Why did Canada's GDP and Energy Use Diverge after 1995?

Ralph Torrie[1,2], Chris Stone[1], David B. Layzell[1,3]

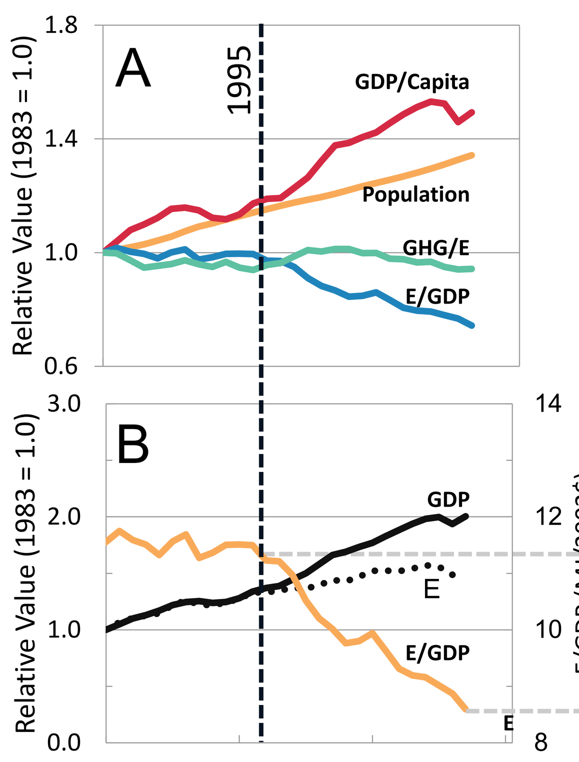
[1] Canadian Energy Systems Analysis Research (CESAR) Init., U Calgary, AB; [2]Torrie Smith Assoc. Coburg, ON; [3] Correspondance: dlayzell@ucalgary.ca

- INTRODUCTION -

Growth in the national economies (measured as Gross Domestic Product, **GDP**) are often correlated with increases in both fuel and electrical energy use (**E**) and greenhouse gas (**GHG**) emissions. This was the case in Canada between 1983-1995 (Fig. 1).

However, uncoupling GDP from E and GHG emissions can make an important contribution to climate change mitigation.

Since 1995, government data on Canada's energy systems has shown a divergence in GDP and E (Fig 1B). We want to know **Why**.



Why did Canada's GDP and energy use (E) diverge between 1995 & 2010?

-2.63 MJ/2002$
(~23% reduction)

Fig. 1. Changes in key parameters of Canada's Energy Systems

- METHODS -

Most data for these analyses were obtained from the Canadian Energy Systems Simulator (CanESS) model [1] which integrates large amounts of government database resources. Energy use was separated into the sectors (i) associated with the productive economy (E_P) & the household economy (E_H):

$$\frac{E_H}{GDP} = \frac{E_H/capita}{GDP/capita} \qquad \frac{E_P}{GDP} = \sum_i \left[\frac{GDP_i}{GDP} X \frac{E_i}{GDP_i}\right] = \sum_i S_i I_i$$

where S_i=GDP_i/GDP and is the structural factor (the share of GDP generated by sector i) and I_i=E_i/GDP_i and is the intensity factor (the energy use per dollar of value added in sector i).

Decompositional analysis was conducted using the Logarithmic Mean Divisia Index (LMDI-I) method [2] which uses the above equations to produce the following four factors that sum to the total change in energy intensity (Δ*E/GDP*) over the study period (T_1=1995 and T_2=2010):

Economic Structure Factor - changes in *E/GDP* due to changes in *GDP$_i$/GDP:*

$$\Delta\left(\frac{E}{GDP}\right)_{structure} = \sum_i L((E_i/GDP)^{T_2}, (E_i/GDP)^{T_1})\ ln\left(\frac{S_i^{T_2}}{S_i^{T_1}}\right)$$

Productive Economy Intensity Factor - changes in *E/GDP* due to changes in

$$\Delta\left(\frac{E}{GDP}\right)_{intensity} = \sum_i L((E_i/GDP)^{T_2}, (E_i/GDP)^{T_2})\ ln\left(\frac{I_i^{T_2}}{I_i^{T_1}}\right)$$

Personal Productivity Impact - changes in *E/GDP* due to changes in GDP/capita:

$$\Delta\left(\frac{E}{GDP}\right)_{productivity} = L((E_H/GDP)^{T_2}, (E_H/GDP)^{T_1}) ln\left(\frac{(GDP/capita)^{T_1}}{(GDP/capita)^{T_2}}\right)$$

Household Per Capita Energy Intensity - changes in *E/GDP* due to changes in per capita residential and personal transportation energy use:

$$\Delta\left(\frac{E}{GDP}\right)_{per\ capita\ intensity} = L((E_H/GDP)^{T_2}, (E_H/GDP)^{T_1}) ln\left(\frac{(E_H/capita)^{T_2}}{(E_H/capita)^{T_1}}\right)$$

Where $L(a,b) = \frac{a-b}{\ln(a/b)}$, for $a \neq b$ and $L(a,b) = 0$ when $a = b$

These equations were applied to annual data for the study period, using annual chained analysis. A similar approach was used for subsequent decomposition analyses within the various sectors.

- RESULTS -

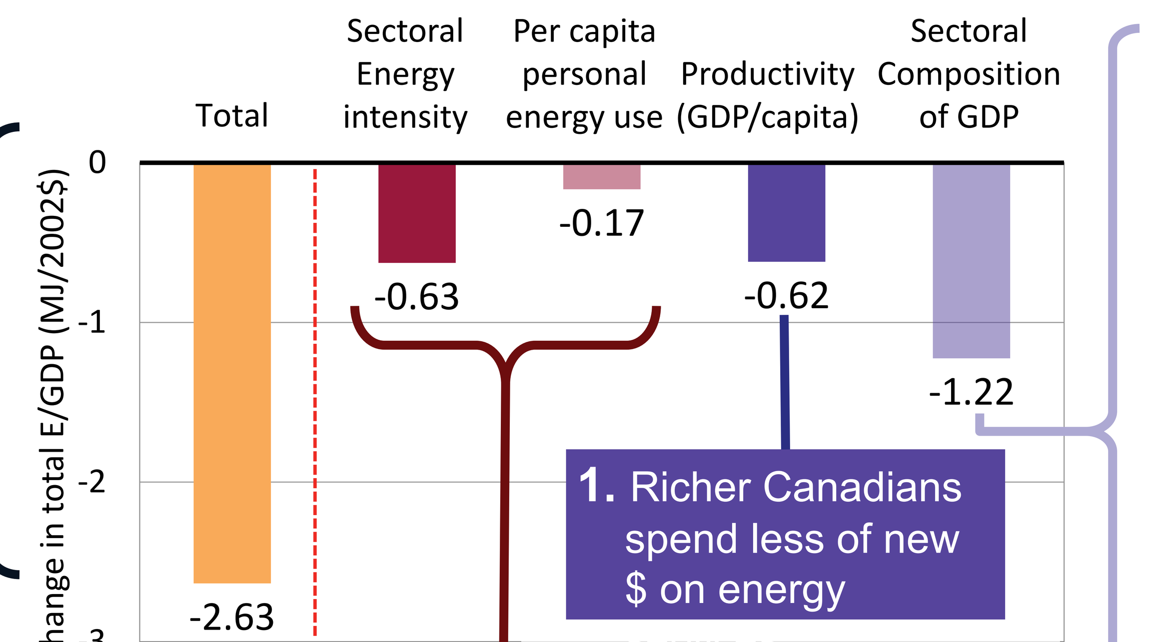


Fig. 2. Factors contributing to ΔE/GDP

2. Loss in manufacturing more than compensated for by an increase in the Commercial & Institutional (C&I) sectors.

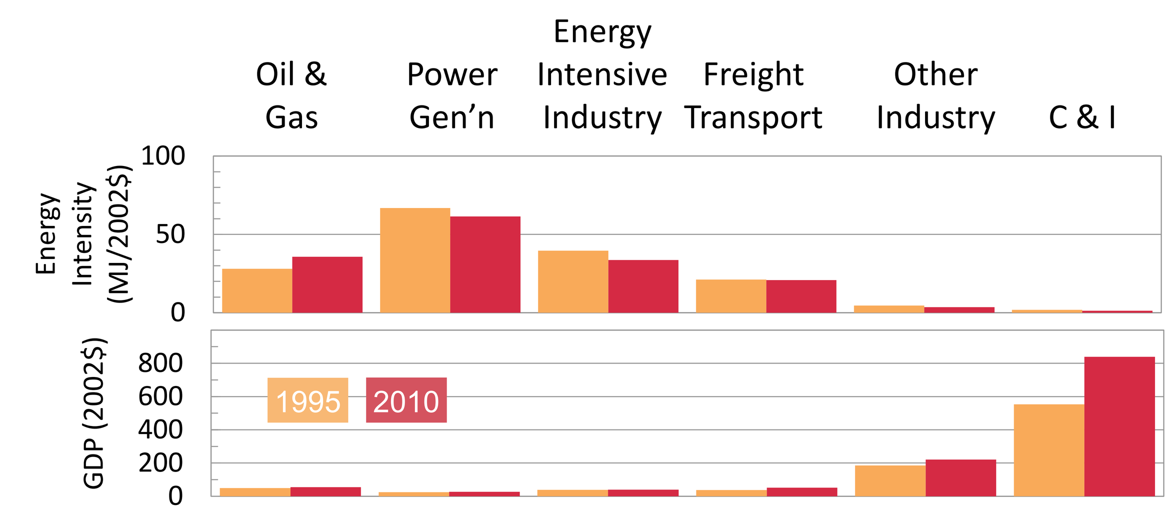


Fig. 3. Changes (1995-2010) in energy intensity & GDP of Sectors in Canadian Economy

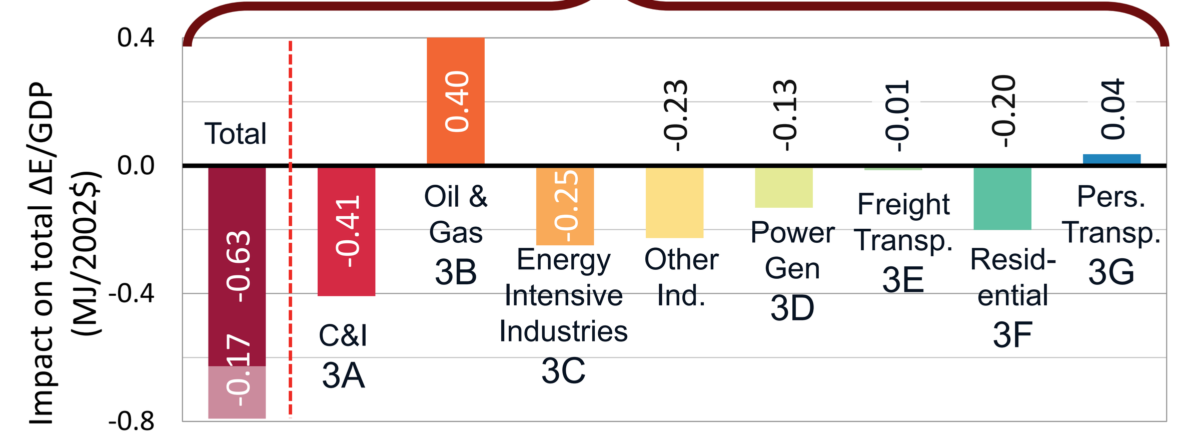


Fig. 4. Breakdown of impacts from sectoral changes on total ΔE/GDP

3. A net decrease in energy intensity (increase in energy efficiency) of Canada's productive and household economies.

Note that large differences exist among sectors in the contribution to net energy intensity…

…and within each sector, large differences exist in the factors contributing to energy intensity change, as shown below.

3A. The **C&I sector** required less floor area per $GDP and had lower energy use/m², due to more efficient buildings.

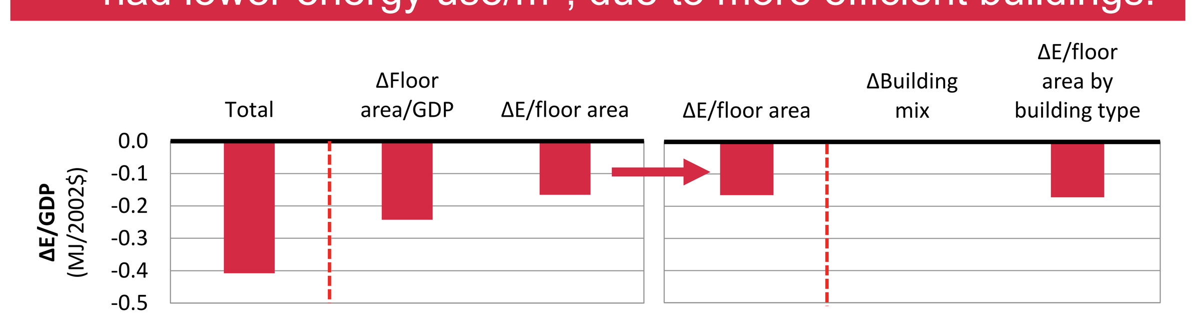


Fig. 5. Changes in ΔE/GDP of the C&I sectors between 1995 & 2010

3B. **Oil & gas** showed an increase in E/GDP due to higher energy costs for extraction. Pipeline and refinery segments showed efficiency improvements:

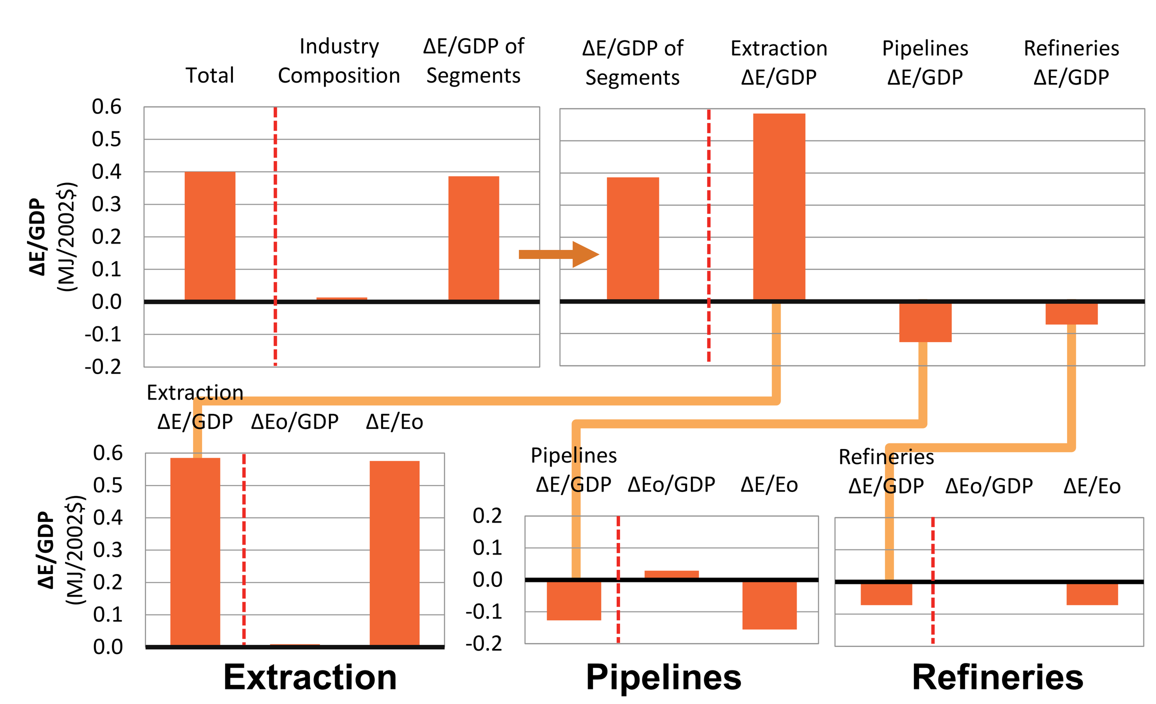


Fig. 6. Changes in ΔE/GDP of the oil & gas sector between 1995 & 2010

3C. The **energy intensive industries** all decreased in their energy use/GDP except for mining:

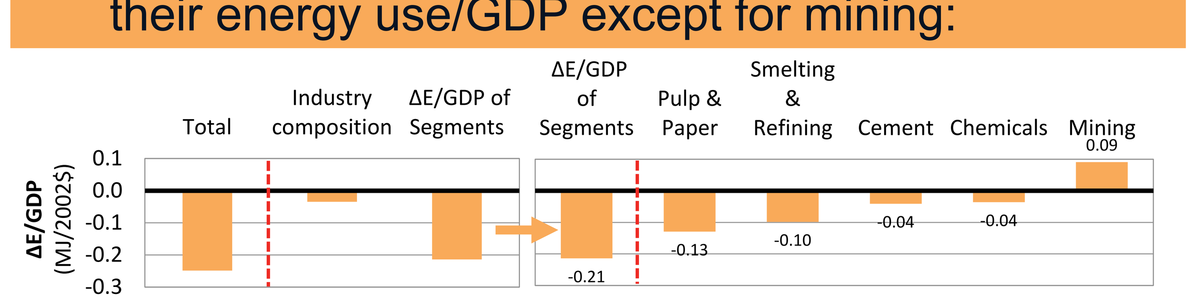


Fig. 7. Changes in ΔE/GDP of the energy intensive sectors between 1995 & 2010

3D. **Power generation** showed a decrease in energy intensity due to improved efficiency & a shift in the generation mix.

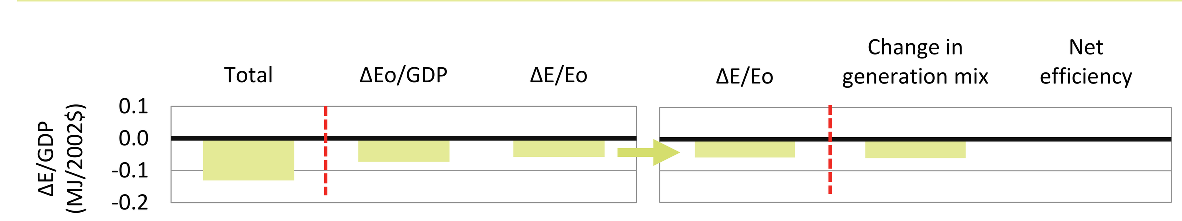


Fig. 8. Changes in ΔE/GDP of the Power Gen sector between 1995 & 2010

3E. **Freight transport** reductions in energy intensity (tonne(t)-km/GDP) were offset by more energy use per t shipped due to mode share change (more truck, less train transport):

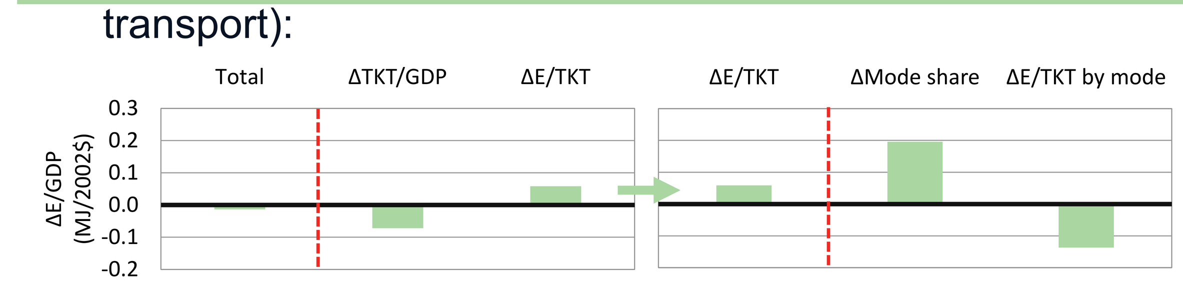


Fig. 9. Changes in ΔE/GDP of the Freight Transport sector between 1995 & 2010

3F. **Residence** sector had lower energy intensities due to lower energy use/m², despite larger dwelling sizes:

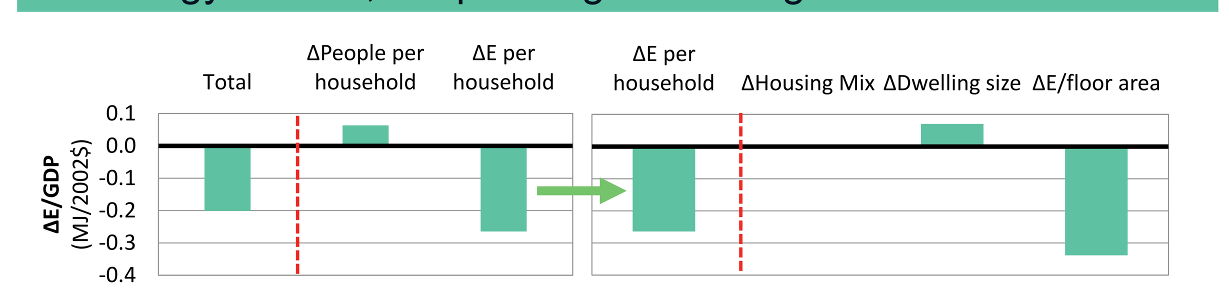


Fig. 10. Changes in ΔE/GDP of Residential buildings between 1995 & 2010

3G. **Personal transport** increases in person-km travelled/yr (i.e. higher energy intensity) were largely offset by vehicle efficiency improvements.

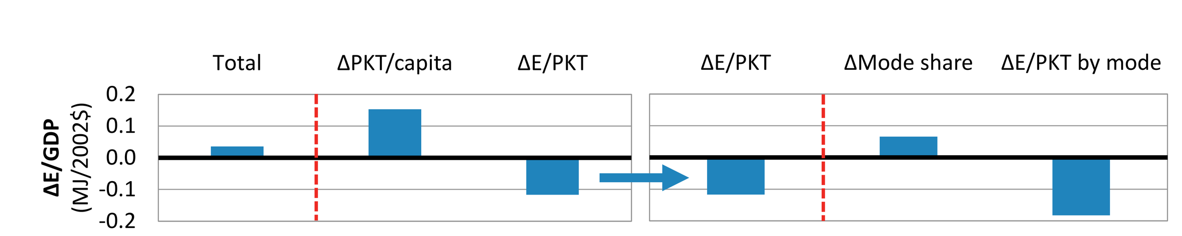


Fig. 11. Changes in ΔE/GDP of Personal transport between 1995 & 2010

- DISCUSSION / CONCLUSION-

Structural Changes in the Canadian economy (i.e. an increase role for Commercial & Institutional sectors that use little energy per GDP$) accounted for 46% of the economy's observed decrease in the energy intensity (MJ//2002$) between 1995 and 2010.

An addition 24% of the observed decrease in energy intensity was attributed to an increase in the wealth of Canadians who don't spend their additional resources on energy services, at least in Canada.

The remaining 30% of the energy intensity change was attributed to a net improvement in energy efficiency in Canada's productive and household economies.

We deconstructed the components of energy use and economic change between 1995 & 2010 and found that some trends increased and some decreased *ΔE/GDP* as shown in Fig. 12.

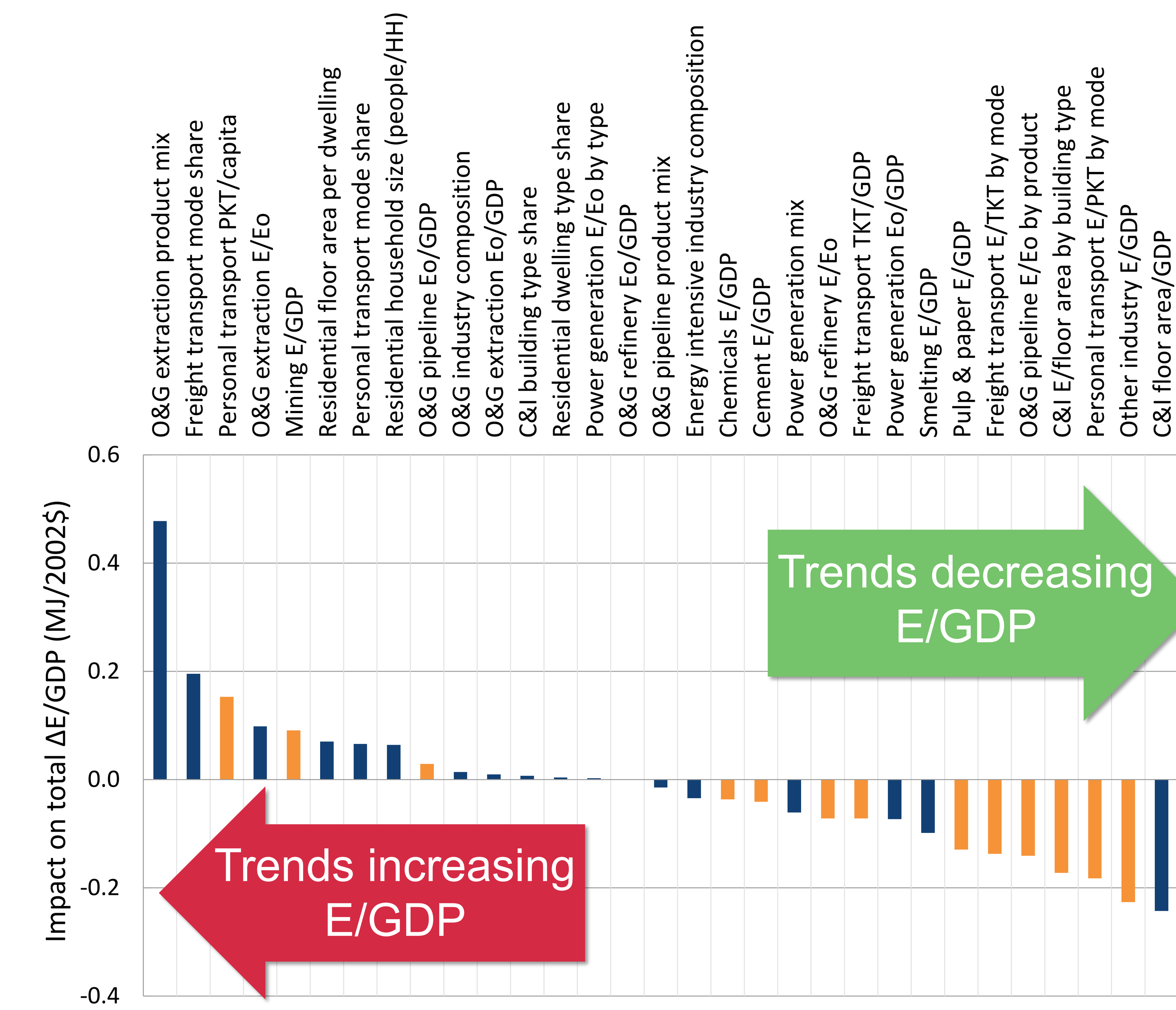


Fig. 12. Contribution to the energy intensity (ΔE/GDP) of the Cdn economy (1995-2010) from 32 underlying trends affecting the productive & household sectors.

This work shows that the observed decoupling of E and GDP between 1995 & 2010 was an emergent property of a large number of changes in the Canadian economy and energy use.

The study also identifies key trends in Canada's energy systems that contribute to increases or decreases in ΔE/GDP. Some of these could provide policy levers to take action on climate change.

- REFERENCES -

[1] CanESS v6 from whatIf? Technologies Inc, Ottawa, ON

[2] B.W. Ang, 2005 "The LMDI approach to decomposition analysis: a practical guide", Energy Policy 33 (2005) 867-871

- ACKNOWLEDGEMENTS -

We thank whatIf? Technologies Inc (Ottawa, ON) for allowing us to access and use the extensive database resources that they have incorporated into their Canadian Energy Systems Simulator (CanESS) model.