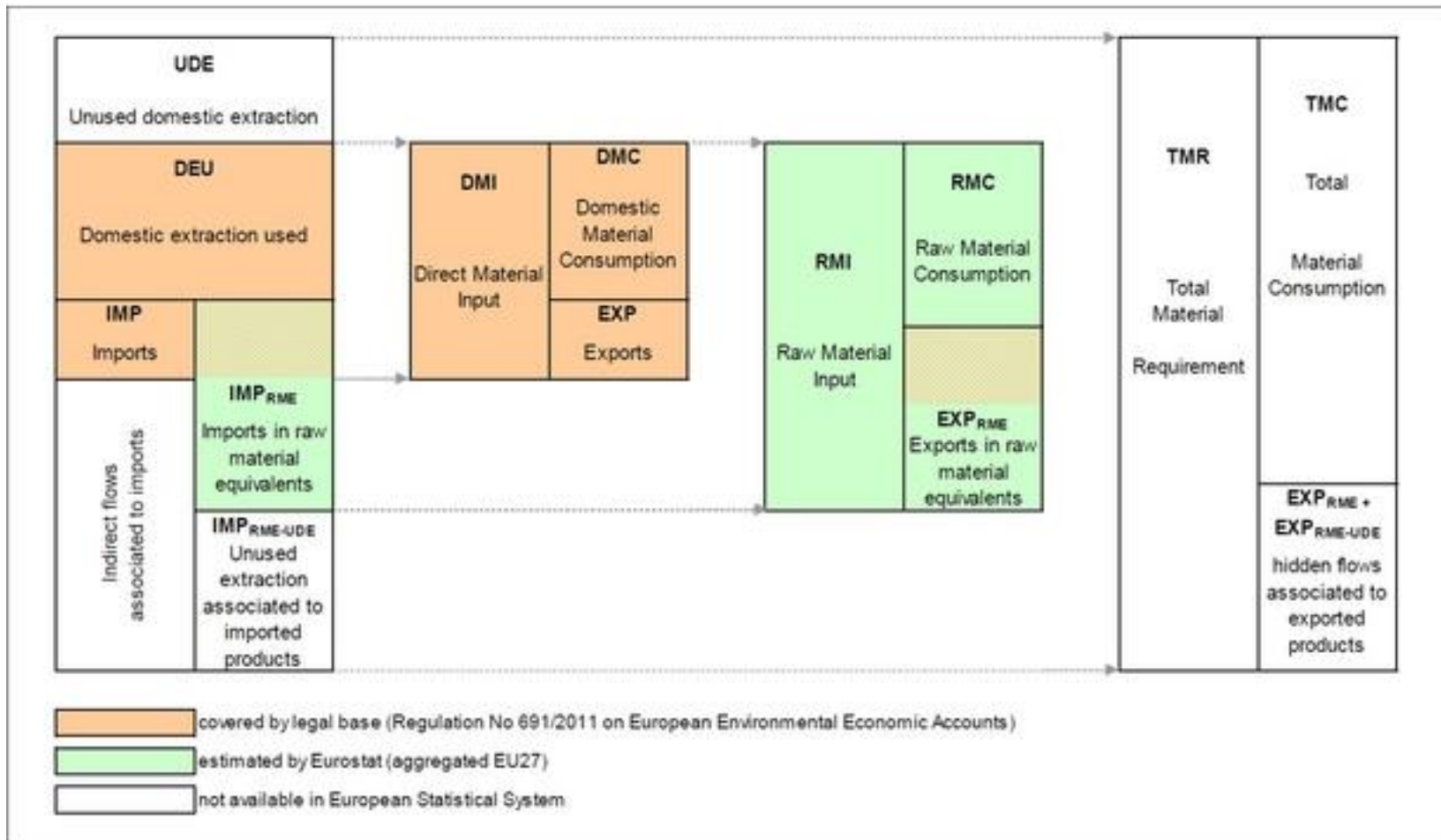
Restrictions:

$$\begin{aligned} \text{BMU1}(\cdot,2 \dots 9) & \geq 0 & \quad \text{['right sign']} \\ \text{BMU1}(\cdot,3 \dots 4 \dots 5 \dots 9 \dots 10 \dots 11) & \leq 0 & \quad \text{['right sign']} \\ 0 > \text{BMU1}(\cdot,7) & > -1 & \quad \text{['right sign']} \end{aligned}$$

Definitions:

BMU1 is a matrix of parameters (for material 1)  
MUI is a matrix of material use (for material 1) by material user for 16 material users and for 53 regions, 000s of tonnes  
QR is a matrix of output of products converted here to 16 material users and 53 regions, m euros at 2005 prices  
PMAT1 is the price of material 1, 2005=1.0  
KR is a matrix of investment by 16 material users and for 53 regions, m euros at 2005 prices  
YRD is a matrix of R&D by 16 material users and for 53 regions, m euros at 2005 prices  
MUM1 is a matrix of imports of material 1 by 16 material users and for 53 regions, 000s of tonnes  
MUD1 is a matrix of domestic extraction of material 1 by 16 material users and for 53 regions, 000s of tonnes

# Material flows variables



Source: Eurostat (2013)

# Material classifications

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## **MT Materials**

- 1 Food
- 2 Feed
- 3 Forestry
- 4 Construction Minerals
- 5 Industrial Minerals
- 6 Ferrous Ores
- 7 Non-ferrous ores
- 8 Water
- 9 Waste
- 10 Unallocated

## **MU Material Users**

- 1 Agriculture
- 2 Mining
- 3 Energy
- 4 Food, Drink & Tobacco
- 5 Wood and Paper
- 6 Chemicals
- 7 Non-metallic Minerals
- 8 Basic Metals
- 9 Engineering etc.
- 10 Other Industry
- 11 Construction
- 12 Transport
- 13 Services
- 14 Households
- 15 Unallocated

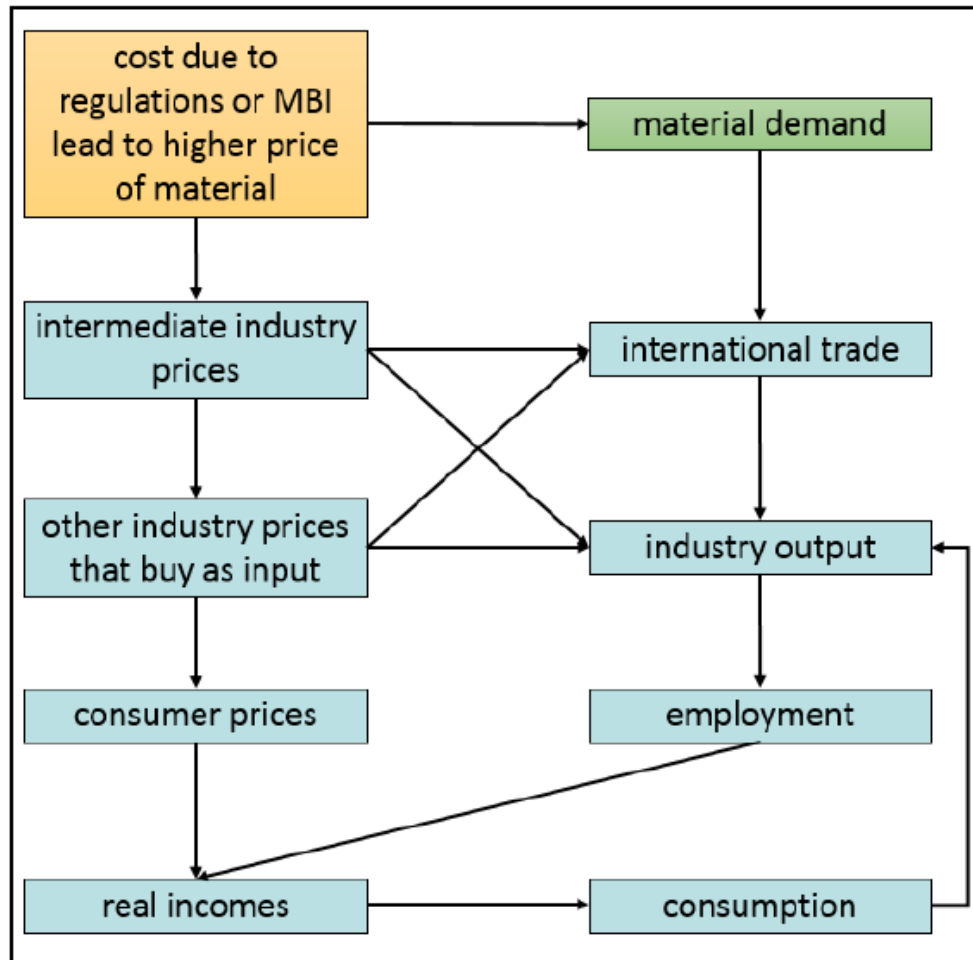
# Materials – policies options in E3ME

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- Materials taxes
- Regulations
- Resource efficiency
- Exogenous change in global commodity price

# E3ME linkages

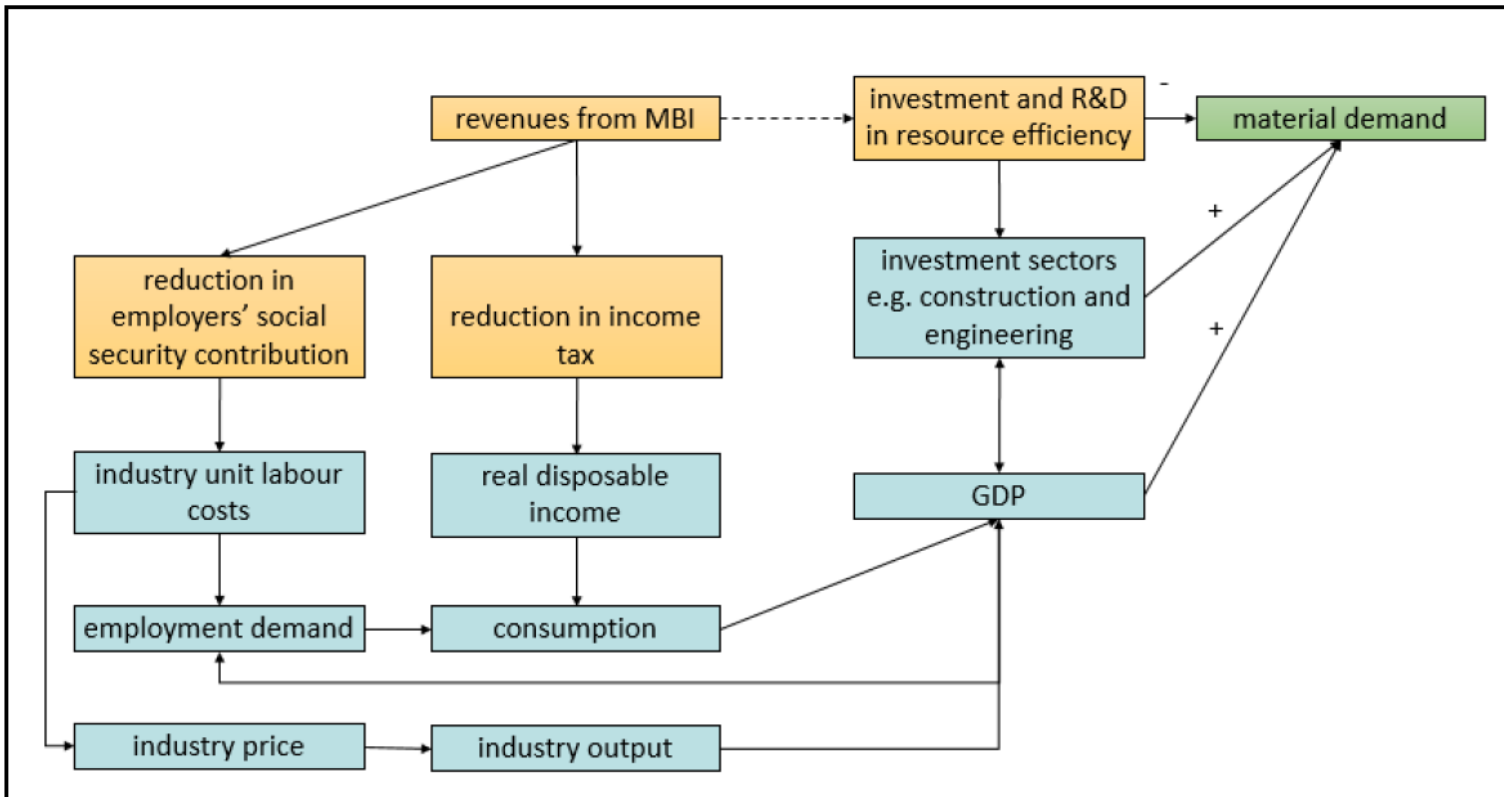
Figure 18: Main economic impacts from MBIs and regulation



[http://ec.europa.eu/environment/enveco/resource\\_efficiency/pdf/RMC.pdf](http://ec.europa.eu/environment/enveco/resource_efficiency/pdf/RMC.pdf)

# E3ME linkages

Figure 19: Main economic impacts from revenue recycling and investment, including the rebound effects



[http://ec.europa.eu/environment/enveco/resource\\_efficiency/pdf/RMC.pdf](http://ec.europa.eu/environment/enveco/resource_efficiency/pdf/RMC.pdf)



# Examples of material–energy nexus

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- Wind and solar technologies need raw material during construction phase
- Bioenergy impacts on food price
- Water and land use will be discussed in the next session

# Thank you!

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