Tracking energy efficiency progress and related emission reductions: The role of data

IEPPEC Training: 'Evaluation and MRV of Energy Savings and Efficiency Programmes and Measures and related GHG emission reductions'

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IEA Energy Data Center

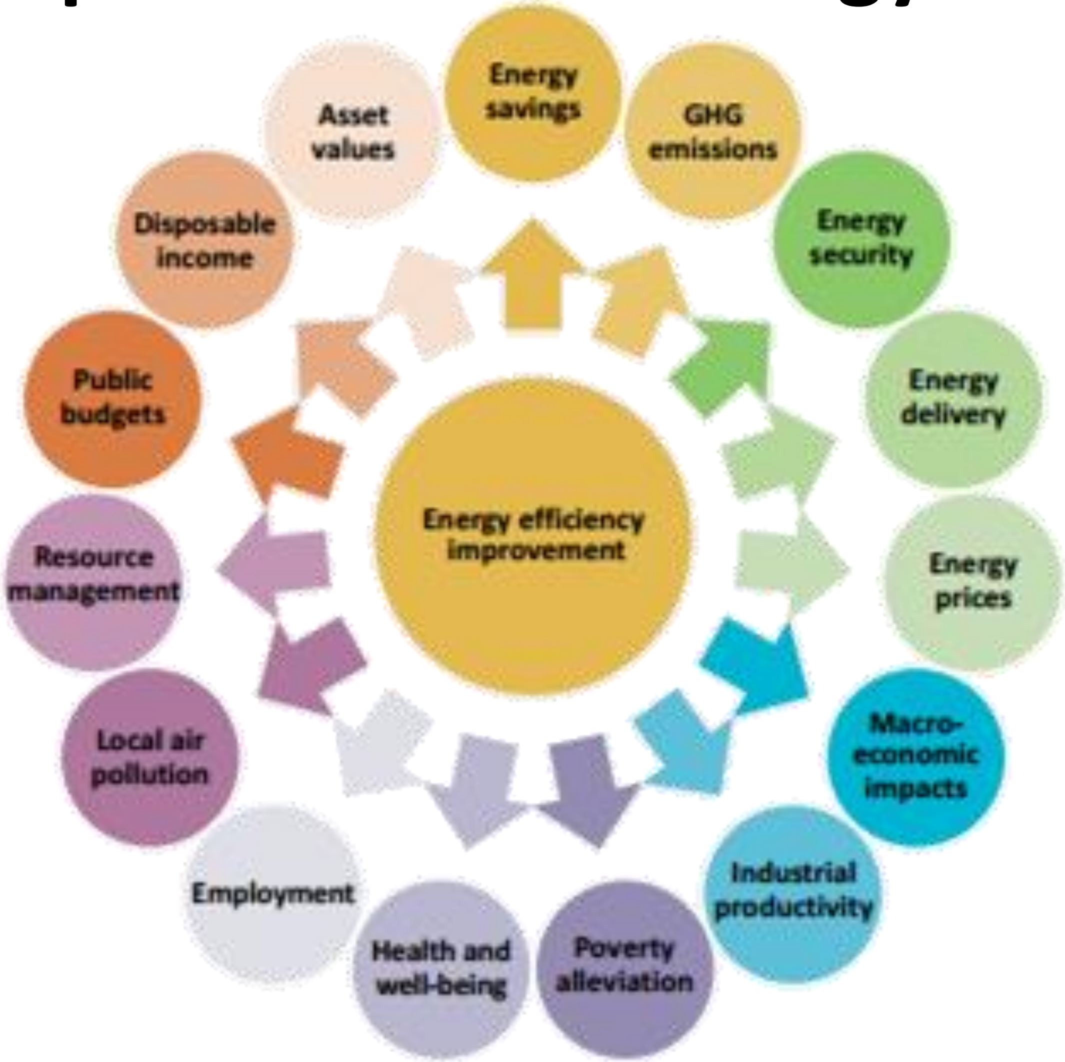
Overview

- **IEA work on energy efficiency monitoring**

- **How to estimate energy efficiency savings?**
  - **IEA Database - Data needed for the IEA analysis (Energy end-use and activity data)**
  - **Methods of data collection/estimations**
  - **Sector by sector typical indicators (Buildings, Industry, Transport)**
  - **Decomposition methodology: key concepts**

- **Exercise – Passenger Transport: Estimating Energy and CO_2 savings**

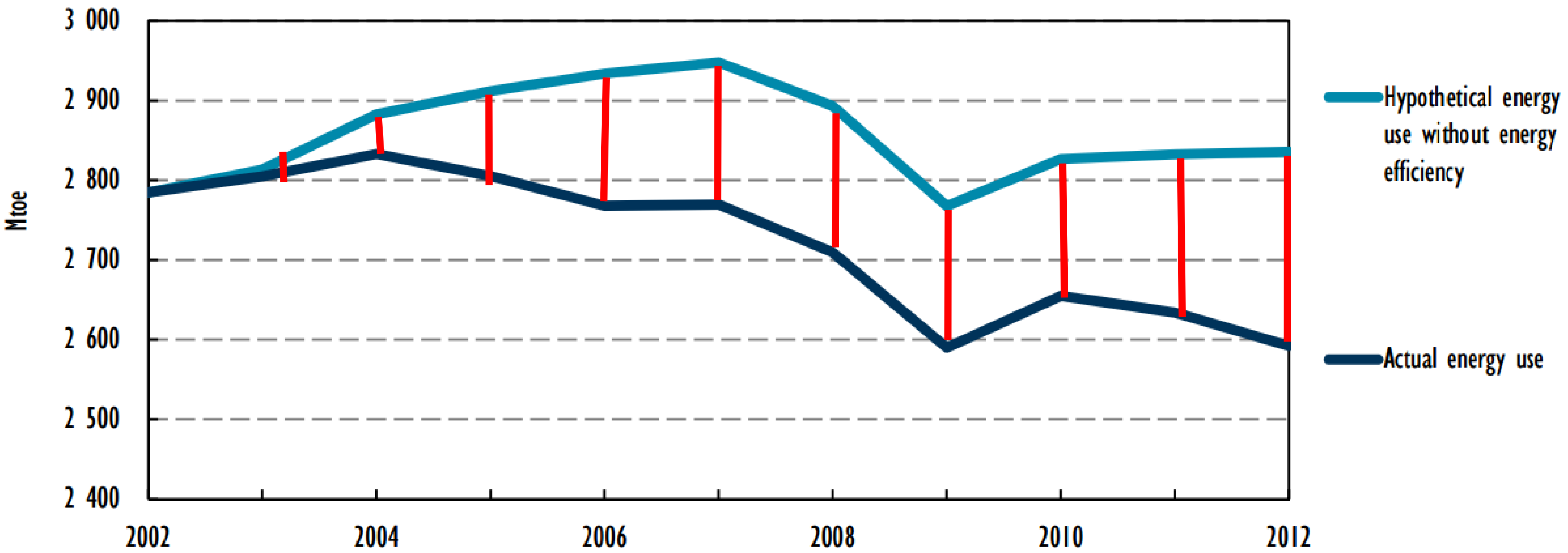
The multiple benefits of energy efficiency



Source: IEA, 2014

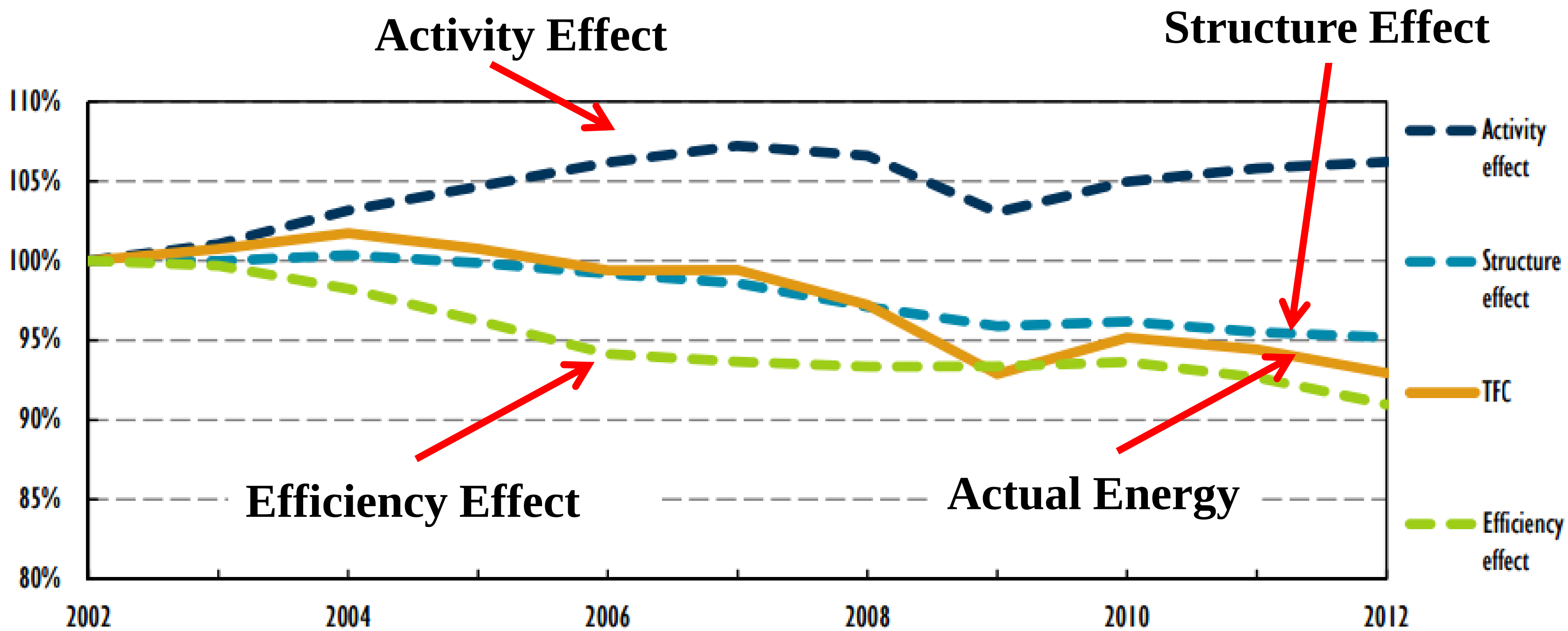
How to estimate energy savings?

Figure 2.3 Actual and hypothetical energy consumption in IEA-18, had efficiency not improved, 2002-12



Energy Efficiency savings during 10 years are equivalent to almost one year consumption

Need to disentangle different factors: activity, structure and efficiency



Notes: Values are indexed to 2002 levels. Decomposition results are multiplicative rather than additive.

Source: IEA Energy Efficiency Indicators database (2015 Edition)

From data to indicators and savings

- Most countries collect energy data for energy balances: on supply and demand for all energy products (e.g. oil, gas, coal, electricity, renewables)
- With these aggregated data some indicators can be calculated E.g Energy Intensity (TFC/GDP)
- However, aggregated indicators could give incomplete messages

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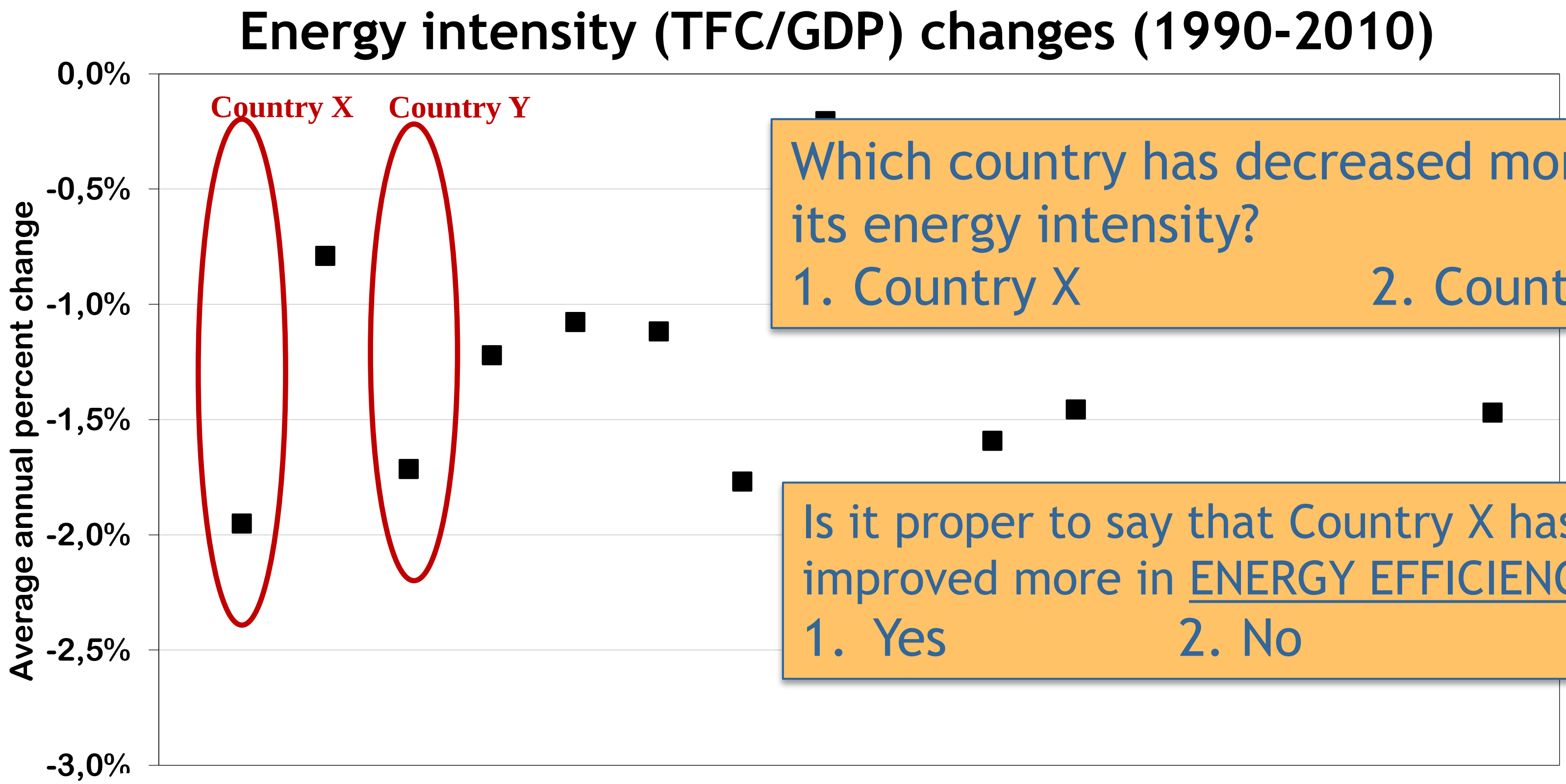
Understanding intensity changes



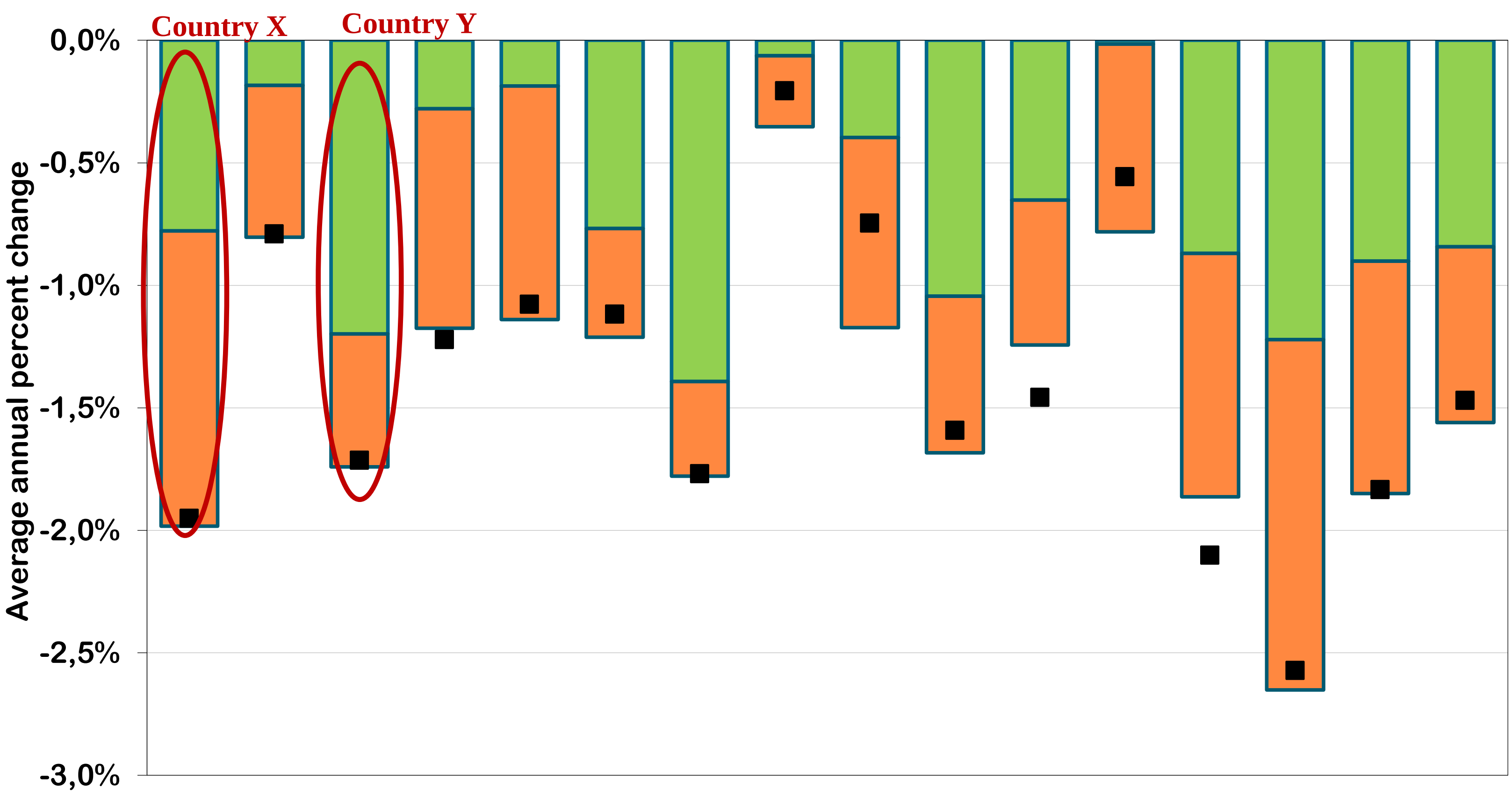
Which country has decreased more its energy intensity?

1. Country X
2. Country Y

Is it proper to say that Country X has improved more in <u>ENERGY EFFICIENCY</u>?

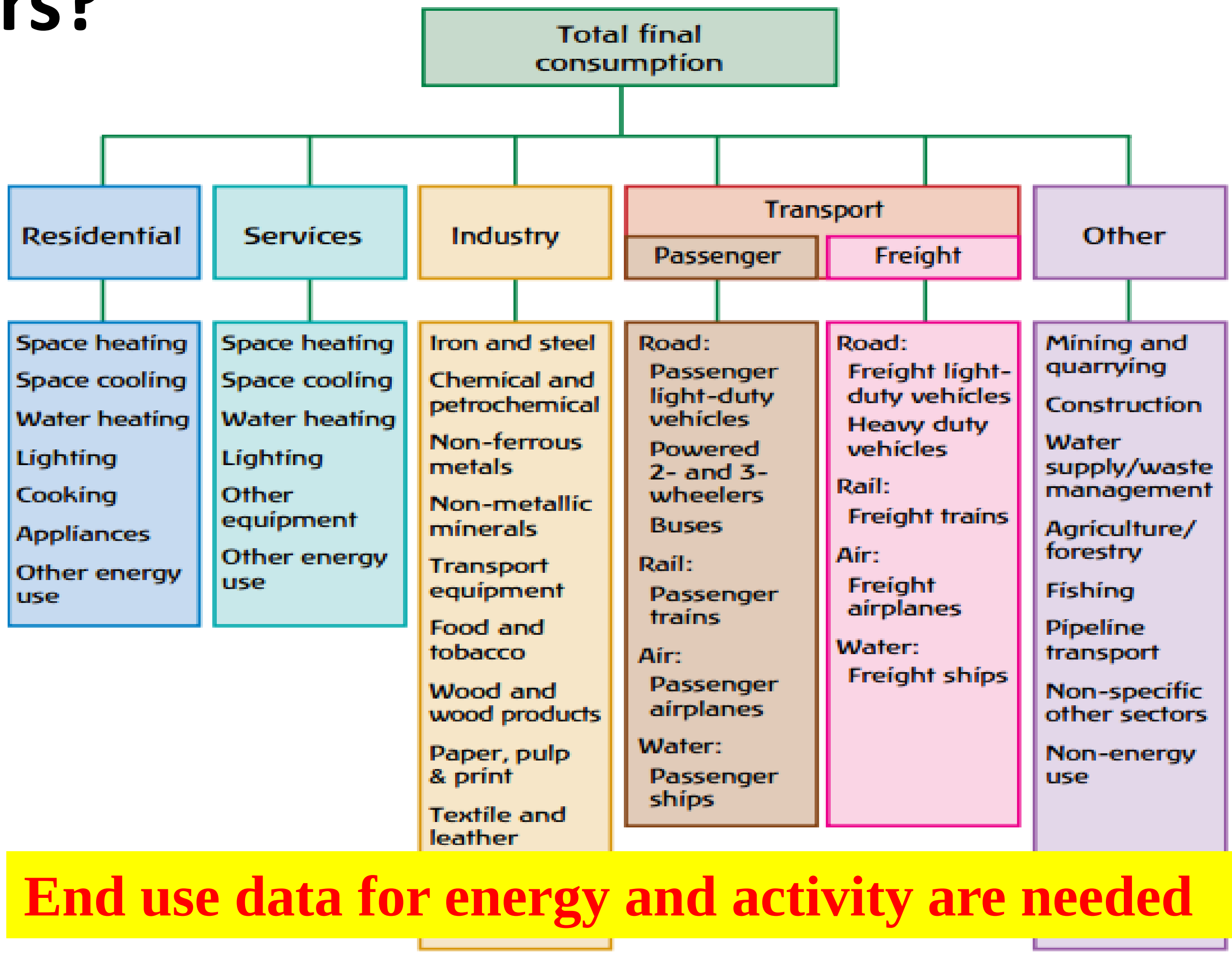
1. Yes
2. No

Understanding the efficiency effect



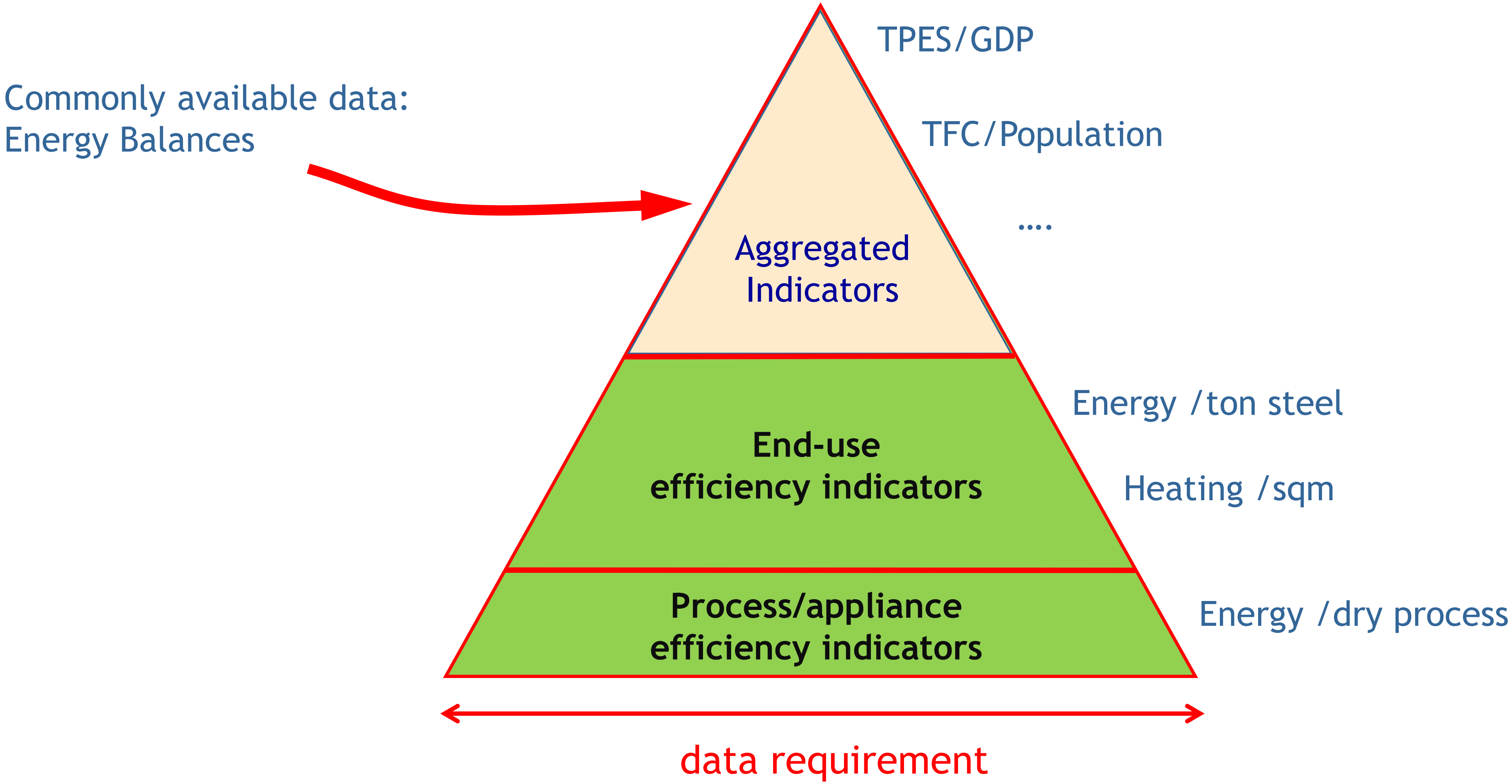
Aggregated indicators could be misleading

Where to monitor efficiency progress across sectors?



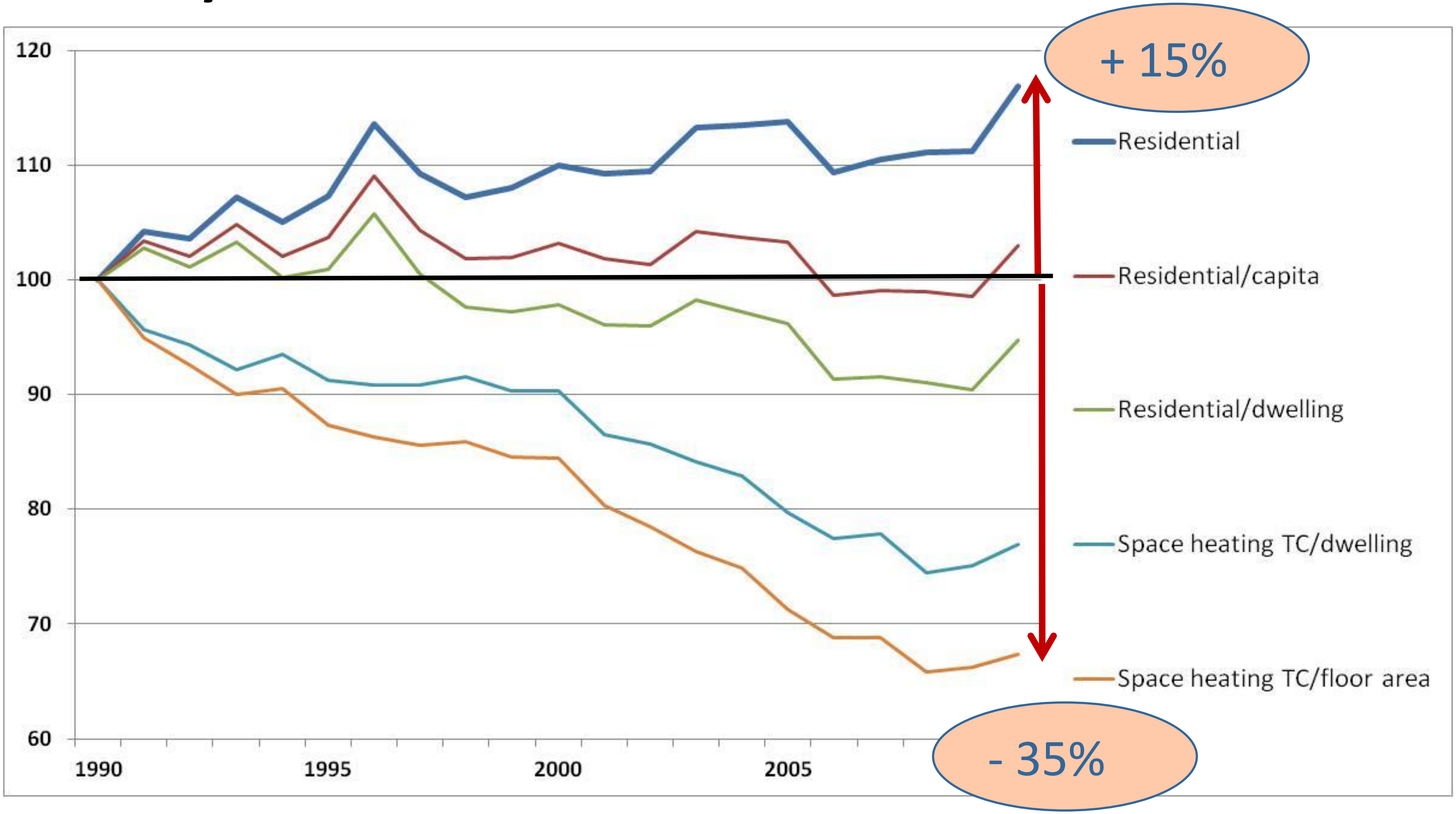
End use data for energy and activity are needed

Energy efficiency indicators: what level of detail?



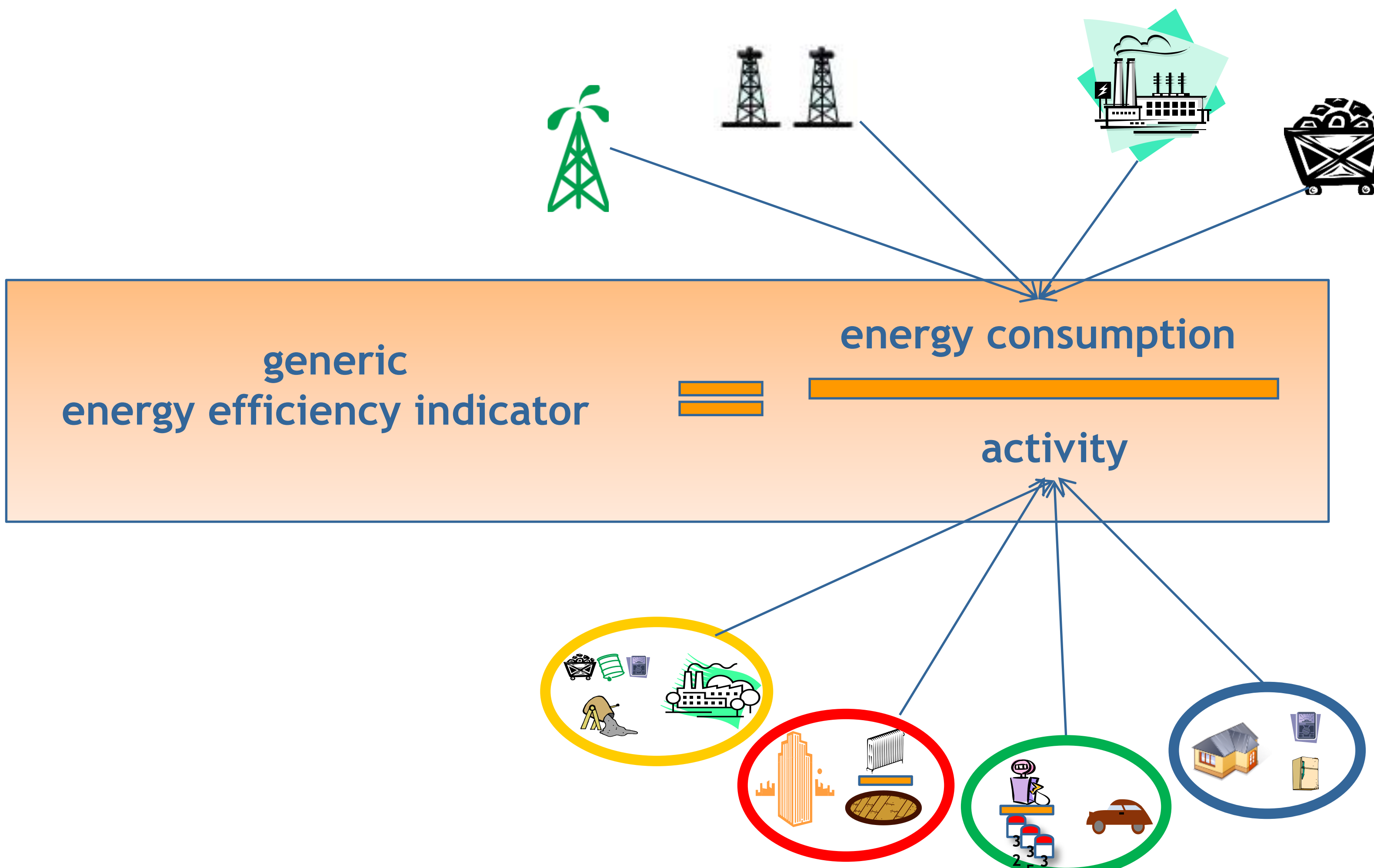
What are the data needed to build a minimum set of disaggregated indicators?

Beyond balances: appropriate metrics for sound energy efficiency assessments



Index: 1990=1. Data for IEA18 (Australia, Austria, Canada, Denmark, Finland, France, Germany, Ireland, Italy, Japan, Netherlands, Norway, Slovakia, Spain, Sweden, Switzerland, UK, USA). Source: IEA energy efficiency indicators database.
TC: Temperature Corrected.

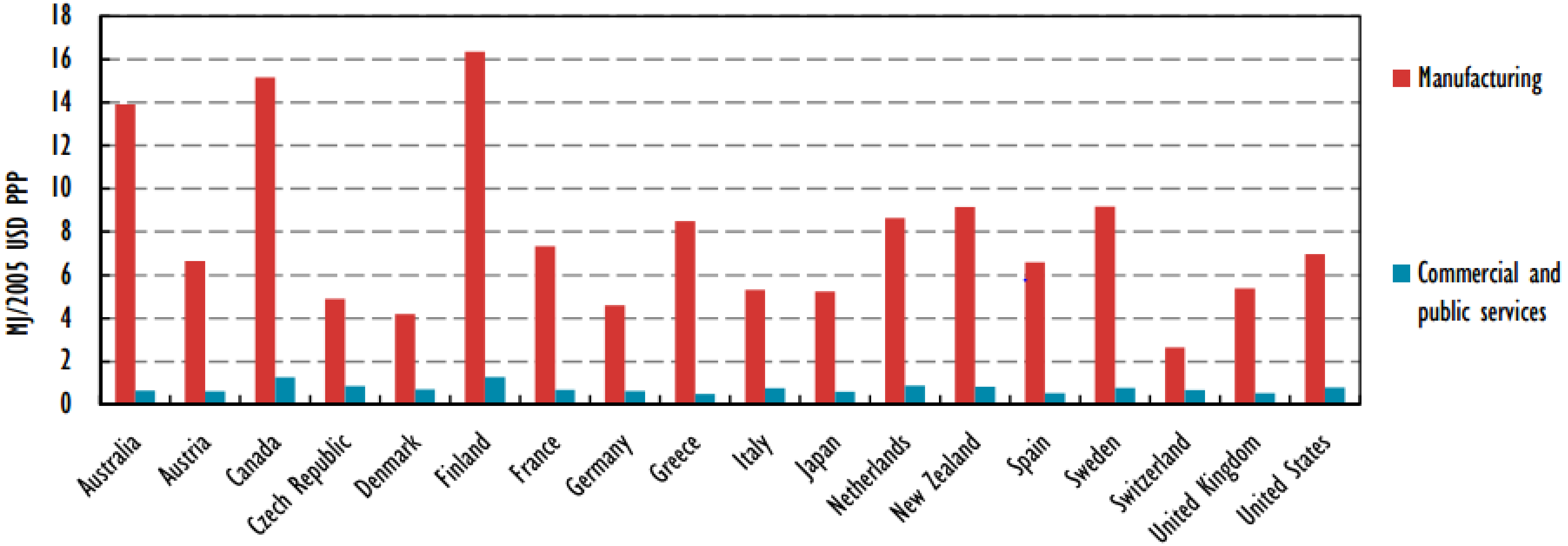
What is an energy efficiency indicator?



Examples of Energy Efficiency Indicators

Example of efficiency indicators: industry and services

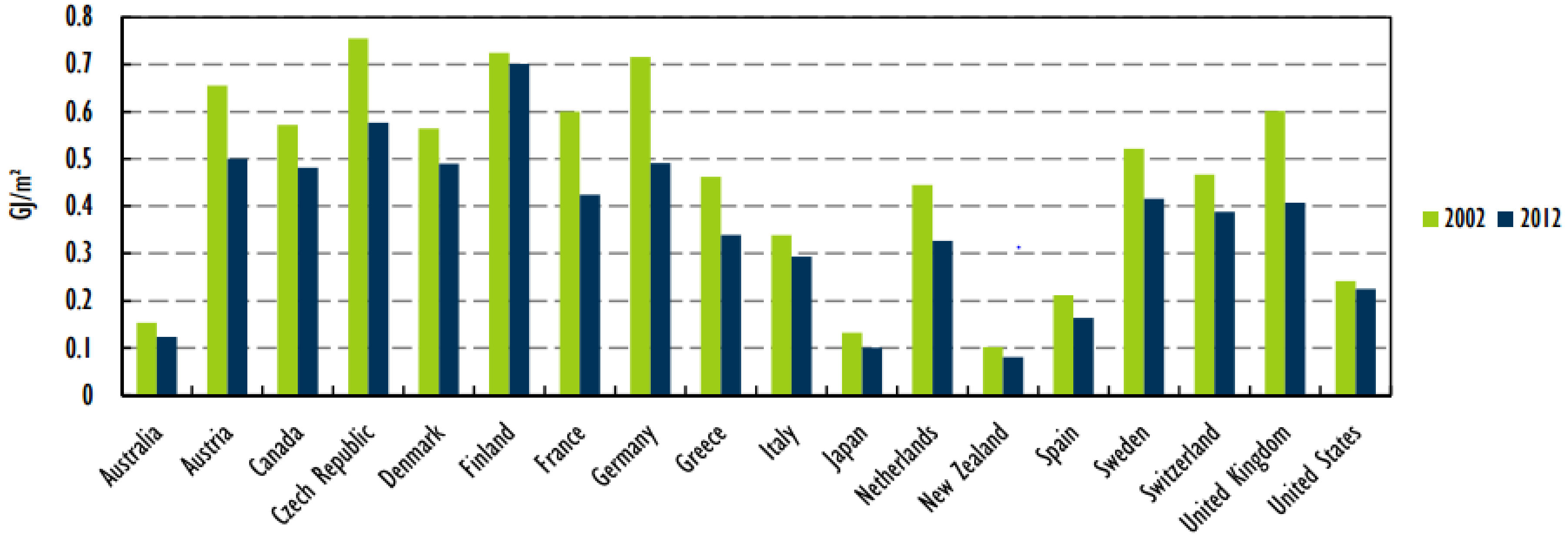
- Energy intensities (value added), 2012



Source: IEA Energy Efficiency Indicators (2015 Edition)

Example of efficiency indicators: buildings

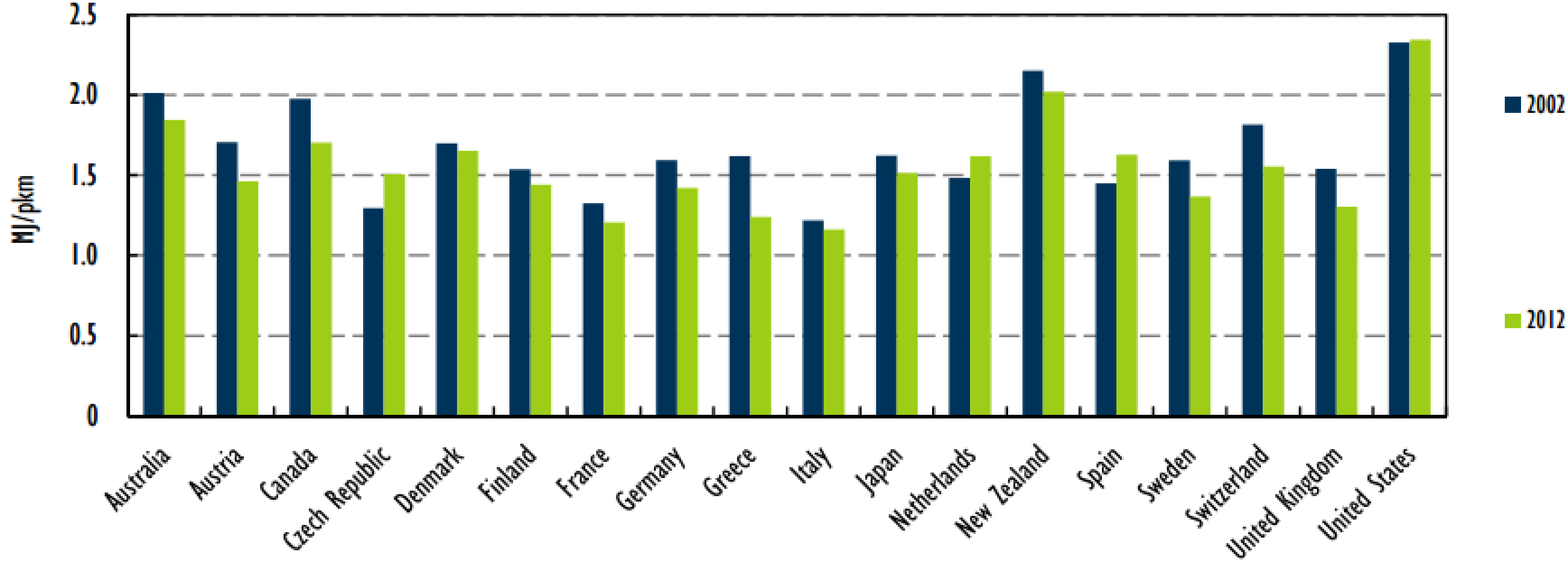
- Residential space heating (GJ/m²)



Source: IEA Energy Efficiency Indicators (2015 Edition)

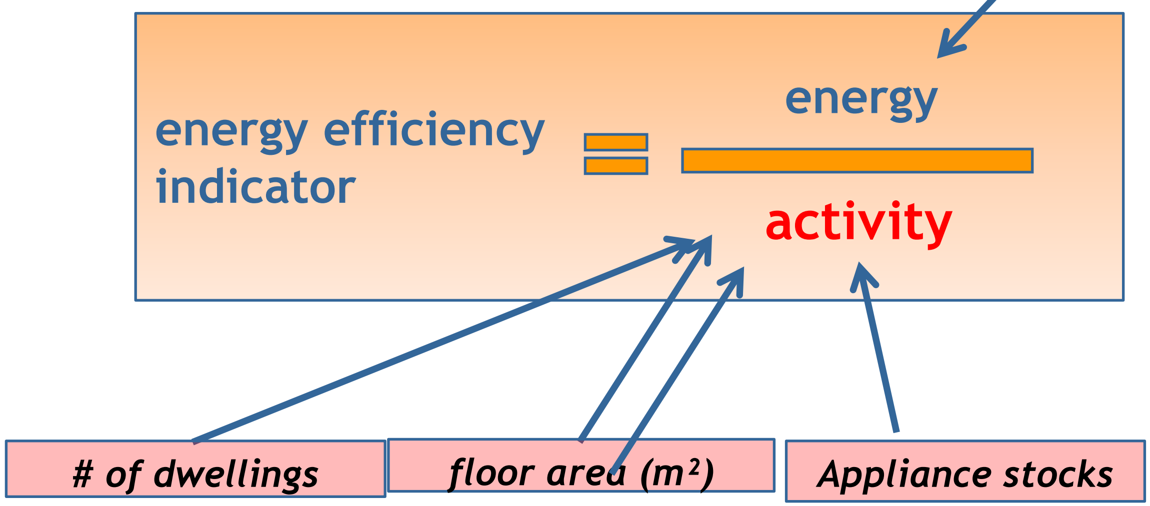
Example of efficiency indicators: transport

- **Passenger transport (MJ/pkm)**



Source: IEA Energy Efficiency Indicators (2015 Edition)

Indicators for Residential



For each end-use:

- Space heating*
- Space cooling*
- Water heating
- Cooking
- Lighting
- Appliances (energy use, stock, diffusion)
  - Refrigerator
  - Freezer
  - Dishwasher
  - Clothes washer
  - Clothes dryer
  - TV
  - Computers

* Temperature corrected, using HDD & CDD

Indicators for Services

For each end-use:

- Space heating*
- Space cooling*
- Lighting
- Other building use
- Non-building use

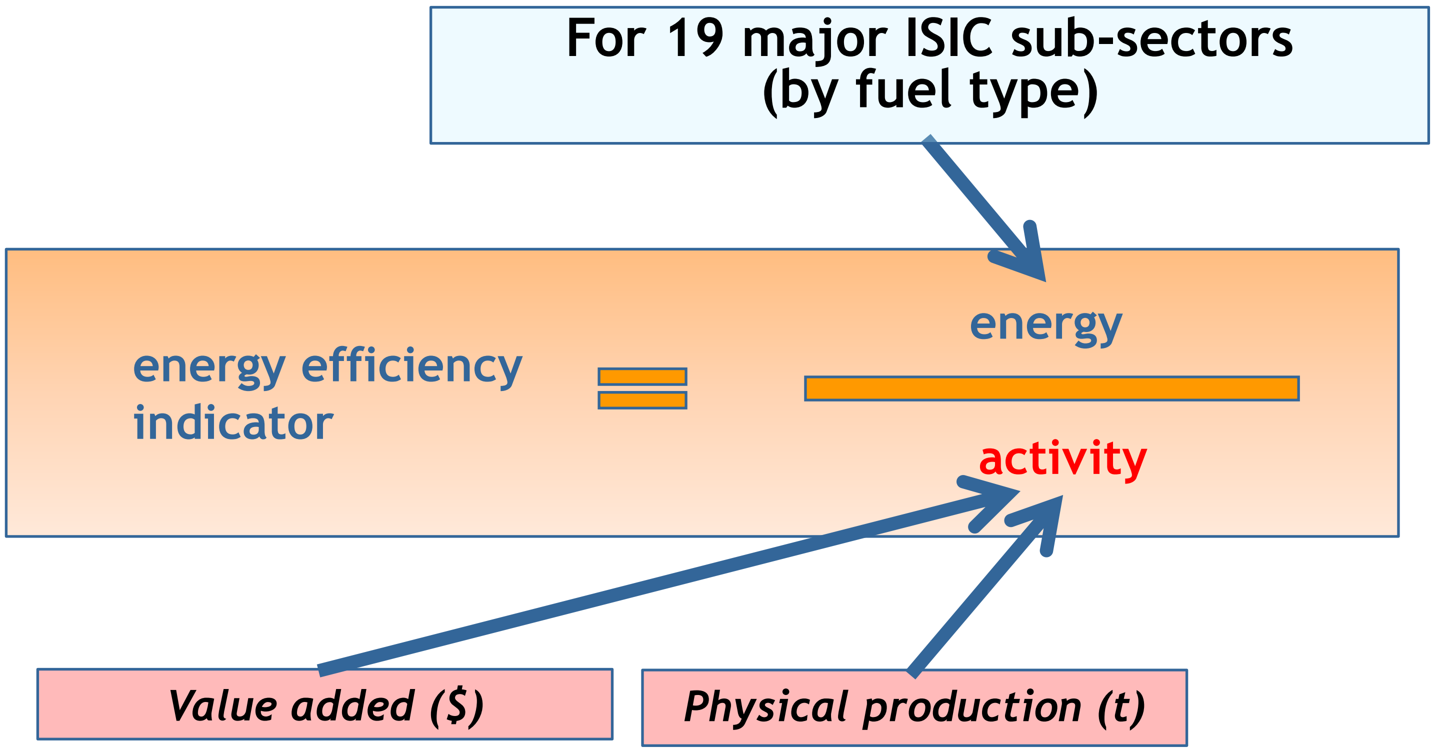
* Temperature corrected, using HDD & CDD

$$\text{energy efficiency indicator} = \frac{\text{energy}}{\text{activity}}$$

Activity:

- *Value added ($)*
- *Floor area (m^2)*
- *# of employees*

Indicators for Industry



- Paper
- Chemicals
- Other non-metallic mineral
- Basic metals

Indicators for Transport

- **Transport segment**
  - **passenger / freight**
- **Transport modes**
  - **road, rail, air, water, etc.**

energy efficiency indicator = energy / activity

Passenger-km **or** ***tonne-km***

Vehicle stock × *Distance travelled*

Transport: defining energy efficiency

- Transport **MORE** and **FURTHER** with **LESS** fuel consumption

- e.g. Is it more energy efficient to use public transport instead of personal cars? (Yes/No/Maybe)
  - Need detailed **ACTIVITY** data in addition to fuel consumption

Activity data needed for transport indicators

- **Activity and structure**
  - Stock of vehicles
  - Vehicle-kilometres
  - Passenger-kilometres
  - Tonne-kilometres

V-km = 2 vehicles * 5 km = 10 v-km

P-km = 6 passengers * 5 km = 30 p-km

Avg. load = p-km/v-km = 30 / 10 = 3 p/v

Typical energy efficiency indicators

- Residential
  - Space heating/m^2
  - Space cooling/m^2
  - Lighting/dwelling
  - Total appliances/dwelling
  - Specific appliance/stock (UEC)
- Industry
  - Total industry/Value added
  - Energy Subsector/VA subsector
    - Iron and steel/VA(Iron and steel)
  - Subsector/physical production
    - Iron and steel/Steel production
    - Cement/Cement production
- Services
  - Total energy/Value added
  - Space heating, cooling etc..
- Transport
  - Passenger transport/population
  - Passenger transport/vkm
  - Passenger transport/pkm
  - Freight transport/tkm

Collecting-estimating Energy Efficiency data

- Two Statistics general principles:
  - Collect what is needed – focus on priorities
  - Research already existing sources (e.g. transport ministry)
- How to collect data
  - Administrative sources – before starting new data collection
  - Surveying – with a representative sample
    - Expanding existing surveys
  - Measuring
    - Costly but very effective for monitoring specific equipment efficiency
  - Modelling – complementary to surveys or stand alone

What the IEA does in terms of EE data

- **To improve the EE data quality and promote sharing of experience**

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The IEA energy efficiency data collection

Energy Efficiency Indicators Template
country name

COUNTRY DATA SECTION (to be re

- MACRO ECONOMIC DATA
- COMMODITIES
- INDUSTRY
- SERVICES
- RESIDENTIAL — ances data
- TRANSPORT

Energy consumption & **Activity** data for:

- ➡ INDUSTRY
- ➡ SERVICES
- ➡ RESIDENTIAL
- ➡ TRANSPORT

IEA DATA and AGGREGATE INDICA

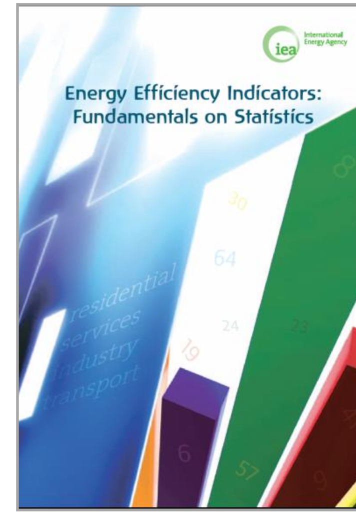
ELECTRICITY GENERATION	Electricity generation from combustible fuels and efficiencies
BASIC INDICATORS	Predetermined set of aggregate energy and activity indicators

SUPPORT TOOLS

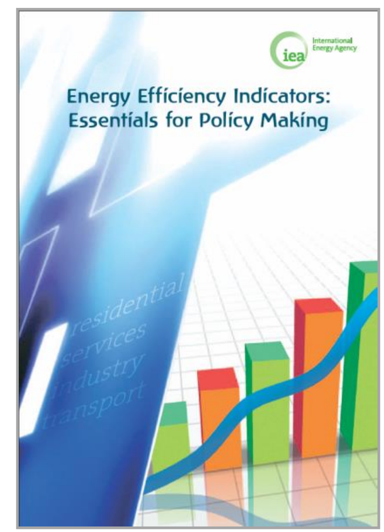
USER REMARKS	To incorporate comments associated to the data from the individual sheets
DATA COVERAGE	Generates a graphical summary of data coverage (completed vs. expected)
SINGLE INDICATOR GRAPHS	To generate a graph for one energy indicator
MULTIPLE INDICATORS GRAPHS	To generate a graph comparing trends from multiple indicators
CONSISTENCY CHECKS	To run the integrated consistency checks

Tools to develop indicators

- **Fundamentals on statistics:**
  to provide guidance on how to collect the data needed for indicators
  - **Includes a compilation of existing practices from across the world**
  - http://bit.ly/1RUqUkb



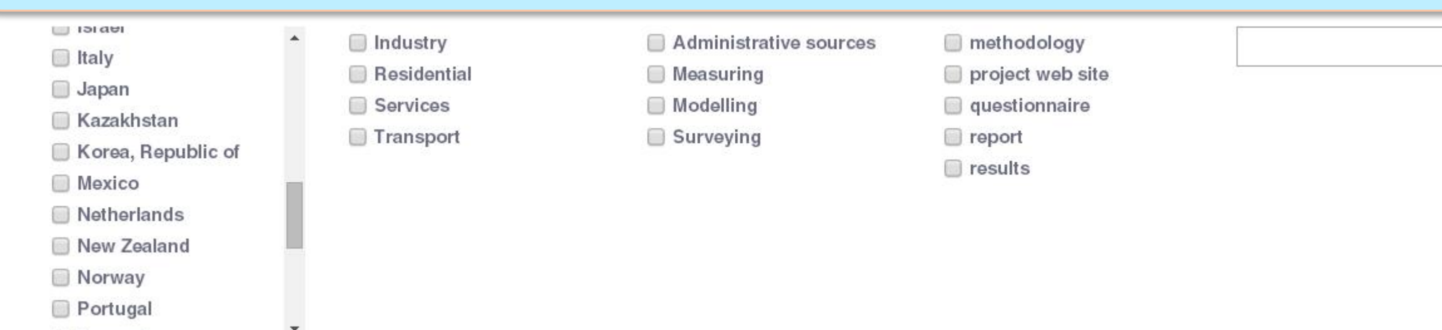
- **Essentials for policy makers:**
  to provide guidance to develop and interpret energy efficiency indicators
  - http://bit.ly/1stibAN
- **Available now and for free from the IEA website translated in different languages**



Country practices database

A platform to share expertise worldwide: practices are available in a searchable database. Share your practice!

https://www.iea.org/eeindicatorsmanual/



Quantitative session

- Decomposition key concepts
  - Energy savings
  - CO_2 savings
- Quantitative exercise
  - Passenger transport decomposition

Decomposition: key concepts

- **Purpose of decomposition**
  - Quantify contributions of pre-defined factors to the change in energy consumption
  - Measure effectiveness of energy policy and technology

Decomposition: Energy Savings

- **There are many methods but the IEA choose the LMDI**

  LMDI = Logarithmic Mean Divisia Index

- Could be applied to specific categories or technology (e.g. new buildings, diesel cars) to monitor impact of specific policies.

Decomposition: Energy Savings

- Decomposing energy consumption in
  - Activity effect
    - Change in the overall level of the activity.
  - Structure effect (Activity mix)
    - Change in the mix of activity.
  - Energy Intensity effect (Efficiency)
    - Changes in the sub-category energy intensities.

Decomposition: key concepts

Sum of each sector energy consumption

Activity of sector i

Energy intensity of sector i

$$E = \sum_{i} E_i = \sum_{i}^{n} A \cdot \frac{A_i}{A} \cdot \frac{E_i}{A_i} = A \cdot \sum_{i}^{n} (S_i \cdot I_i)$$

Energy consumption

Overall activity of all sectors

Activity share of sector i = structure effect

Decomposition: key concepts

Change due to the structure effect

$$E^T - E^0 = \Delta E_{tot} = \Delta E_{act} + \Delta E_{str} + \Delta E_{int}$$

Change in Energy consumption from time 0 to time T

Change due to the activity effect

Change due to the efficiency effect

Decomposition: key concepts
LMDI Formulas

Additive

$$\Delta E_{act} = \sum_i w_i \ln\left(\frac{Q^T}{Q^0}\right)$$

$$\Delta E_{str} = \sum_i w_i \ln\left(\frac{S^T}{S^0}\right)$$

$$\Delta E_{int} = \sum_i w_i \ln\left(\frac{I_i^T}{I_i^0}\right)$$

$$w_i = \frac{E_i^T - E_i^0}{\ln E_i^T - \ln E_i^0}$$

Decomposition: Energy Savings

- **Once the changes from each effect are calculated we:**
  - **We calculate the hypothetical energy use (HEU) if no efficiency improvements happened.**

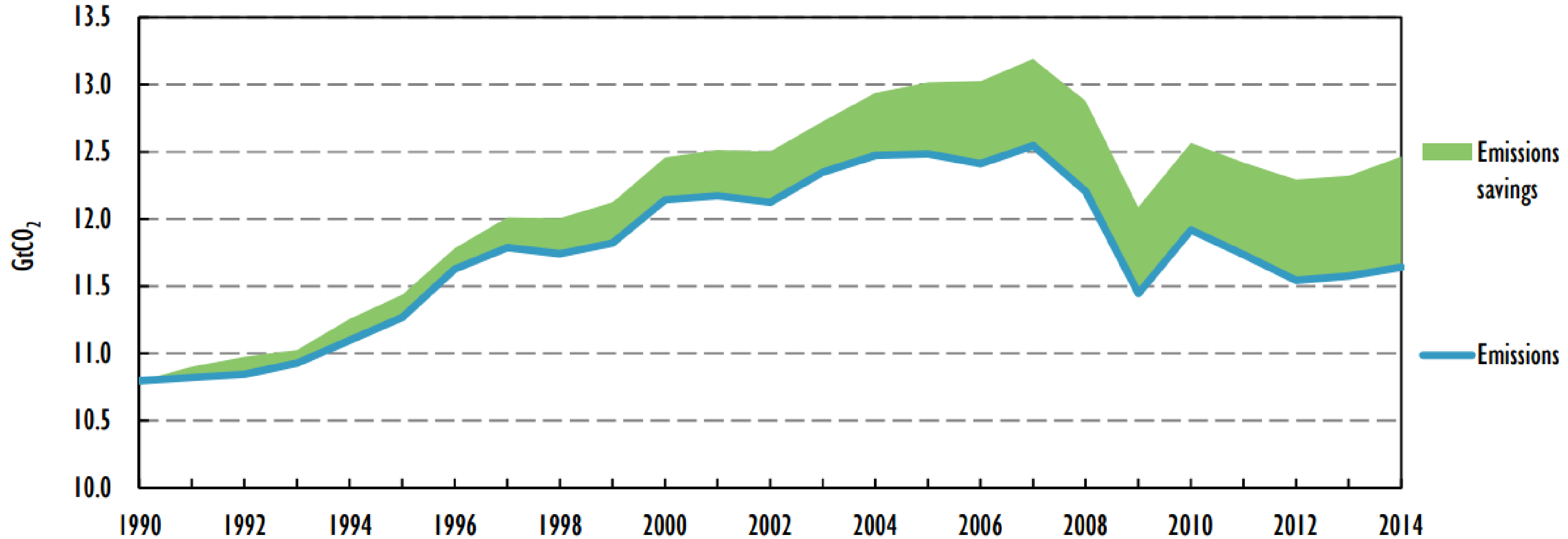
$$E^T - \Delta E_{int} = \quad = \Delta E_{act} + \Delta E_{str} + E^0$$

  - **We subtract actual energy to obtain the savings from energy efficiency improvement**

Savings = HEU – ACTUAL ENERGY

Decomposition: CO_2 Savings

Figure 1.12 IEA emissions from fossil fuel combustion, and emissions savings from energy efficiency investments, 1990-2014



Source: IEA (2014e), "CO_2 emissions by product and flow", *IEA CO_2 Emissions from Fuel Combustion Statistics* (database), available at http://dx.doi.org/10.1787/data-00430-en (accessed 1 June 2015).

Decomposition: CO_2 Savings

- <u>Further for CO_2</u> savings decomposing emissions in
  - Activity effect, Structure effect and Intensity effect
  - Carbon factor effect (CO_2/Energy)
    - Fuel mix effect
      - Decouple the fuel switching effect (e.g. Coal to Gas or renewables …)
    - Carbon intensity effect
      - Change in Emission per unit of energy consumed of fuels (Coal, Oil …)

$$G_t = A_t \cdot \sum_i \left[S_t^i \cdot I_t^i \cdot \sum_f \left(F_t^{i,f} \cdot C_t^{i,f} \right) \right]$$

EXERCISE

- **Country X wants to estimate the energy and emission savings in 2014 due to energy efficiency improvements from 1990-2014 in the passenger transport sector.**

Exercise – Decomposition passenger transport

Question 1: To decompose the passenger transport what data are needed?

Answer1:
Activity data: passenger-kilometer
Energy data: Passenger transport Energy consumption

Passenger	Unit	1990	2014
ACTIVITY DATA			
Private vehicles	10^9 PKM	742.690	796.992
Private vehicles	10^9 VKM	346.534	567.910
ENERGY DATA			
Private vehicles	PJ	1163.722	1373.689

***Tip: Activity data and Energy data**

Exercise – Decomposition passenger transport

Question2: Decomposition in activity factor and intensity (or efficiency) factor.

How do I calculate the intensity of the passenger transport?

Answer2: Energy/pkm

Passenger	Unit	1990	2014
ACTIVITY DATA			
Private vehicles	10^9 PKM	742.690	796.992
V-km			
Private vehicles	10^9 VKM	346.534	567.910
ENERGY DATA			
Private vehicles	PJ	1163.722	1373.689
PARAMETERS FOR DECOMPOSITION			
Intensity			
Private vehicles	MJ/pkm	1.567	1.724

$$\frac{E}{A} \qquad \frac{MJ}{pkm}$$

Exercise – LMDI Additive Method

Calculating the savings in 2014

$$E^T - E^0 = \Delta E_{tot} = \Delta E_{act} + \Delta E_{str} + \Delta E_{int}$$

Additive

$$\Delta E_{act} = \sum_i w_i \ln\left(\frac{Q^T}{Q^0}\right)$$

$$\Delta E_{str} = \sum_i w_i \ln\left(\frac{S^T}{S^0}\right)$$

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ENERGY DATA			
Private vehicles	PJ	1163.722	1373.689

PARAMETERS FOR DECOMPOSITION			
Intensity			
Private vehicles	MJ/pkm	1.567	1.724

LMDI I Decomposition Additive -Fixed			
Coefficients wi			
Private vehicles	'	0.00	1265.80

$$w_i = \frac{E_i^T - E_i^0}{\ln E_i^T - \ln E_i^0}$$

Exercise – LMDI Additive Method

Calculating the savings in 2014

Continue..

$$E^T - E^0 = \Delta E_{tot} = \Delta E_{act} + \Delta E_{str} + \Delta E_{int}$$

PARAMETERS FOR DECOMPOSITION			
Intensity			
Private vehicles	MJ/pkm	1.567	1.724
LMDI I Decomposition Additive -Fixed			
Coefficients wi			
Private vehicles		0.00	1265.80
Intensity			
wi*ln(It/I0)			
Private vehicles		0.00	120.64
Intensity Decomposition			
Dact annual		0.000	120.644
HEU Intensity Annual	PJ	1163.722	1253.045
Savings	PJ	0.000	-120.644

Additive

$$\Delta E_{act} = \sum_i w_i \ln\left(\frac{Q^T}{Q^0}\right)$$

$$\Delta E_{str} = \sum_i w_i \ln\left(\frac{S^T}{S^0}\right)$$

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$$w_i = \frac{E_i^T - E_i^0}{\ln E_i^T - \ln E_i^0}$$

Exercise – LMDI Additive Method

Calculating the savings in 2014

$$E^T - E^0 = \Delta E_{tot} = \Delta E_{act} + \Delta E_{str} + \Delta E_{int}$$

$$E^T - \Delta E_{int} = \Delta E_{act} + \Delta E_{str} + E^0$$

Hypothetical Energy use if no efficiency improvements happened

Additive

$$\Delta E_{act} = \sum_i w_i \ln\left(\frac{Q^T}{Q^0}\right)$$

$$\Delta E_{str} = \sum_i w_i \ln\left(\frac{S^T}{S^0}\right)$$

$$\Delta E_{int} = \sum_i w_i \ln\left(\frac{I_i^T}{I_i^0}\right)$$

$$w_i = \frac{E_i^T - E_i^0}{\ln E_i^T - \ln E_i^0}$$

Intensity			
wi*ln(It/I0)			
Private vehicles		0.00	120.64
Intensity Decomposition			
Dact annual		0.000	120.644
HEU Intensity Annual	PJ	1163.722	1253.045
Savings	PJ	0.000	-120.644

Exercise – LMDI Additive Method

Calculating the savings in 2014

2014 Savings = HEU – Actual energy use

ENERGY DATA			
Private vehicles	PJ	1163.722	1373.689

Intensity			
wi*ln(It/I0)			
Private vehicles		0.00	120.64
Intensity Decomposition			
Dact annual		0.000	120.644
HEU Intensity Annual	PJ	1163.722	1253.045
Savings	PJ	0.000	-120.644

They are negative..
Means that efficiency as we have defined had a negative effect.

Exercise – Decomposition passenger transport

Question 3: Why efficiency savings are negative?

Tip: We calculated efficiency as Energy/pkm

Answer3: Pkm includes the number of passengers

If we take a look at occupancy – Passenger per vehicle = pkm/vkm we see that it decreased.

Therefore it is possible that the technical efficiency had a positive effect.

Occupancy			
passenger vehicles	**p/v**	2.143	1.403

Exercise – calculate the savings by adding an occupancy effect

Question 4: How do we define efficiency to decouple the occupancy effect?

Tip: use distance travelled

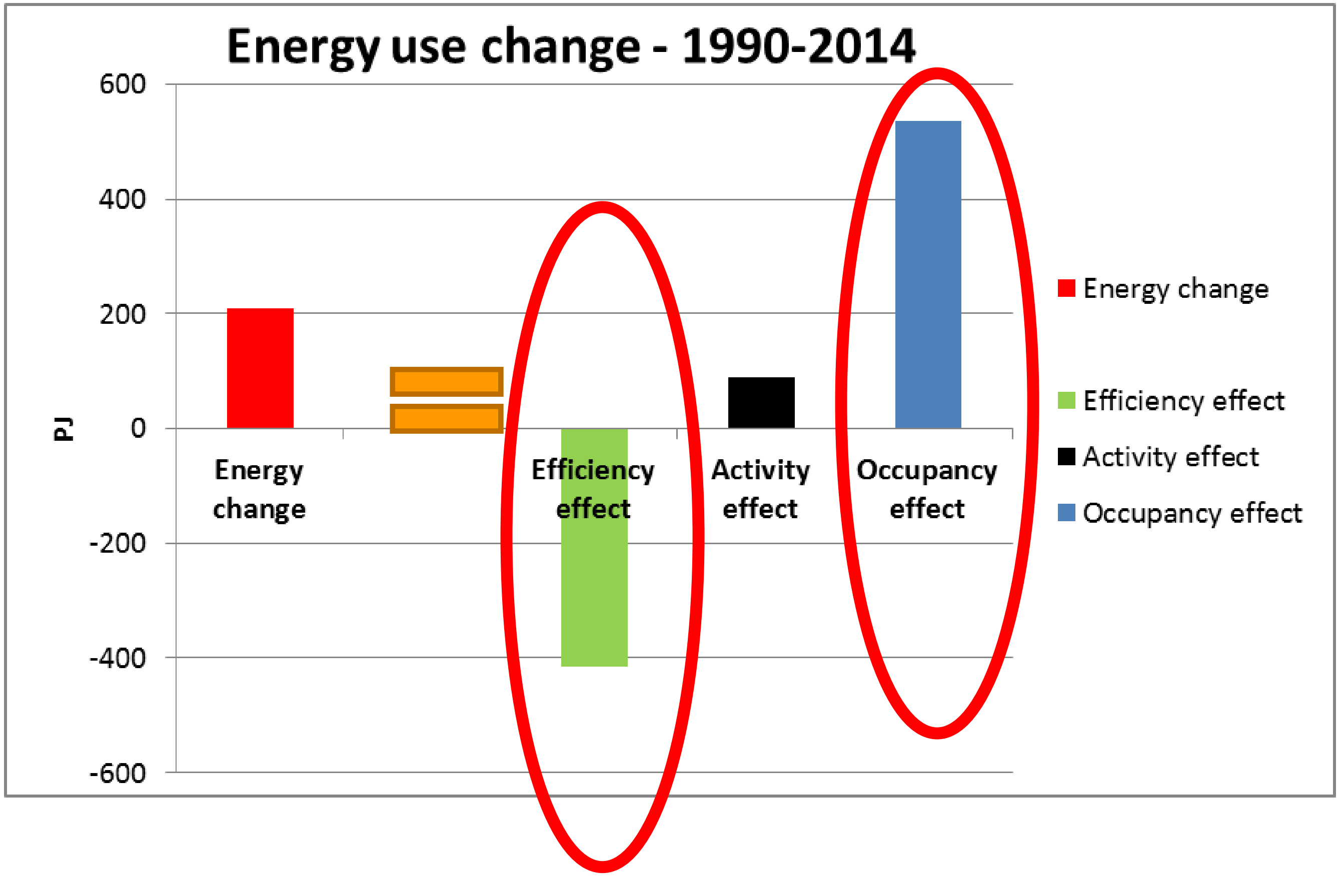
Answer4: Energy/vkm

Question5: How do we define occupancy effect

Answer5: vkm/pkm (inverse occupancy) because:

$$\frac{E}{pkm} = \boxed{\frac{E}{vkm}} \boxed{\frac{vkm}{pkm}}$$

Exercise – results



Exercise – calculate the emissions savings

In 1990 gasoline was 90% of total passenger transport while in 2014 only 60%

Assume that diesel cover the rest of energy consumption

Emission factors		
Gasoline	69.3	(t CO_2/TJ)
Diesel	74.06667	(t CO_2/TJ)

Question6 : Calculates the CO_2 savings. Where would you start from?

Answer: Start to calculate the average emission factor = CO_2/Energy

Total Emissions = Gasoline-energy * Gasoline-emission-factor + Diesel-Energy * Diesel-emission-factor

Average emission factor = Total emission / Total Energy

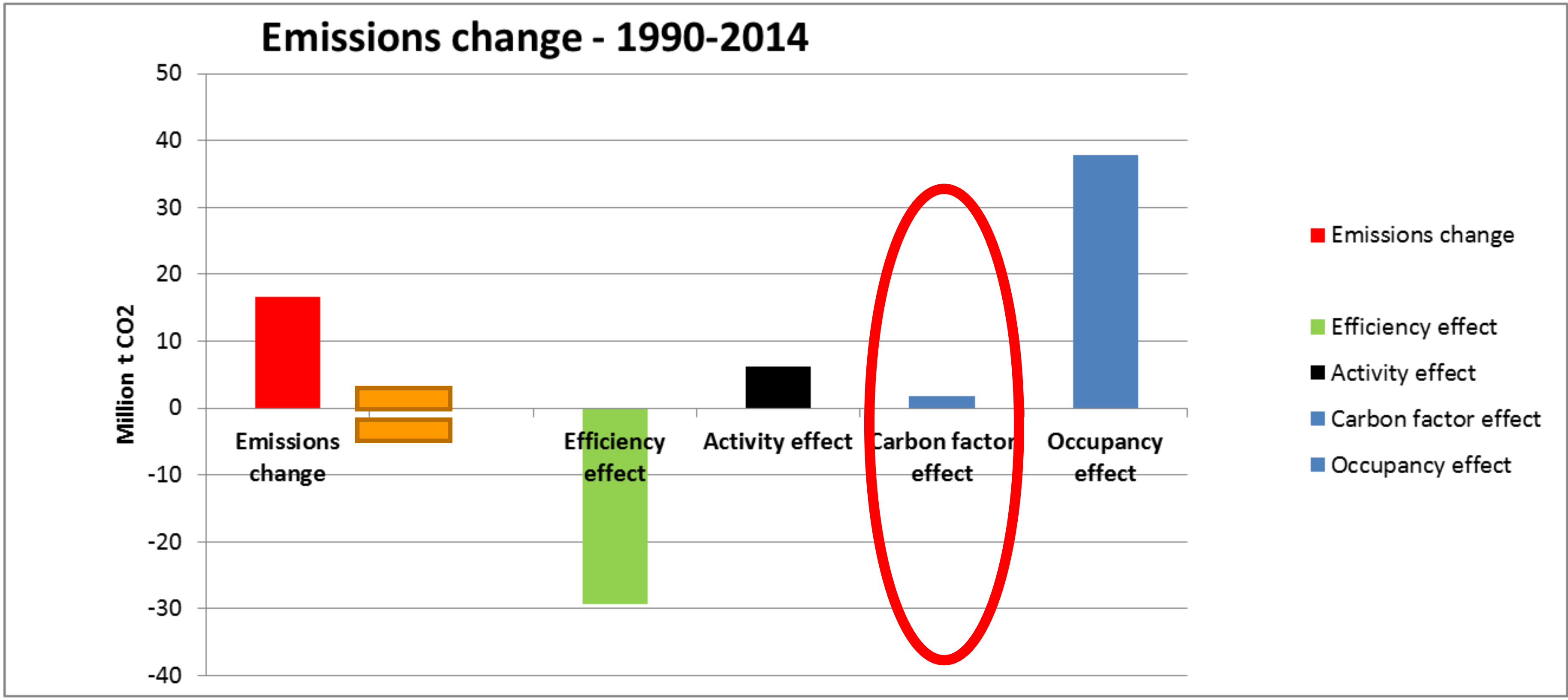
ENERGY DATA			
passenger vehicles - Gasoline	PJ	1047.350	824.214
passenger vehicles - Diesel		116.3722	549.475701
Total emissions	**Million t CO_2**	**81.20068**	**97.8158326**
Emission factor	**(t CO_2/TJ)**	**69.77667**	**71.2066667**

A simple way of calculating CO_2 savings would be multiplying the Emission factor to the savings calculated previously

Exercise – calculate the emissions savings

- In the case of this example the result would be reliable
- However, a carbon factor effect should be added in the decomposition
  - To account of the change on the average emission factor
    - (mainly due to fuel switching)
  - Switch from coal to gas can offset big amounts of emissions

Exercise – results



Thank you very much

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