

An aerial photograph of a dense forest of evergreen trees, likely spruce or fir, covering a hillside. The trees are lush green, and the perspective is from a high angle, looking down into the canopy. The lighting is bright, suggesting a sunny day, though some areas are in shadow.

Life cycle assessment and rebound effects

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Learning outcomes

After the lecture and assignment you can:

- 1. Differentiate*** between production- and consumption-based environmental accounting
- 2. Explain*** what is a rebound effect (unwanted and desirable) and why it must be taken into account in environmental policies and actions
- 3. Make*** an appealing info-brochure (to consumers)

Contents of the lecture

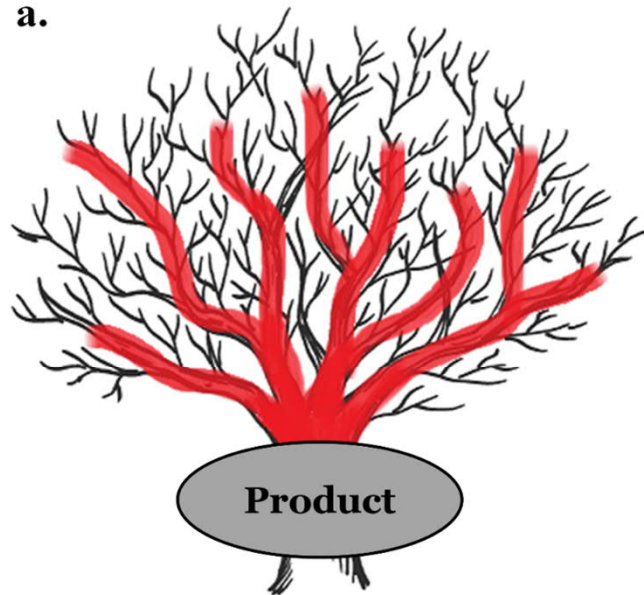
1. Revision of LCA
 - Process LCA and EE IO analysis
2. Production- and consumption-based environmental assessments
3. Carbon footprints of consumers
4. Rebound effect



LIFE CYCLE ASSESSMENT

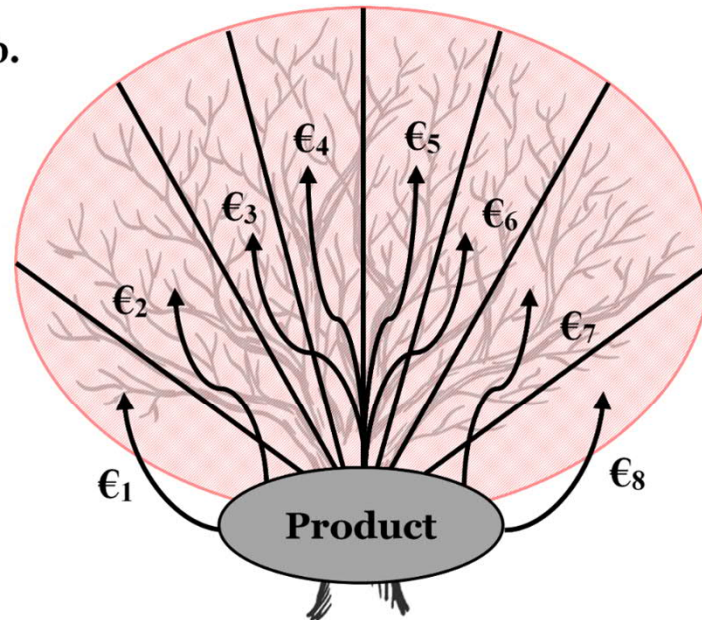
Process LCA, EE IO analysis (EIO-LCA), and hybrid-LCA

a.



**Process LCA –
truncation error**

b.



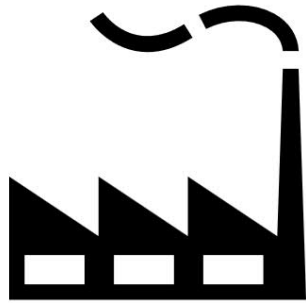
**EE IO analysis –
aggregation error**

Ottelin 2016

An aerial photograph of a suburban town. The foreground shows large green agricultural fields. The middle ground is dominated by a dense residential area with many houses and apartment buildings. The background features a flat landscape under a sky with scattered clouds. The text 'PRODUCTION- AND CONSUMPTION-BASED ASSESSMENTS' is overlaid in large white letters across the center of the image.

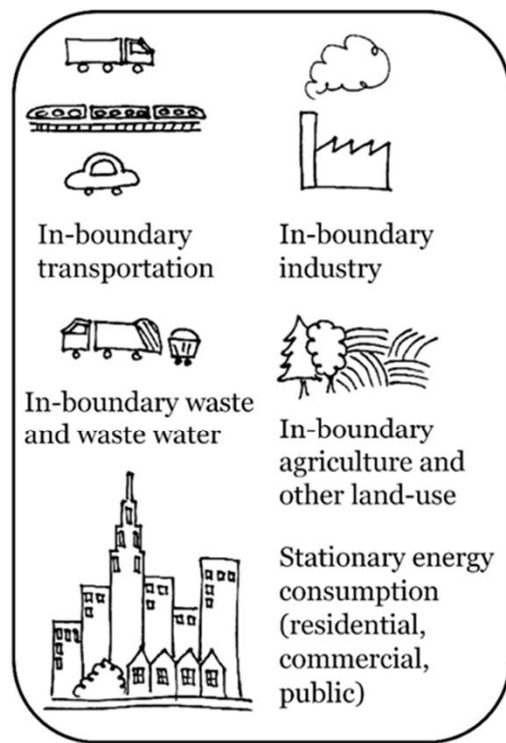
PRODUCTION- AND CONSUMPTION- BASED ASSESSMENTS

Production- and consumption-based assessments

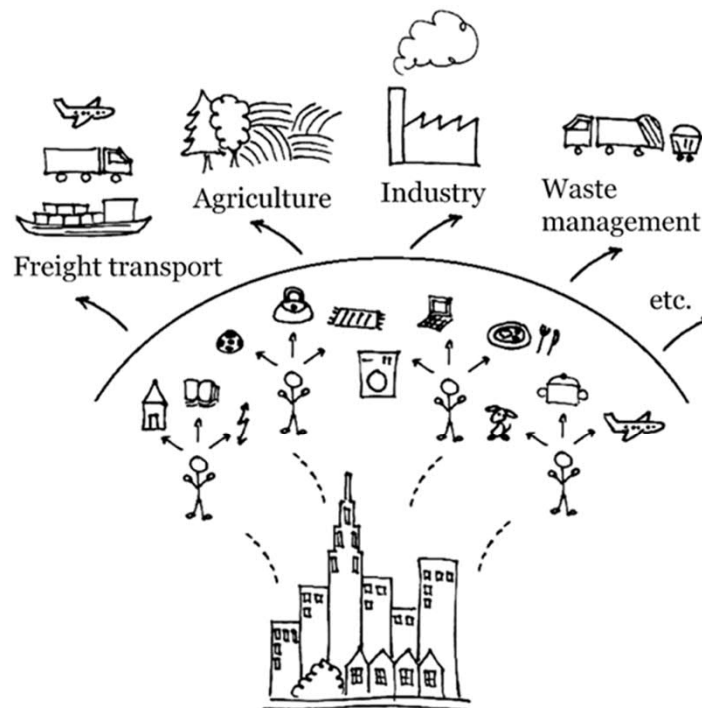


- Who are responsible for the emissions, producers or consumers?
- Which side environmental policies typically target?
- Could policies targeting only one side be problematic? Why?

Production- and consumption-based emission accounting of geographical areas



Production-based accounting

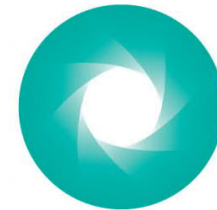


Consumption-based accounting

Greenhouse gas protocol

- Scope I: Direct GHG emissions
- Scope II: Emissions caused by purchases of energy
- Scope III: Indirect GHG emissions caused by purchases of products and services (embodied GHG emissions)

- Be aware of double counting!



GREENHOUSE
GAS PROTOCOL

Carbon map

Wiedmann et al. 2015

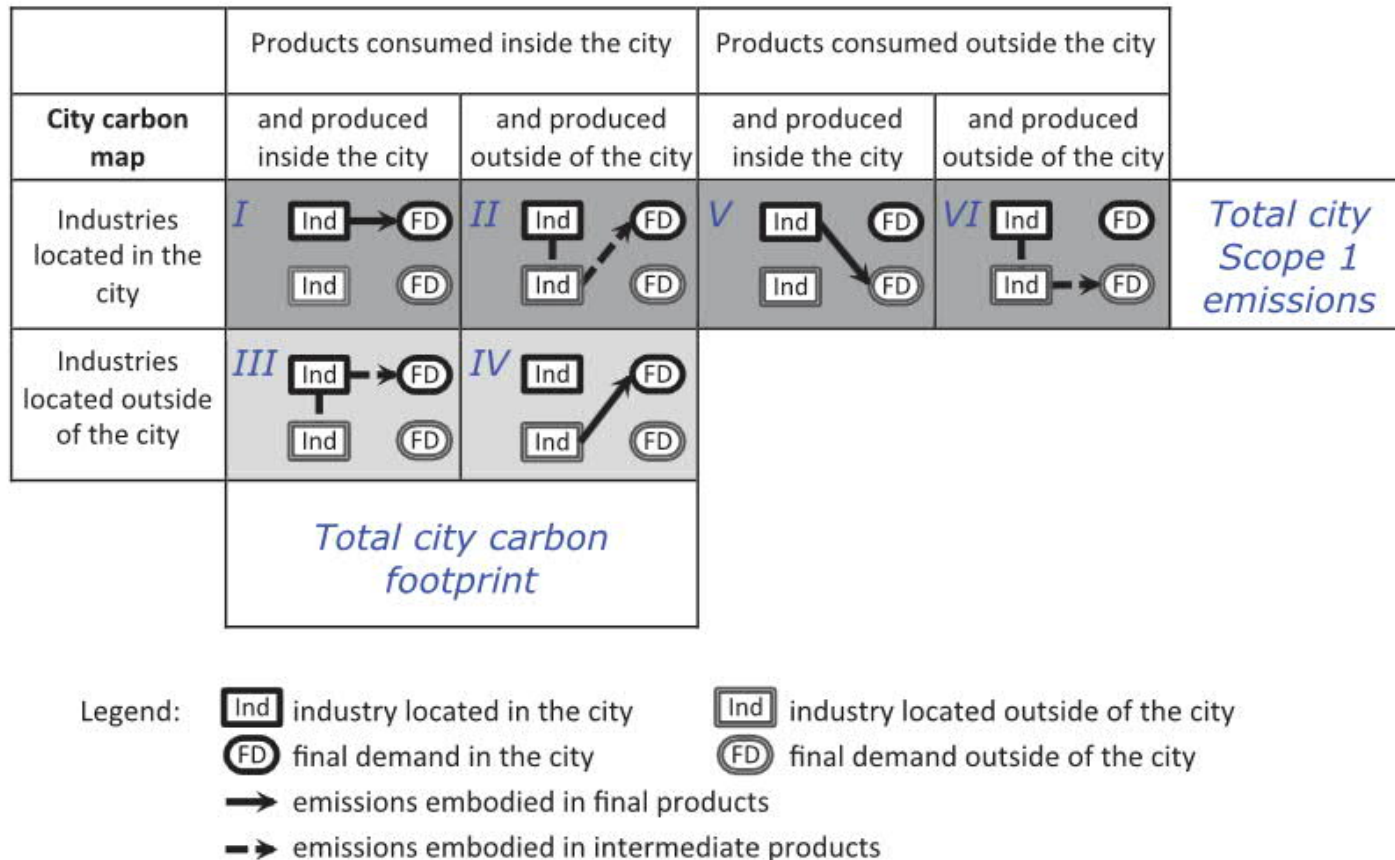


Figure 2 Overview schematic of a city carbon map and flows of embodied emissions. Emissions from the city's industries (Scope 1, and partly Scope 2) are located in the map's sections I, II, V, and VI (shaded in dark gray). Segments III and IV represent emissions from industries outside of the city that are associated with (embodied in) the city's final demand (lightly shaded, Scope 3). The sum of segments I to IV is the total carbon footprint of the city (see also figure 1 in Choi 2015).

An aerial photograph of a city center, featuring a large, multi-story building complex with a prominent curved facade and a central courtyard. The building has a mix of brick and lighter-colored sections. To the right, a major road interchange with multiple lanes and a roundabout is visible, with numerous cars and taxis. The surrounding area is filled with other urban buildings, streets, and green spaces. The text "CARBON FOOTPRINT" is overlaid in large, white, bold letters across the center of the image.

CARBON FOOTPRINT

Carbon footprint of consumers

- IO- or hybrid-LCA

Consumption (€) * GHG intensity (CO₂-eq kg/€) = carbon footprint (CO₂-eq kg)

- So, based on this formula

What are the two main ways to reduce your carbon footprint?

An aerial photograph of a town and surrounding landscape. A wide river flows through the scene, curving to the right. The foreground and middle ground are filled with residential houses, many with autumn-colored trees. In the background, there are large, flat agricultural fields under a clear blue sky. The text "REBOUND EFFECT" is superimposed in large, white, bold, sans-serif capital letters across the center of the image.

REBOUND EFFECT

Simplified demonstration

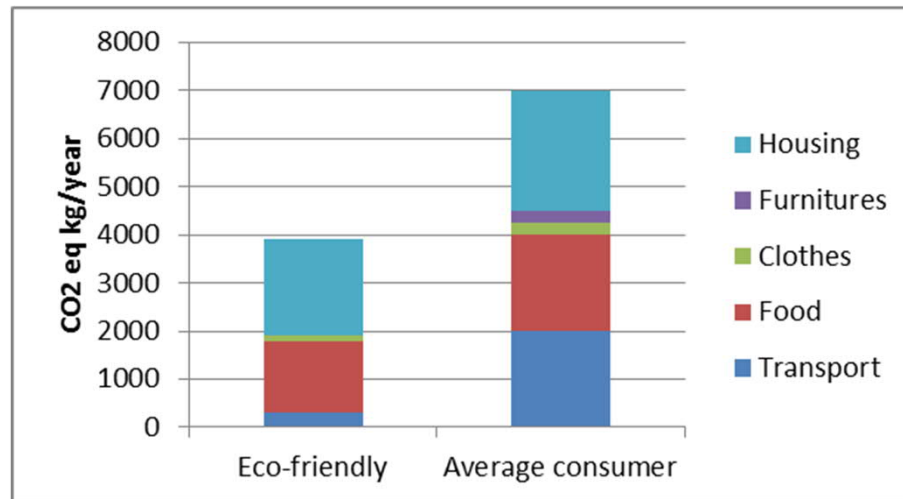
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- Two consumer types:
 - eco-friendly
 - average consumer
- Attach products to the right consumer

Simplified demonstration

2/4

Eco-Friendly	CO2 kg/year	Average consumer	CO2 kg/year
Public transit	300	Private car	2000
Beans & Tofu	1500	Chicken & Pork	2000
Organic cotton, second-hand	100	Desired clothes	250
Second-hand sofa	0	New sofa	250
Apartment in city center	2000	Detached house in suburban area	2500
Total	3900		7000



Simplified demonstration

3/4

Eco-Friendly	CO2 kg/year	€/year	Average consumer	CO2 kg/year	€/year
Public transit	300	600	Private car	2000	3000
Beans & Tofu	1500	2000	Chicken & Pork	2000	2200
Organic cotton, second-hand	100	300	Desired clothes	250	600
Second-hand sofa	0	100	New sofa	250	800
Apartment in city center	2000	12000	Detached house in suburban area	2500	10000
Total	3900	15000		7000	16600

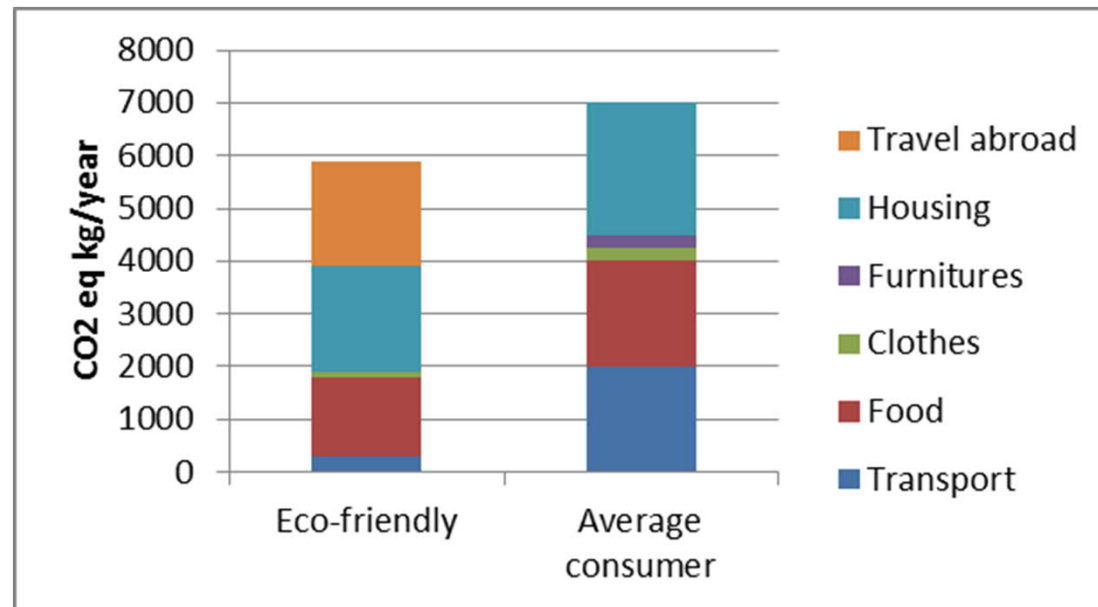
Eco-friendly choices lead to extra 1600 €/year

What would you do with this money?

- Trip to India: 1600 €, 2000 kg CO2 eq

Simplified demonstration: Rebound effect

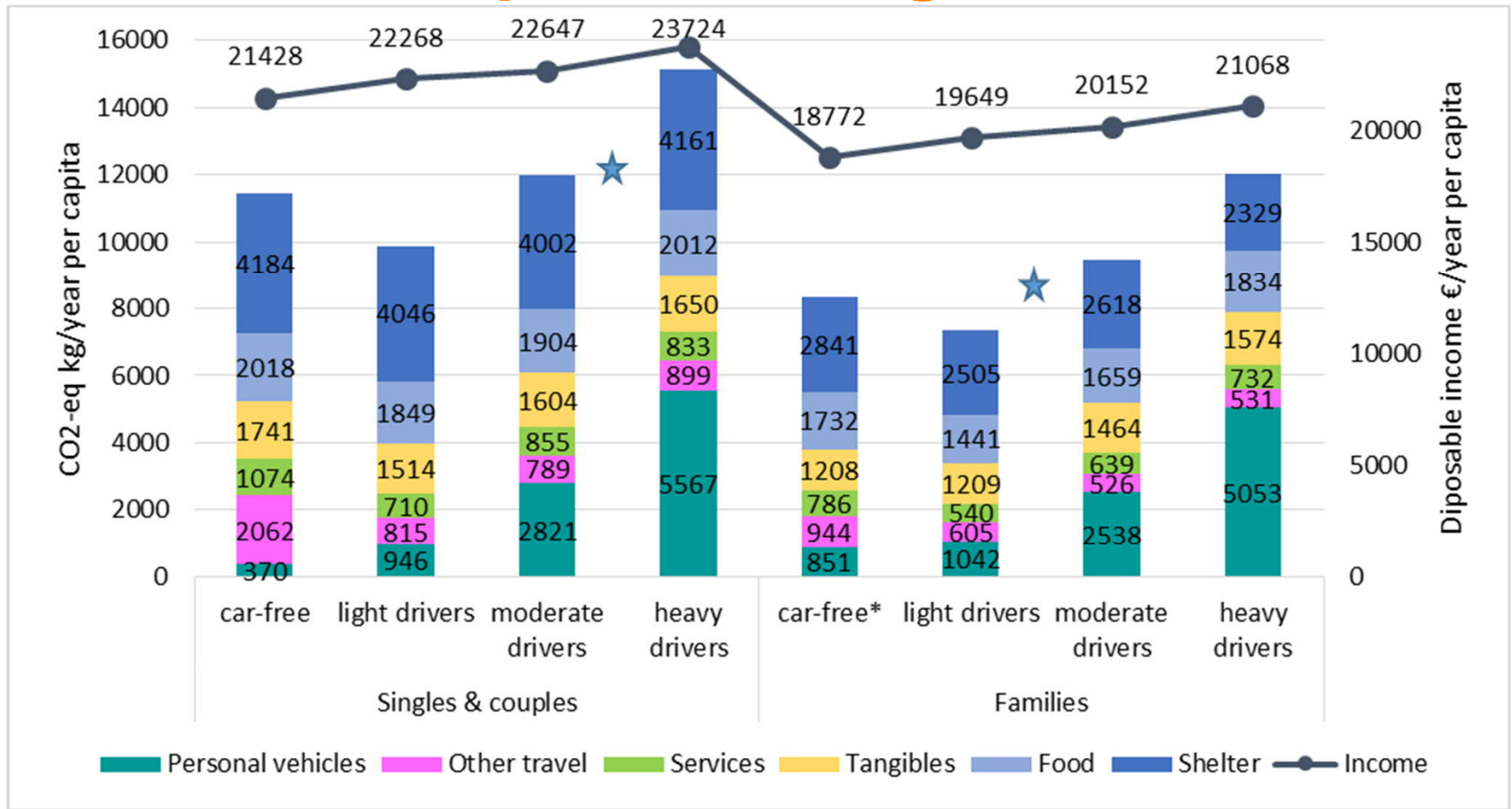
4/4



A wooden boardwalk with a metal mesh railing overlooking a misty forest of tall evergreen trees. The boardwalk is made of dark wood planks and runs along the edge of a forest. The railing is made of metal mesh and wooden posts. In the background, there are many tall evergreen trees, some of which are partially obscured by mist. A person in a red jacket is visible in the distance on the boardwalk. The overall atmosphere is serene and natural.

REAL EXAMPLES

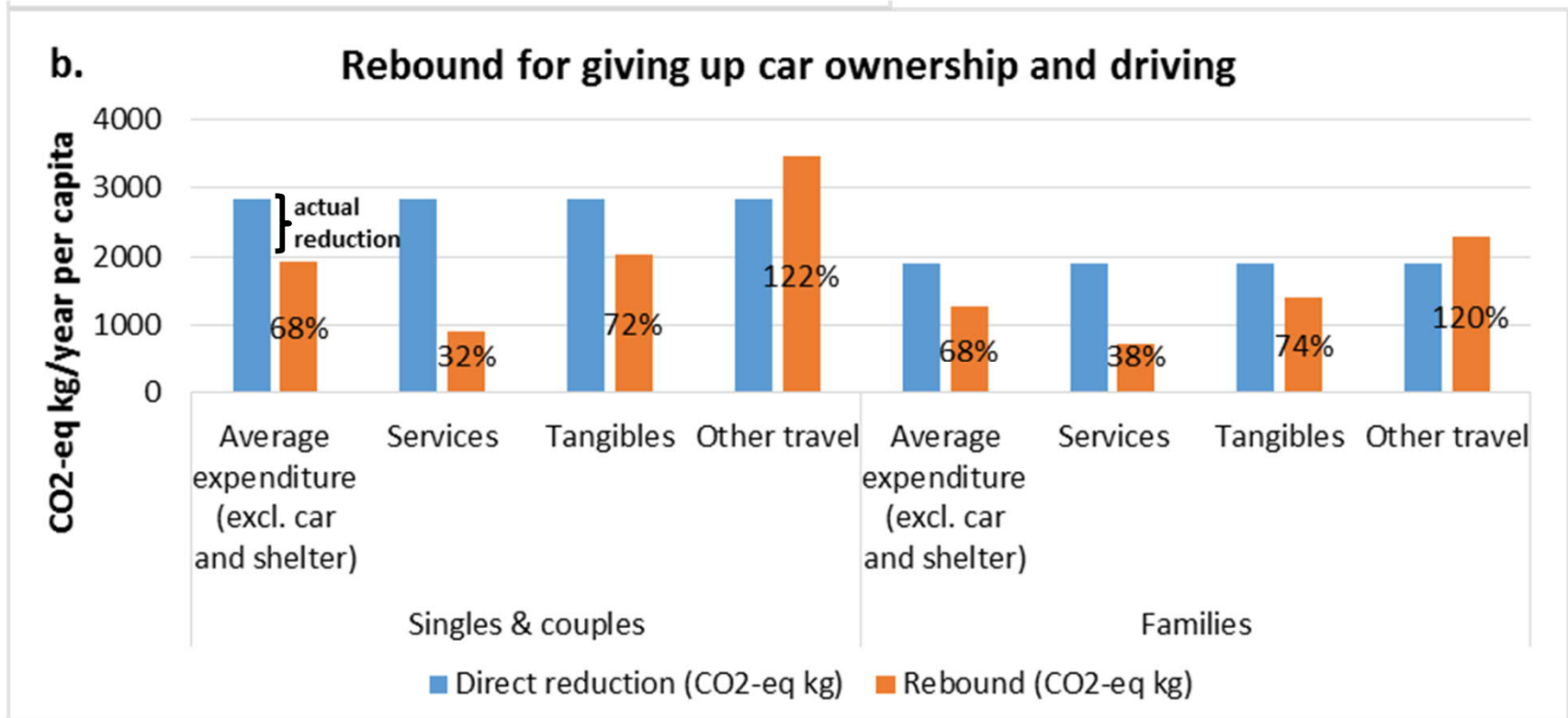
Rebound effect for reduced car ownership and driving



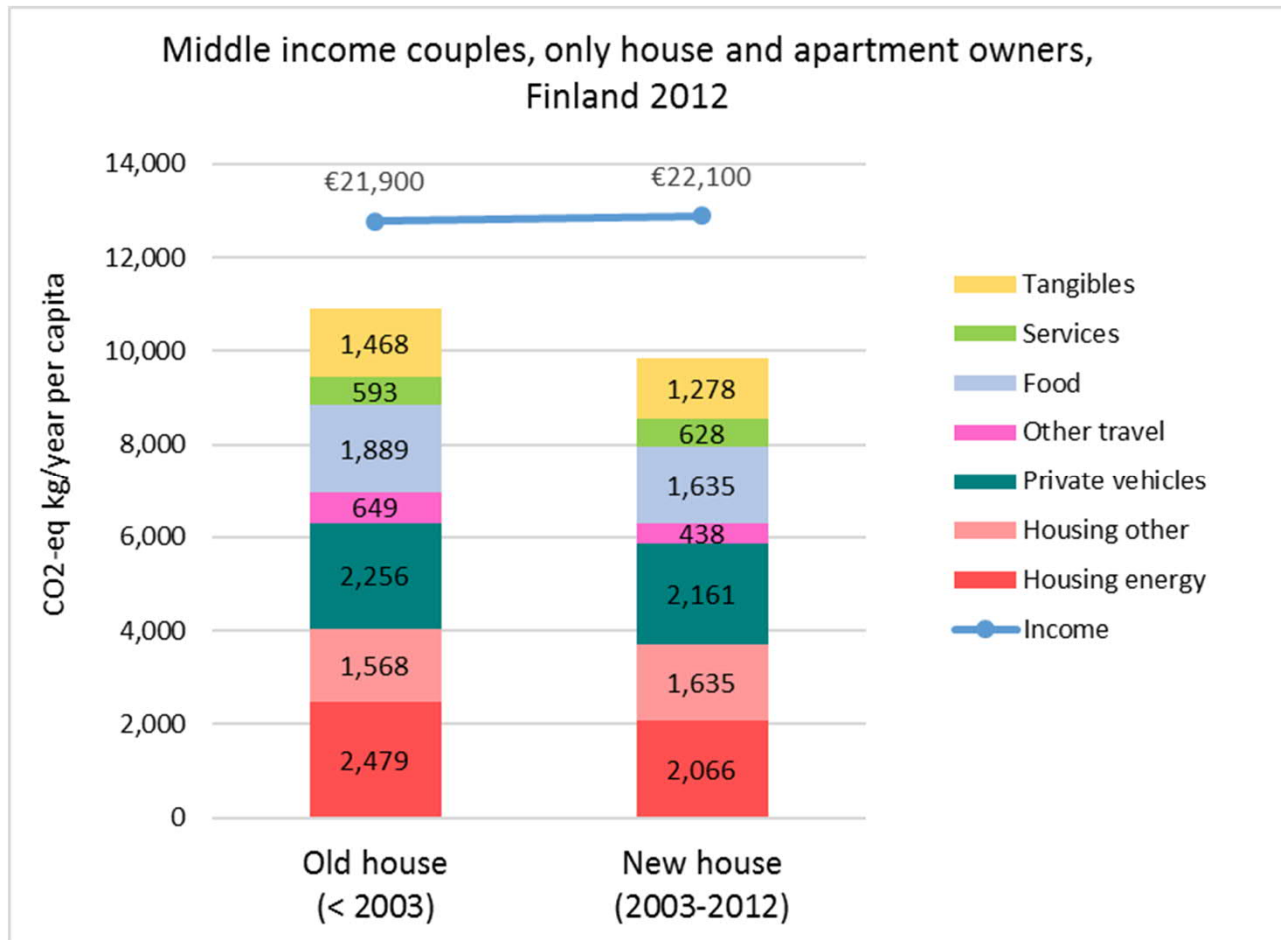
Light drivers < 370 l gasoline/year per capita,
 Heavy drivers > 1000 l gasoline/year per capita

Ottelin et al. 2017

Rebound for abandoning a car



Rebound for new energy efficient housing



Ottelin, unpublished

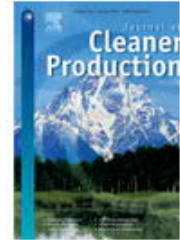
An aerial photograph of a city street in winter, covered in snow. The sun is low in the sky, creating a warm, golden glow over the scene. The street is lined with multi-story buildings, and several cars are parked along the side. In the background, a body of water and industrial cranes are visible. The text "REBOUNDS FOR POLICY ACTIONS" is overlaid in large, white, bold, sans-serif capital letters across the center of the image.

REBOUNDS FOR POLICY ACTIONS



Journal of Cleaner Production

Volume 170, 1 January 2018, Pages 1523-1535

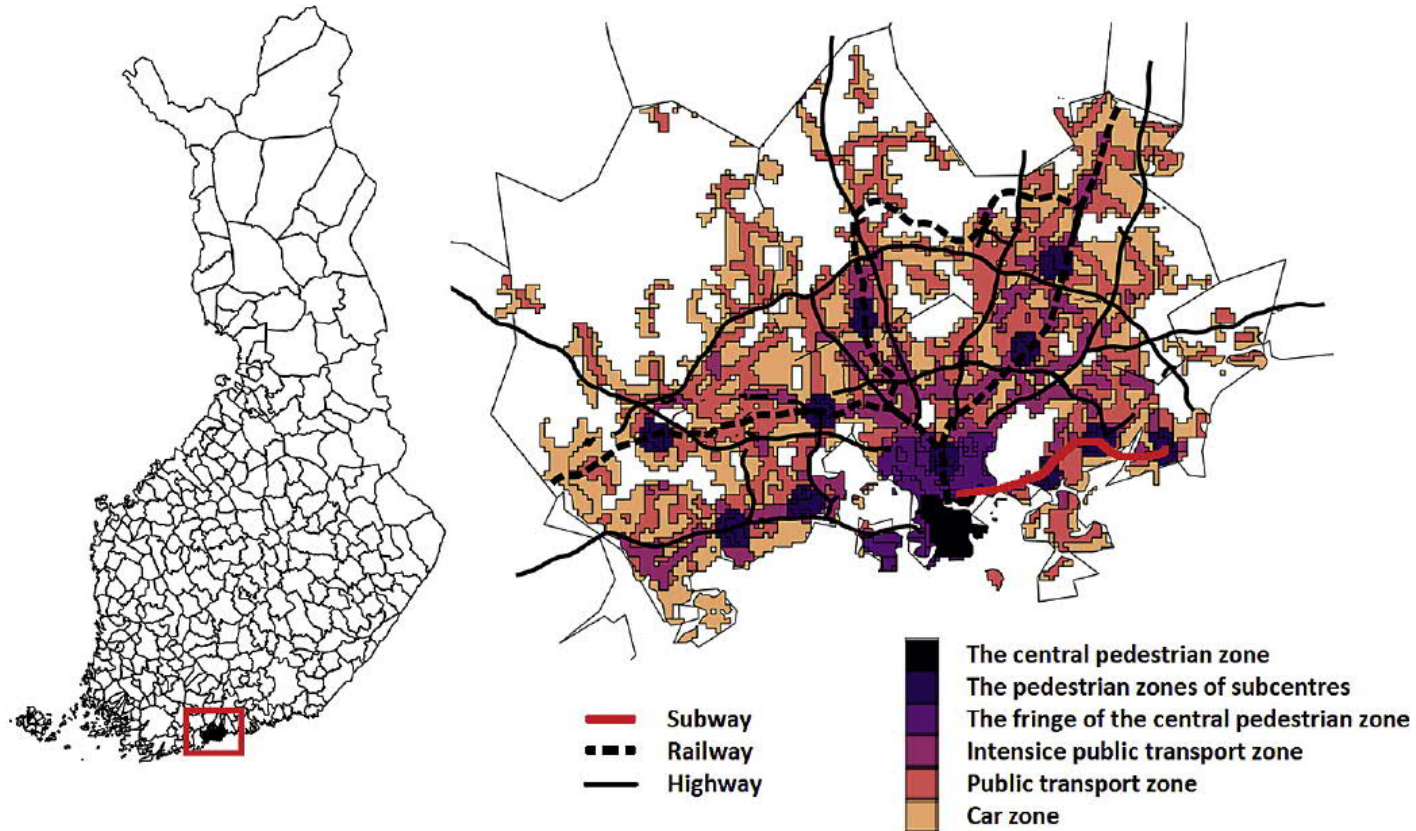


Carbon footprint trends of metropolitan residents in Finland: How strong mitigation policies affect different urban zones

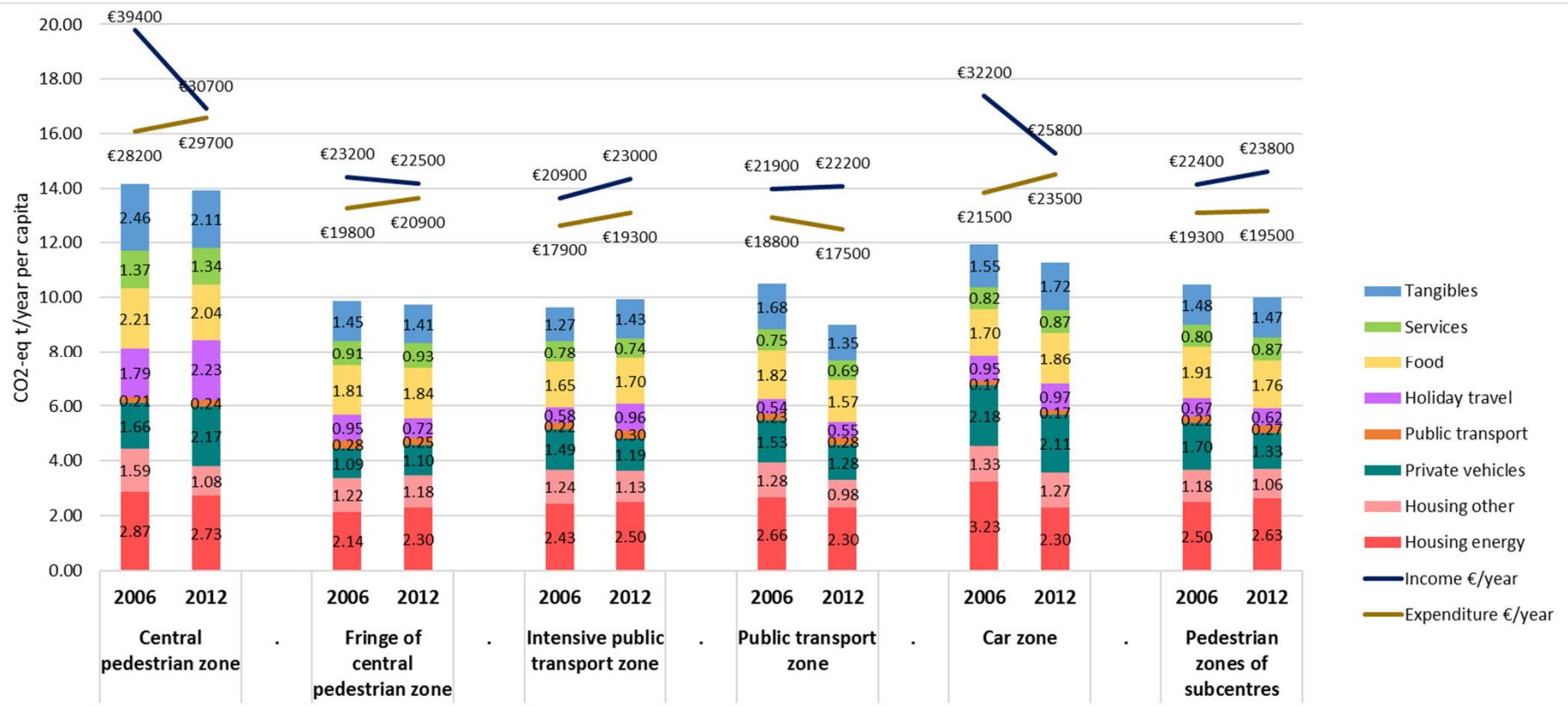
Juudit Ottelin ^a  , Jukka Heinonen ^b, Seppo Junnila ^a

- Main points:
 - Time series
 - Detailed urban zones
 - One metropolitan area
 - (the economic crisis in 2008)

Urban zones (Finnish Environment Institute)



Carbon footprint trends of metropolitan residents



Environmental Research Letters

LETTER

Rebound effects may jeopardize the resource savings of circular consumption: evidence from household material footprints

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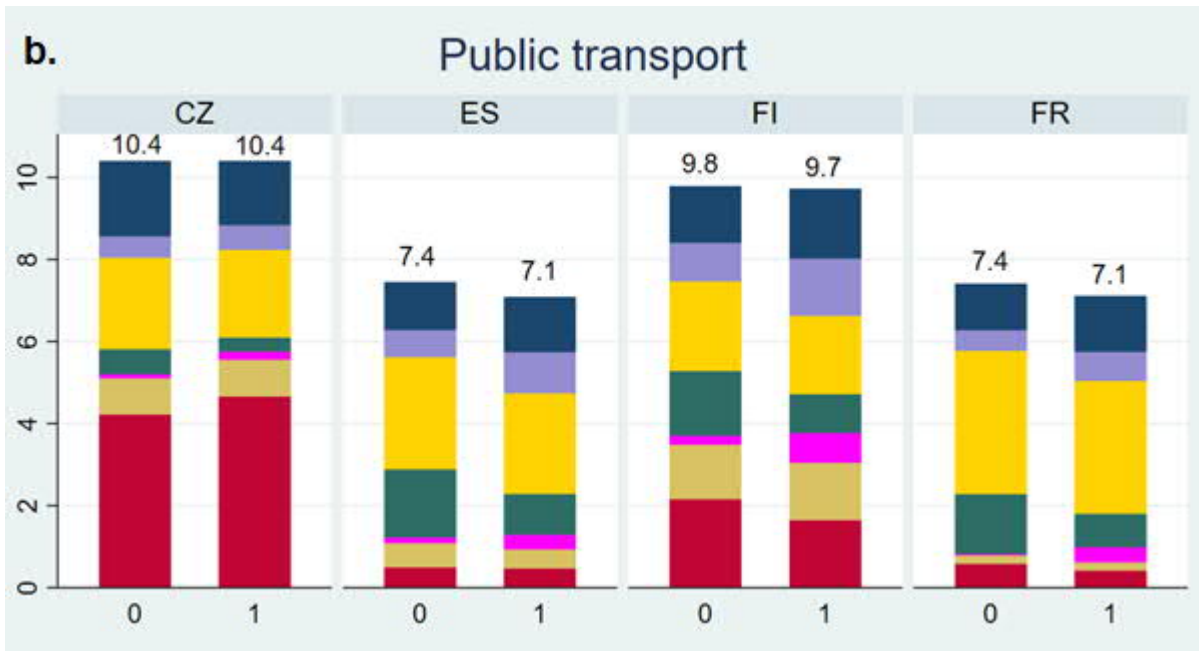
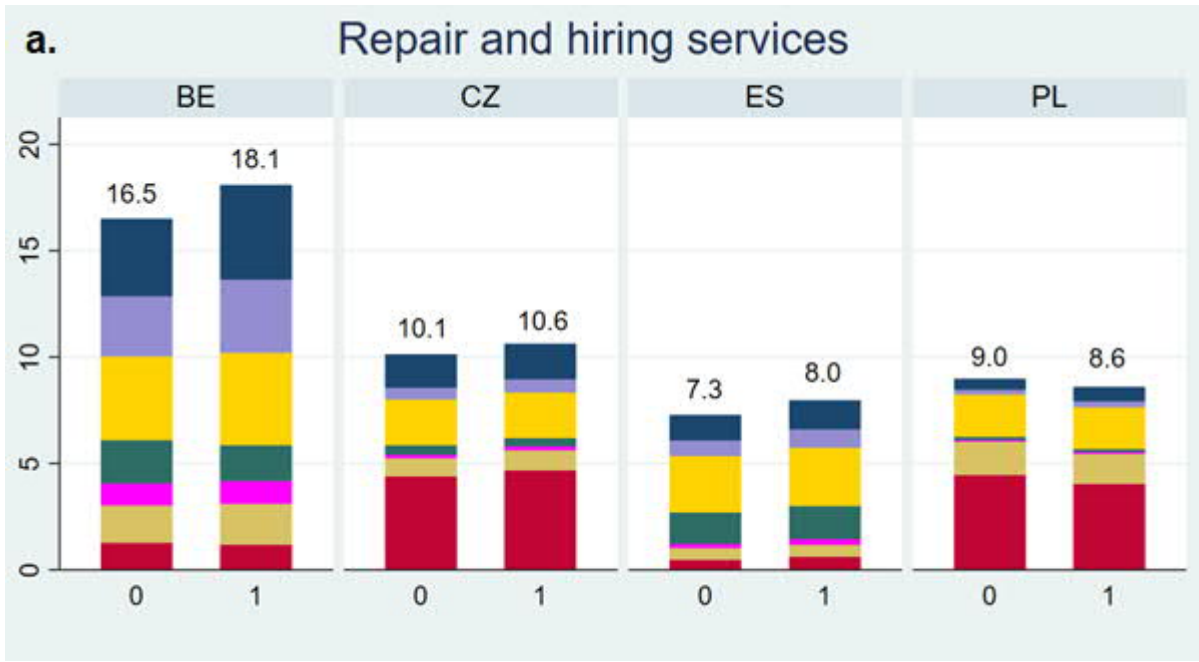
² Leiden University, Institute of Environmental Sciences, Leiden, The Netherlands

³ Stedin, Asset Management, Rotterdam, The Netherlands

⁴ Leiden University, The Netherlands Leiden University College, The Hague, The Netherlands

- Main points:
 - 240,000 European households
 - Identification of circular consumption patterns
 - Material footprints

Dependent variable	Circular consumption						Linear consumption					
	Repair (d)	Refurbish (d)	Public transport (d)	Rental housing (d)	Services	Maintenance	Motor fuels (d)	Air travel (d)	Purchase of vehicles (d)	Tangibles	Meat	Waste
Income	0.53	0.43	0.09	-1.24	0.74	0.68	0.78	0.76	0.37	0.75	0.26	0.42
Life phase: Singles (ref.)												
Young (16-24 y.)	-0.11	-0.31	1.09	1.28	0.26	-0.31	0.49	0.56	0.90	0.39	-0.32	-0.30
Couples	0.52	0.74	0.18	-1.03	-0.05	0.05	1.18	0.49	0.73	0.09	-0.01	-0.44
Single parents	0.46	0.38	0.63	-0.69	-0.05	-0.15	0.97	0.58	0.73	0.21	-0.31	-0.47
Young families (<5-y. child)	0.75	0.88	0.28	-1.44	-0.07	-0.11	1.96	0.85	1.32	0.19	-0.43	-0.85
Families	0.97	1.06	0.81	-1.73	-0.06	-0.11	2.01	0.96	1.31	0.14	-0.13	-0.79
Senior singles (>=65 y.)	0.31	0.20	-0.43	-0.91	-0.12	0.52	-0.91	-0.10	-1.10	-0.14	0.10	0.06
Senior couples (>=65 y.)	0.80	0.88	-0.37	-1.98	-0.12	0.28	0.74	0.50	-0.10	-0.07	0.12	-0.31
Deg. urb.: Rural areas (ref.)												
Towns and suburbs	0.16	-0.07	0.21	0.48	0.04	-0.04	-0.04	0.22	-0.13	0.01	-0.04	0.14
Cities	0.32	-0.22	0.57	1.10	0.12	-0.12	-0.60	0.35	-0.31	0.04	-0.10	0.04
Education: Primary (ref.)												
No formal	-0.38	-0.02	0.15	-0.27	-0.20	-0.17	-0.69	-0.36	0.28	-0.22	-0.10	-0.10
Lower secondary	0.32	-0.04	0.10	0.19	0.17	0.07	0.24	0.29	0.05	0.20	-0.02	0.07
Upper secondary	0.41	0.12	-0.02	0.20	0.23	0.18	0.56	0.50	0.05	0.29	0.00	0.14
Post-secondary non-tertiary	0.51	0.04	0.22	0.22	0.35	0.20	0.58	0.57	0.01	0.40	-0.05	0.08
Tertiary first stage	0.64	0.16	0.28	0.35	0.46	0.23	0.75	0.82	0.05	0.48	-0.08	0.17
Tertiary second state	0.58	-0.01	0.53	0.48	0.48	0.39	0.37	0.91	-0.08	0.54	-0.13	0.15
Not specified	0.15	-0.03	-0.13	0.32	0.19	0.02	0.26	0.39	-0.18	0.12	-0.07	0.45
Gender (Female)	0.07	-0.03	0.24	0.09	0.02	0.05	-0.36	0.10	-0.07	0.10	-0.05	-0.04



Conclusions

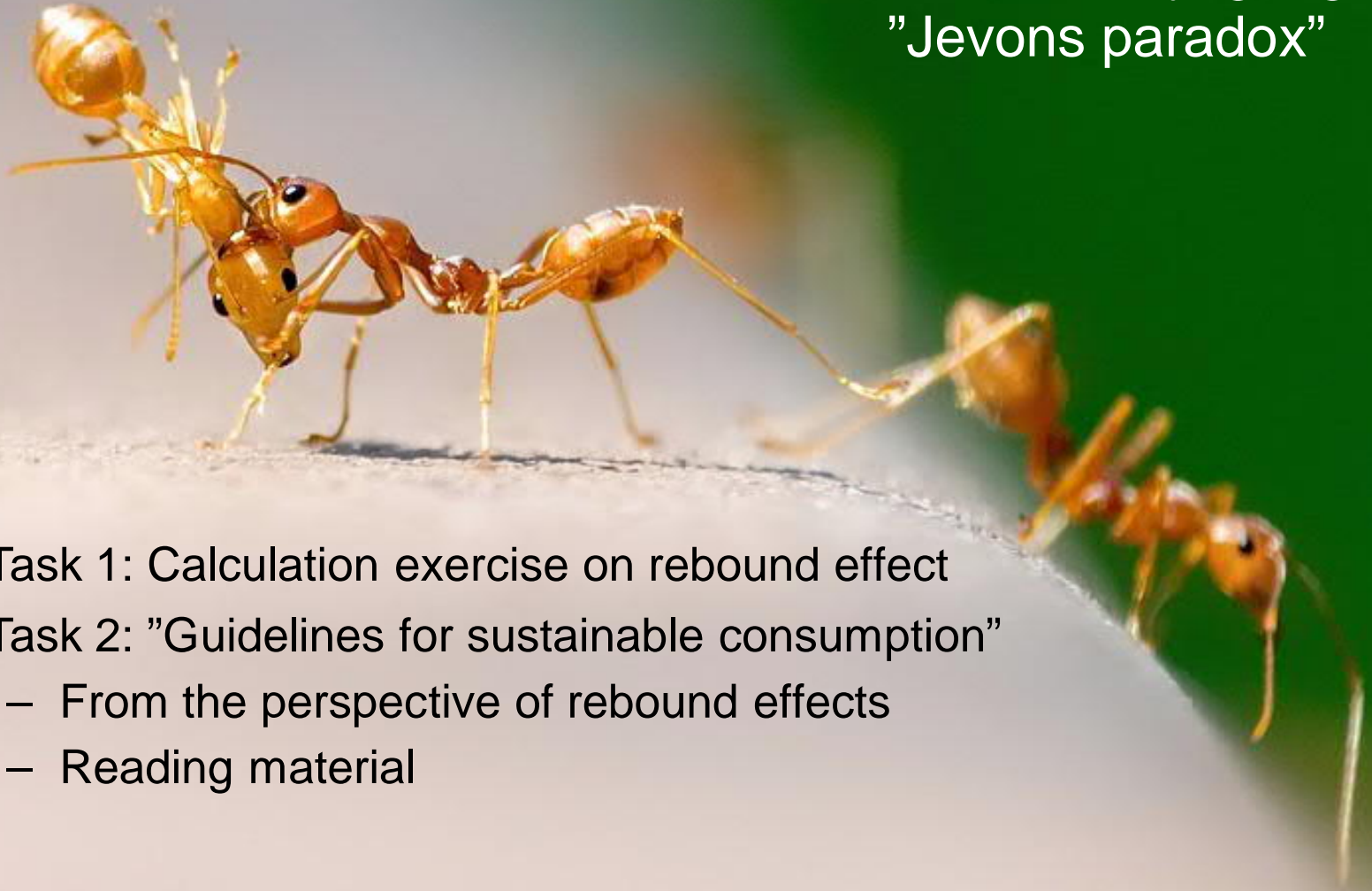
A wide-angle photograph of a snowy landscape. The foreground is covered in a thick layer of snow, with numerous footprints scattered across it. In the middle ground, there are some small, bare bushes and a few thin trees. The background features a dense forest of evergreen trees under a clear blue sky.

- Production- and consumption-based assessments:
 - Complementary – both are needed
- Consumption-based assessments capture rebound effects
- Rebound effects may jeopardize the effectiveness of environmental policies if not taken into account
- Although rebounds are usually considered unwanted, there are also desirable rebound effects (positive spill-over effects)

Group tasks

- For curiosity, google "Jevons paradox"

- Task 1: Calculation exercise on rebound effect
- Task 2: "Guidelines for sustainable consumption"
 - From the perspective of rebound effects
 - Reading material



References

- Ottelin, J., Cetinay, H., & Behrens, P. 2020, " Rebound effects may jeopardize the resource savings of circular consumption: evidence from household material footprints", *Environmental Research Letters*, 15(10), 104044.
- Ottelin, J., Heinonen, J. & Junnila, S. 2018, "Carbon footprint trends of metropolitan residents in Finland: How strong mitigation policies affect different urban zones", *Journal of Cleaner Production*, vol. 170, pp. 1523-1535.
- Ottelin, J., Heinonen, J. & Junnila, S. 2017, "Rebound effect for reduced car ownership and driving", in *Nordic Experiences of Sustainable Planning: Policy and Practice*, ed. Kristjánsdóttir S., Routledge.
- Ottelin, J. 2016, "Rebound effects projected onto carbon footprints-Implications for climate change mitigation in the built environment", Doctoral dissertation, Aalto University.
- Wiedmann, T.O., Chen, G. & Barrett, J. 2016, "The Concept of City Carbon Maps: A Case Study of Melbourne, Australia", *Journal of Industrial Ecology*, vol. 20, no. 4, pp. 676-691.