# The Effects of ICT on Environmental Sustainability

## Revisiting a System Dynamics Model Developed for the European Commission

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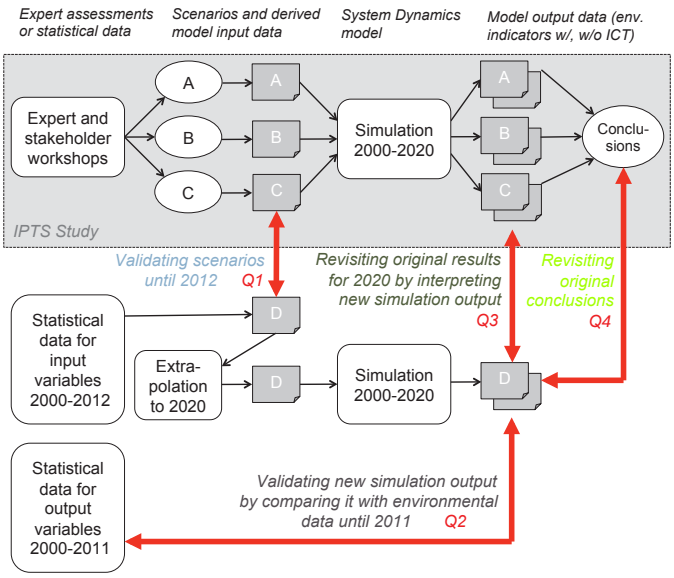
## AIM

In 2014, we revisit a 2002 model commissioned by the European Commission's Institute for Prospective Technological Studies (IPTS), to explore the future impacts of information & communication technology (ICT) on environmental sustainability in the EU-15 for the time horizon of 2000-2020.

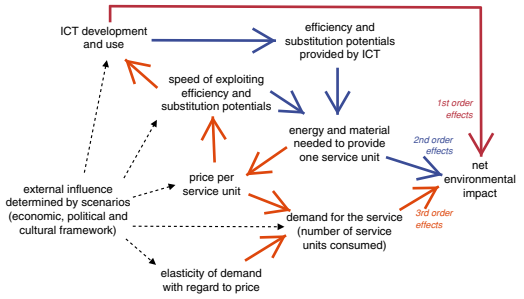
We analyze the results in light of empirical data available for 2000-2012.




## 3 LEVELS of ICT Effects:

1st order: Lifecycle of ICT Hardware
2nd order: Services by ICT applications
3rd order: Emerging effects (e.g. rebound)

## MODEL CAUSAL STRUCTURE




## 3 SCENARIOS

- A TECHNOCRACY: strong economic growth and employment driven by large companies in the service sector and is enabled by low regulation.
- B GOVERNMENT FIRST: strong environmental regulation, resulting in only moderate growth, no progress in employment, but good conditions for small/medium-sized enterprises.
- C STAKEHOLDER DEMOCRACY: steady economic growth, leading to an increase in the number of households, desk workers, and total labor force.

## RESEARCH QUESTIONS

### Q1. *Which of the 3 scenarios in the IPTS study comes closest to reality?*

**NONE** of the 3 scenarios dominantly represents reality during the period 2000-2012.

Scenarios A and B come closest to the real-world data in **7 cases each**, and Scenario C in **5 cases**.

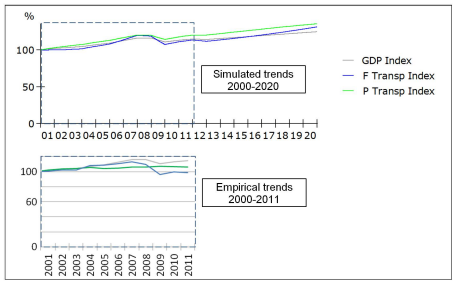
| No | External variable | Scenario assumptions used as simulation input, 2000-2020 | | | Empirical data for EU15 2000-2012 | Scenario closest to reality |
|---|---|---|---|---|---|---|
| | | A | B | C | | |
| M2 | GDP Annual Growth Rate | 2.56 % | 2.12 % | 2.3 % | 1.11 % (14.2% increase over 2000-2012) | B |
| M4 | Labor Demand Annual Growth Rate | 0.42 % | 0.15 % | 0.27 % | 0.57 % (8.3% increase over 2000-2012) | A |
| M7 | Population Annual Growth Rate | 0.16 % | 0.16 % | 0% | 0.46 % (5.7% increase over 2000-2012) | A & B |
| M8 | Number of Households Annual Growth Rate | 0.85 % | 0.18 % | 0.7 % | 1.51 % for 2005-12 (11.1% increase over 2005-2012) | A |
| M15 | Number of SMEs Annual Growth Rate | 0.21 % | 0.84 % | 0.42 % | 0.78% for 2005-12 (5.6% increase over 2005-2012) | B |
| M16 | Office Work Demand Annual Growth Rate | 0.42 % | 0.0 % | 0.27 % | 1.28 % for 2008-2011 | A |
| E400 | Fossil Energy Price Annual Change Rate | 0.35 % | 3 % | 0.35 % | 2.8 % Automotive gas oil price as proxy | B |
| U400 | Shift to Energy-Efficient ICT Half-life | 15 a | 15 a | 7.5 a | ~ 7.5 a | C |
| T400 | ICT-Induced Spatial Settlement Dispersion | 0 | +25 % | +25 % | 20% increase in average commuting distance over the period 2000-2010 in Finland as proxy | B & C |
| E12 | D&T Electricity Use Efficiency Potential | +50 % | | | ~ 30 a (7.9% increase in efficiency over 9 years 2000-2009 in EU-27) | A & C |
| E13 | D&T Electricity Use Efficiency Half-life | 15 a | 7.5 a | 15 a | | |
| E17 | D&T Electricity Price Annual Growth Rate | -0.45 % | 0 % | -0.45 % | 3.9 % (35% increase over 2005-2013) | B |
| E19 | Electricity Supply Efficiency Potential | +25 % | | | ~ 10 a (7.1% increase in efficiency over 10 years 2000-2010) | A & C |
| E20 | Electricity Supply Efficiency Half-life | 20 a | 10 a | 20 a | | |
| U201 | Average Useful Life of ICT Annual Change Rate | -8.0 % | 0 % | -8.0 % | -7.3% over 8 years 2000-2008 | A & C |
| W31 | MSW Recycling Potential | 53 % | | | ~ 10 a (28% recycling rate in 2011) | B |
| W32 | MSW Recycling Half-life | 20 a | 8 a | 20 a | | |

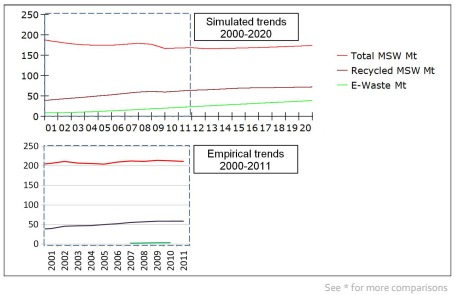
Data source: *EuroStat*; ...
See * for more comparisons

### Q2. *Are the main trends the IPTS model predicts for a realistic scenario consistent with the currently available data?*

We defined a **NEW** scenario, **Scenario** D based on the empirical data available today.

The predictions were roughly plausible, but cannot be taken as precise predictions. The purpose of the model was **NOT** to predict the development of the environmental indicators in absolute terms, but the relative impact of ICT on these indicators. (simulation tool: *PowerSim*)

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### Q3 - Q4. *Can the main quantitative and qualitative results regarding the impact of ICT provided by the IPTS study be confirmed or disconfirmed and their uncertainty reduced by the currently available data?*

**ICT Impact Index** = $\frac{\text{the value for the reference simulation run}}{\text{the value for the corresponding "ICT freeze" run}}$

= 1 means that ICT has no influence
> 1 means that ICT increases the environmental burden
< 1 means that ICT reduces the environmental burden

| ICT impact index | A worst | A mean | A best | B worst | B mean | B best | C worst | C mean | C best | D worst | D mean | D best |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Freight Transport | 1.04 | 1.01 | 0.90 | 1.32 | 1.27 | 1.11 | 1.03 | 0.98 | 0.83 | **0.99** | **0.95** | **0.81** |
| Passenger Transport | 1.03 | 1.02 | 1.01 | 1.04 | 1.04 | 1.02 | 1.03 | 1.02 | 1.00 | **1.03** | **1.05** | **1.04** |
| Energy | 0.98 | 0.95 | 0.89 | 1.03 | 0.99 | 0.92 | 0.97 | 0.93 | 0.85 | **0.94** | **0.90** | **0.82** |
| GHG | 0.97 | 0.93 | 0.87 | 1.03 | 0.98 | 0.90 | 0.97 | 0.92 | 0.83 | **0.81** | **0.89** | **0.79** |
| Materials | 0.90 | 0.88 | 0.79 | 1.00 | 0.97 | 0.87 | 0.90 | 0.86 | 0.74 | **0.85** | **0.83** | **0.71** |

### Revisiting the main conclusions of the IPTS study

✓ confirmed ✖ not confirmed

ICT applications supporting a product-to-service shift (virtual goods)
✓ Reducing influence on total material demand (dematerialization effect)

ICT applications for heating management (intelligent heating)
✓ reducing effect on energy consumption in the domestic/tertiary sector (mainly heating)

ICT applications for passenger transport efficiency
✓ Stimulating influence on total passenger transport. more cost / time efficient (rebound)

ICT applications for mobile work
✓ Time utilization. Advantage for public transport compared to private car transport

ICT applications for freight transport efficiency
✖ ICT now slightly inhibits growth of freight transport. This ICT effect is mainly due to its dematerialization effect, which is stronger than in the original study.

## CONCLUSIONS

**None of the three scenarios** that were developed by experts to specify the external factors needed to run the model were **realistic** from today's point of view.

If the model is re-run with more realistic input data for the first half of the simulation period, the **main results regarding the impact of ICT remain qualitatively the same**; they seem to be relatively robust implications of the causal system structure, as it is represented in the model.

Overall, the impacts of ICT for mitigating greenhouse gas emissions and other environmental burdens for 2020 tend to be **slightly stronger** if the simulation is based on the empirical data now available.

* Read more in the book chapter: Modeling the Impacts of ICT on Environmental Sustainability: Revisiting a System Dynamics Model Developed for the European Commission, *ICT Innovations for Sustainability* (L. M. Hilty & B. Aebischer, eds.) Springer 2015

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