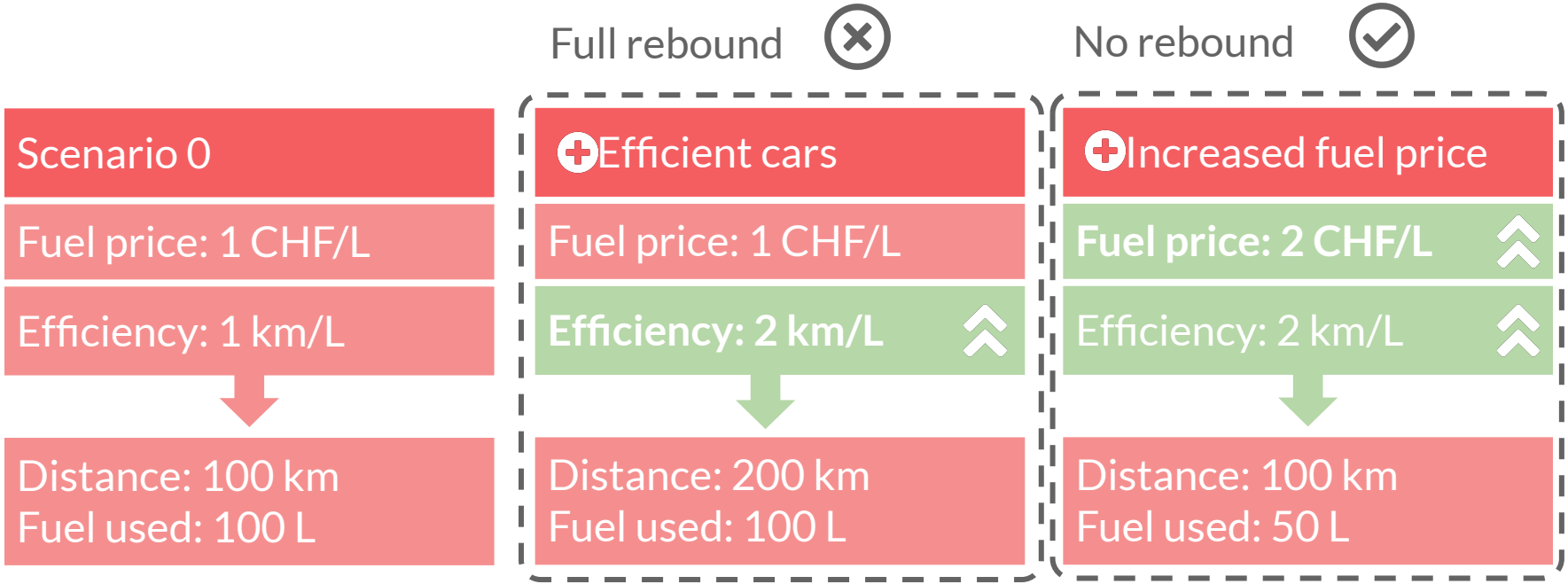
# Applications with little or no rebound

## Digitalization and the rebound effect

# A thought experiment

Budget: 100 CHF
Goal: Drive as far as possible.



# Application 1: Japanese vending machines

# Japanese vending machines (VM)

- 5.4 Millions machines (1990). → One machine per 23 Japanese.
- 3.7% of total electricity consumed in Japan (Coleman 1997).
- Biggest contribution from refrigerated VMs that are running 24/7.
- Energy efficiency improved by 58% within 15 years (since 1990).

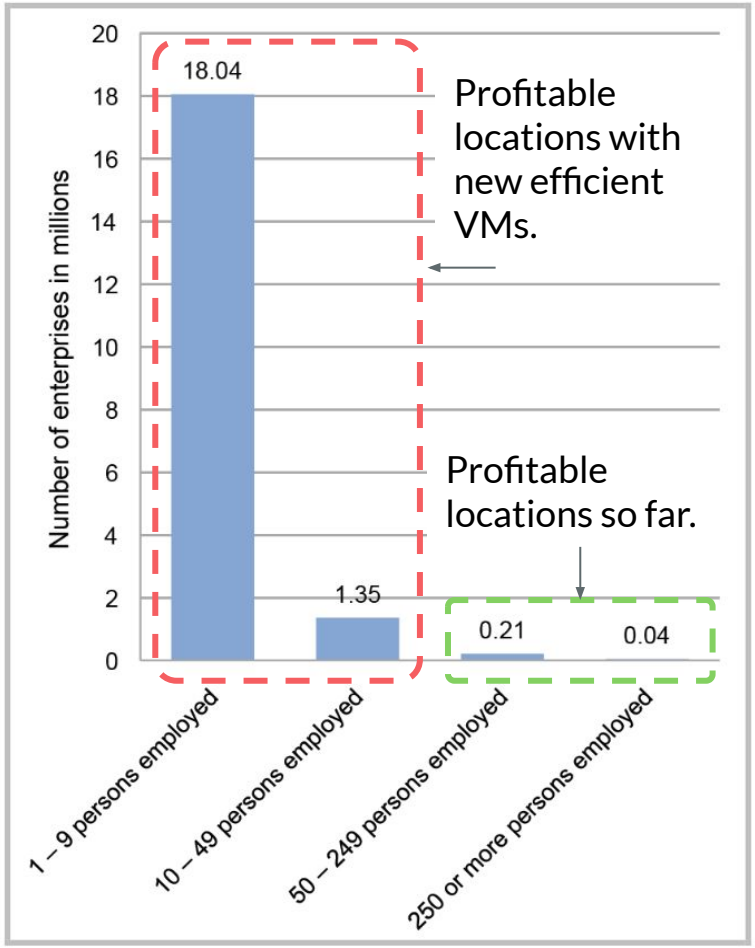

Image source: https://commons.wikimedia.org/wiki/File:Vending_machine_of_soft_drink_and_ice_cream_in_Japan.jpg

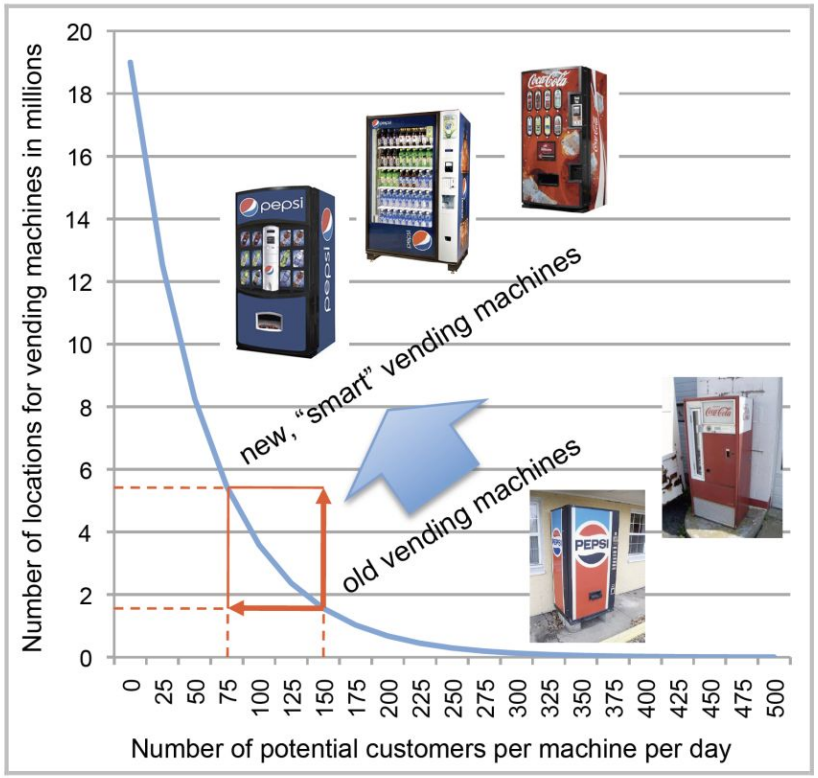
# Where is the rebound?

## Hilty's hypothesis:

- Old machines required a lot of consumers to be profitable.
  → Only installed in large offices.
- Efficient machines open up the marked: Profitable to install in smaller offices.

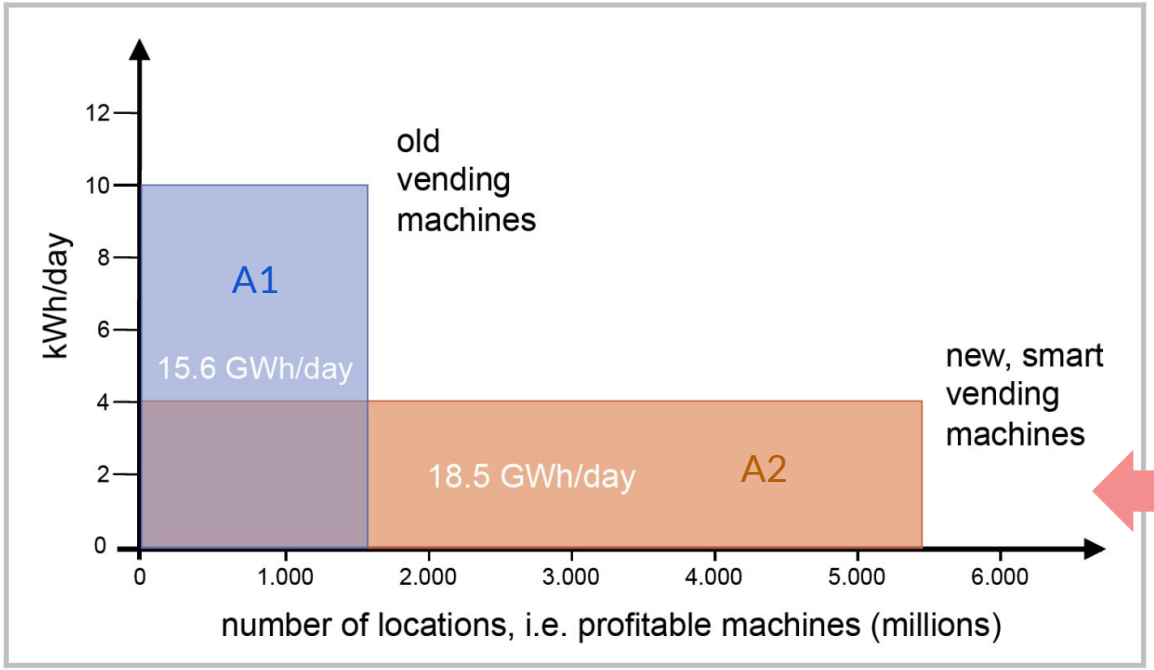
Data for EU, but it is roughly the same in all economies.






Linear decrease of potential customers per machine generates exponential increase of marketable VMs.

# Worse than rebound...



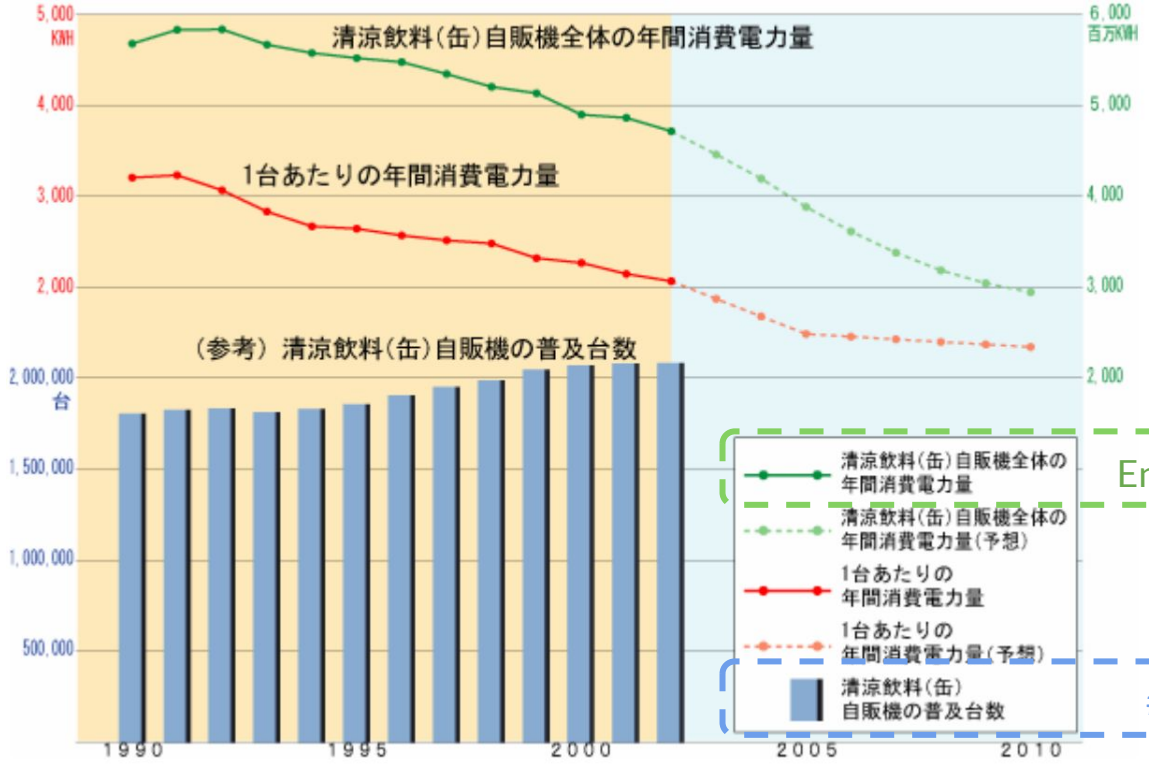

A1 < A2

⇒ Improved energy efficiency resulted in **increased** overall energy consumption.

Backfire

But this was just speculation...

# How it looks in reality:



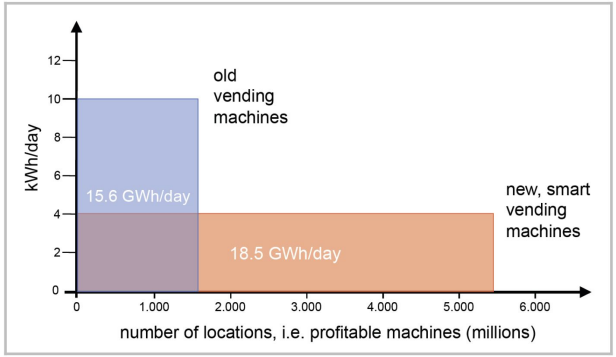

Where is the expected rebound/backfire?

Energy consumption per machine.

#VMs in Tokyo.

[1][4]

# Expectation

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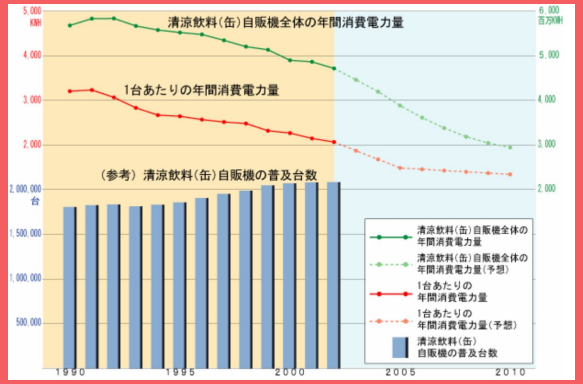
# Reality



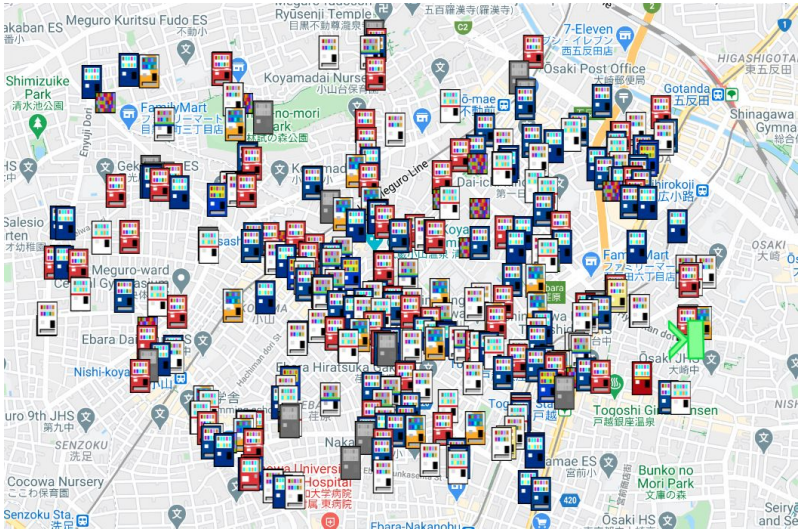

## Underlying assumptions:

1. If money can be made, money will be made.
2. Increased efficiency ⇒ Reduced operational cost.
3. Growth of VM market is only limited by the operational cost.

# Limiting factors

Two additional factors limiting the growth of japanese VMs:

## Space



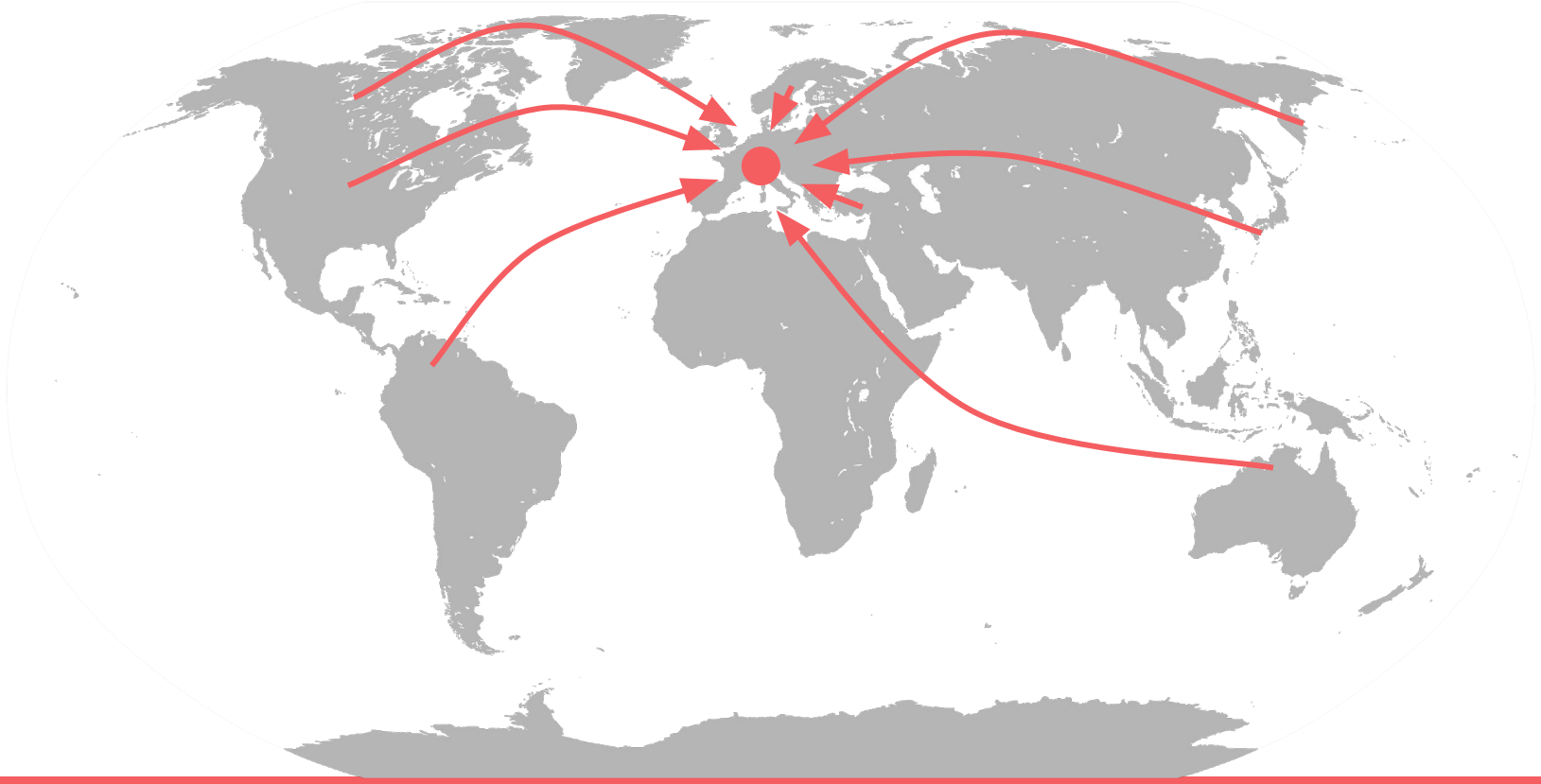

Area south of meguro station.
(Image source: https://sagasoda.com)

## Fukushima nuclear disaster (2011)

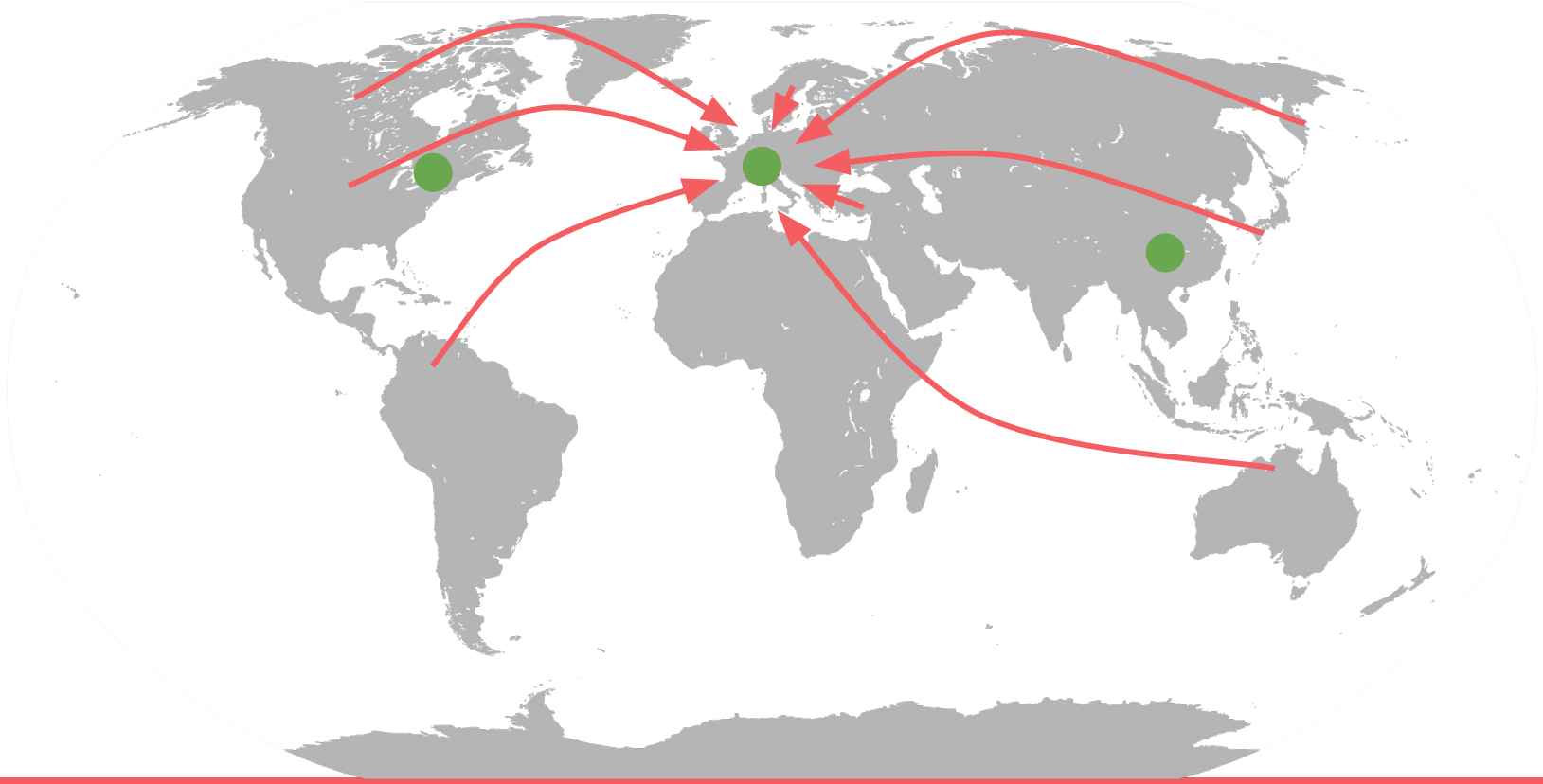
Aerial view of the fukushima catastrophe/
(Image source: https://peaceandjustice.org.uk)

# Application 2: Multi-site conferences

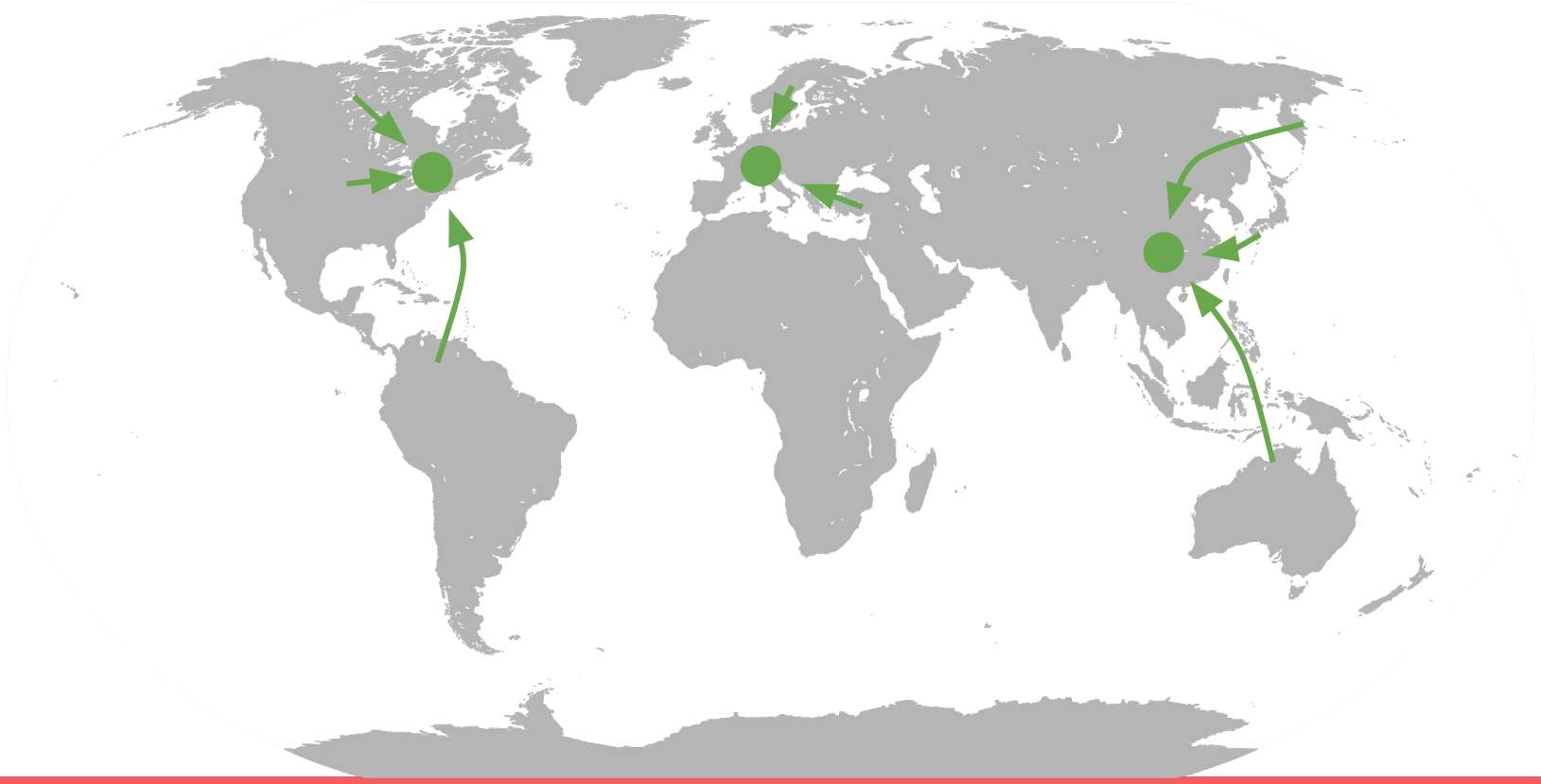
# General idea



# General idea



# General idea



# System under study: 2-site event

- Between University of Zurich and Nagoya University.
- 531 participants (372 in Davos, 159 in Nagoya).
- Partially shared events due to time-difference.


# ICT infrastructure


TelePresence system by Cisco.

Fotos graciously provided by Vlad Coroamă

# Social interactions during breaks

Attendees were generally satisfied with the cross-site interactions. (Q&A, coffee breaks etc.)

Fotos graciously provided by Vlad Coroamă

[2][7]

# Measuring environmental impact (EI)

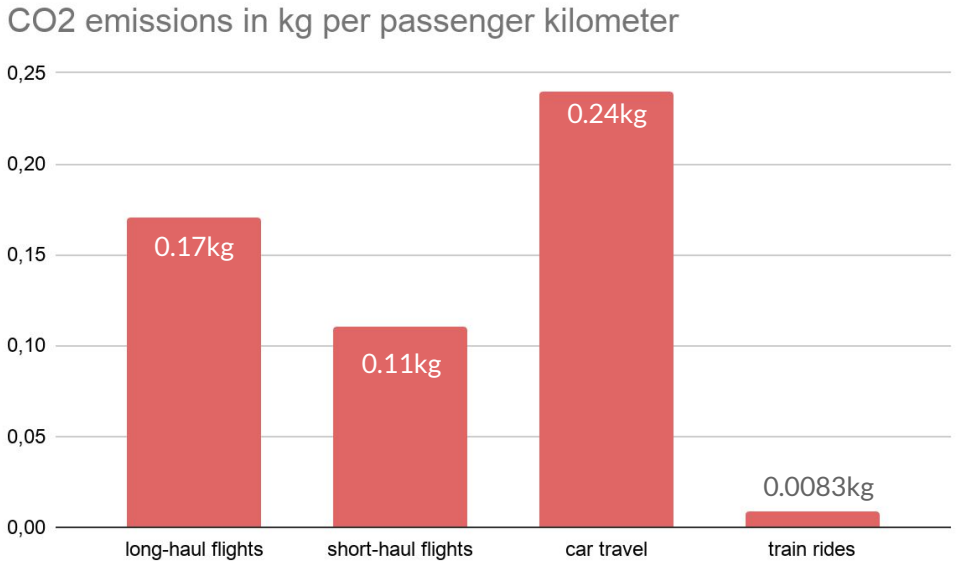
- Investigate **difference in CO2 emissions** between 1-site and multi-site model.
- Non travel-related EI assumed to be the same in both models.
  (I.E. Program booklet, flyers, hotel stay etc.)
- 96.3% of EI in 1-site conferences due to travel of attendees (Hischier and Hilty).
  ⇒ **Focus only on rebound effects w.r.t. travel.**
- Impact of additional ICT infrastructure needed for 2-site event was shown to be negligible (even under most pessimistic assumptions).

# Assessing the travel emissions

- Estimates from ecoinvent database.
- Attendees specified specified the different travel stops, and used means of transportation.

**Example:**

1. **Airplane**: New York → Paris
2. **Airplane**: Paris → Zurich;
3. **Train**: Zurich Airport → Davos

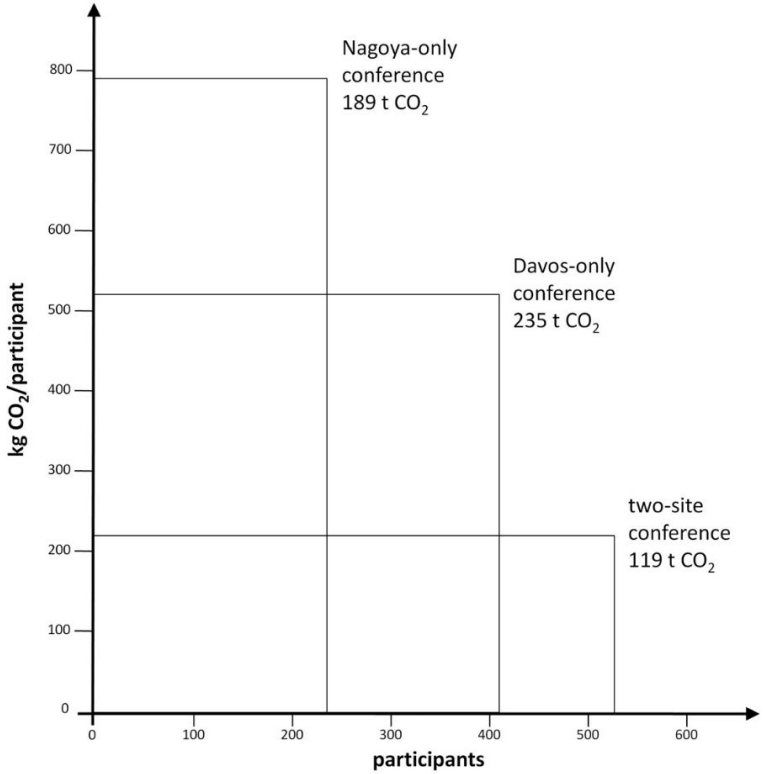


# Alternative scenarios


- Hypothetical scenarios obtained from survey + extrapolation: “Would you travel to Nagoya if the conference was only in Japan?”
- Hypothetical travel routes were calculated under very conservative assumptions: Only train + direct long-haul flight.

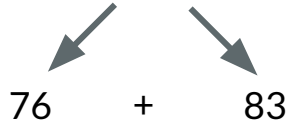
# Results: travel emissions

| CO2 (#Attendees) | Davos | Nagoya | Total |
|---|---|---|---|
| Nagoya-only | 154 t (79) | 35 t (159) | 189 t (238) |
| Davos-only | 84 t (372) | 151 t (76) | 235 t (448) |
| AS-IS | 84 t (372) | 35 t (159) | 119 t (531) |



# Substitution: Davos-only ⇒ Davos-Nagoya

| Attendees | Davos-only | Davos-Nagoya |
|---|---|---|
| Davos | 372 | 372 |
| Nagoya | 76 | 159 |




- 76 who would have travelled to Davos, will still travel to Davos.
- 83 additional Japanese will attend if there is the possibility to attend in Nagoya.
  → **This is the expected rebound: 2-site attracts more people than 1-site.**
- Still: Overall reduction of CO2 by almost 50%: **235 t → 119 t.** (last slide)
- Similar results in the other substitution (Nagoya-only → Davos-Nagoya).

# Application 3: Real-time feedback during showers

# The salience bias


Image source: https://thedecisionlab.com/biases/salience-bias/

"The salience bias describes our tendency to focus on items or information that are more noteworthy while ignoring those that do not grab our attention."

Quote source: https://thedecisionlab.com/biases/salience-bias/

[3][10][11]

# Salience bias example: Showering

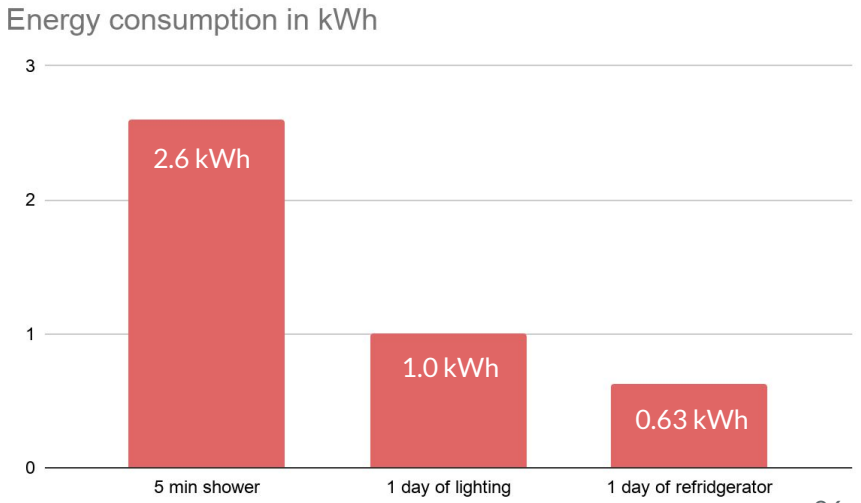
- Immediate “reward” of sensual comfort during warm showers overshadow the negative EI of water and energy consumption.
- Idea: Make energy consumption more salient by real-time feedback.
- Many people indicate willingness change behaviour in order to protect environment. (Diekmann et al. 2009, Naderi 2011)

Image source: https://millers-va.com/bad-showering-habits-that-are-ruining-your-bathroom/

[3][8][9]

# Environmental impact of showers

- On average: 45 L of hot water per 5 minutes of showering.
  → Requires 2.6 kWh to heat up.
- Water heating is second biggest contributing factor to residential energy usage.
- 14%-18% of average home's energy use.
  (Swiss Federal Office for the Environment 2013)



# The device

- Activated automatically each shower.
  → Unit of measurement = 1 shower.
- Measures energy and water consumption.
- Also displays water temperature and duration of shower.
- Polar bear: ice floe melts as energy consumption increases.


The amphiro a1 smart shower meter.

# Experimental conditions

- Duration of study: 2 month.
- Roughly 700 participating households.
- Only 1- and 2-person households were admitted.

## Control

- Water temperature [°C]

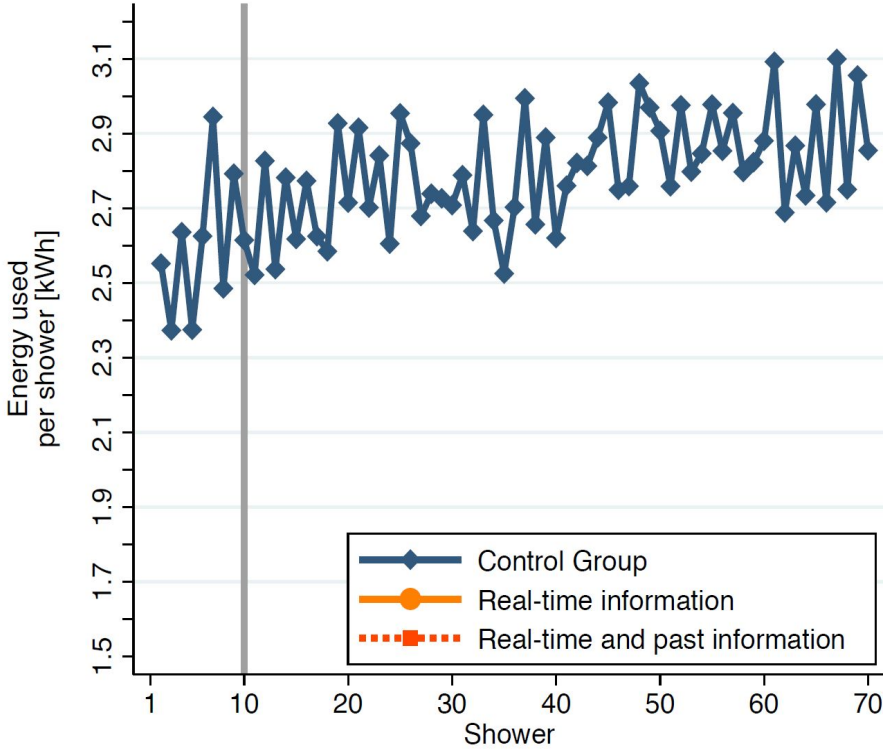

## Real-time condition

- Water temperature [°C]
- Water consumption [L]
- Energy consumption [kWh]


## Real-time + past feedback

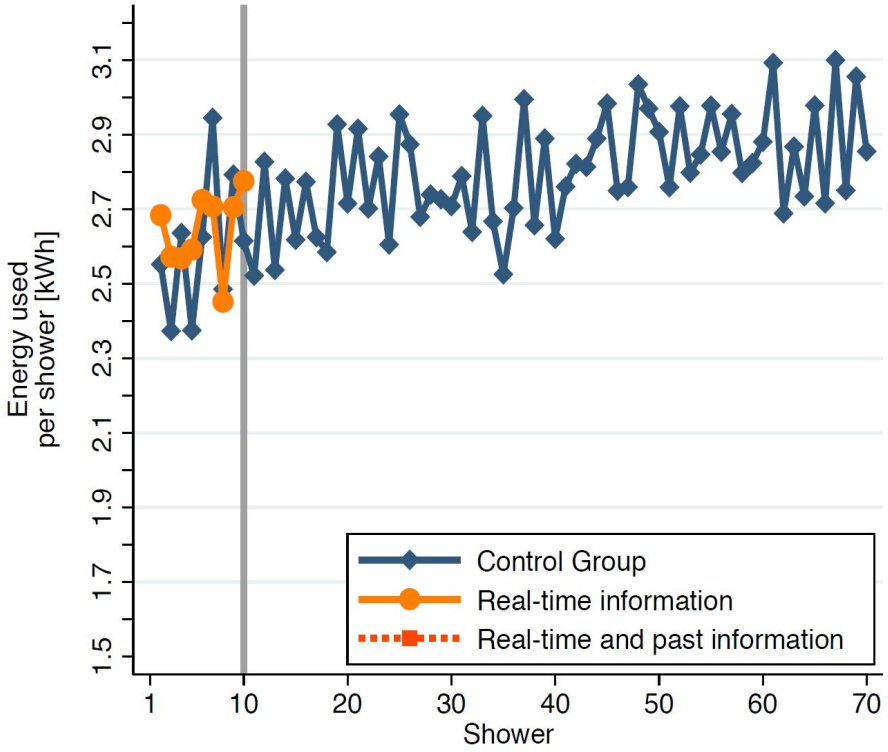
- Water temperature [°C]
- Water consumption [L]
- Energy consumption [kWh]
- Water consumption of previous shower [L]

# Results


Energy used
per shower [kWh]
1.5
1.7
1.9
2.1
2.3
2.5
2.7
2.9
3.1
1
10
20
30
40
50
60
70
Shower
Control Group
Real-time information
Real-time and past information


38

# Results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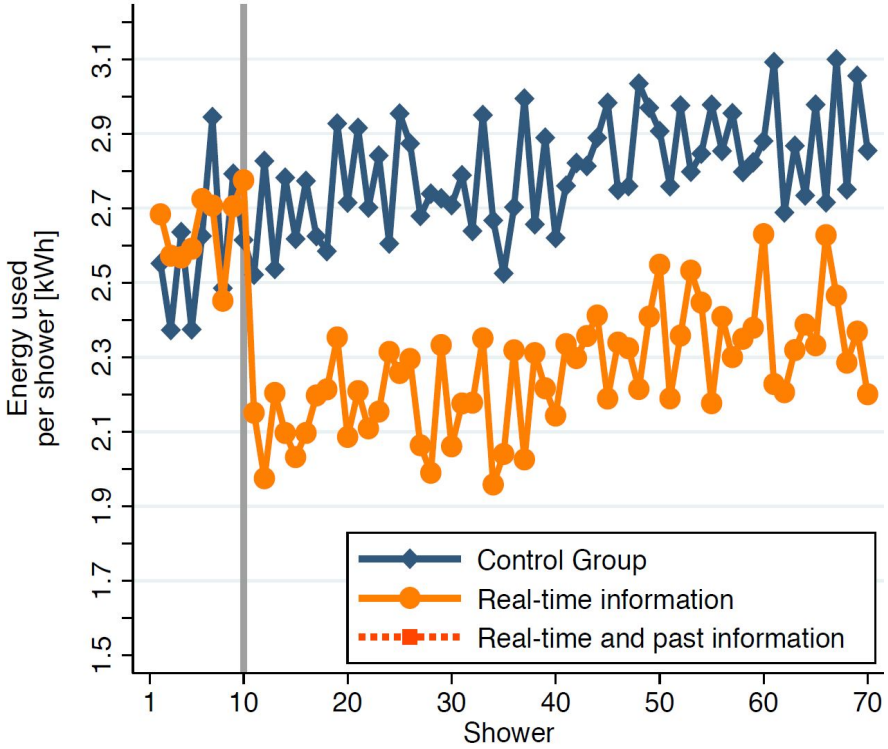
2.9
3.1
1
10
20
30
40
50
60
70
Shower
Control Group
Real-time information
Real-time and past information


38

# Results

**22%** drop of energy use.




# Conclusion

[1][2][3]

# Comparison of the applications

| 1: Japanese VM | 2: Multi-site conferences | 3: Real-time feedback |
| --- | --- | --- |
| Rebound effect dramatically reduced by market saturation.<br>⇒ Energy improvements translate directly to reduced energy consumption. | Rebound might not be as bad if the efficiency gain is sufficiently big. | Consumer “becomes more efficient” (i.e. uses less energy to shower).<br>⇒ Directly translates to energy savings. |

# The car example (cont.)

50 chf

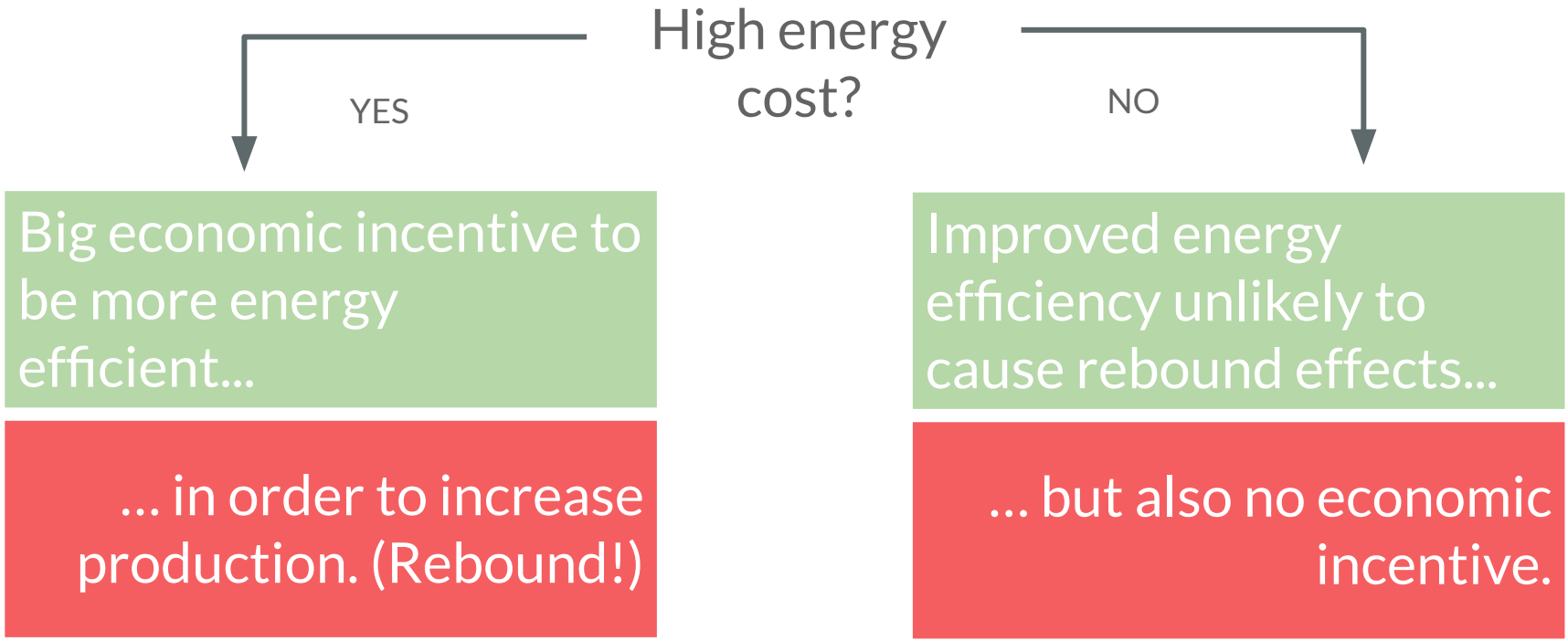
Budget: ~~100 CHF~~

Goal: Drive as far as possible.

| Scenario 0 | Japanese VM → Limited Market | Multi-site conferences → Large efficiency increase | Real-time feedback → Becoming CO2 aware |
|---|---|---|---|
| Fuel price: 1 CHF/L | Fuel price: 2 CHF/L | Fuel price: 1 CHF/L | Fuel price: 1 CHF/L |
| Efficiency: 1 km/L | Efficiency: 2 km/L | Efficiency: 4 km/L | Efficiency: 1 km/L |
| Distance: 100 km<br>Fuel used: 100 L | Distance: 100 km<br>Fuel used: 50 L | Distance: 200 km<br>Fuel used: 50 L | Distance: 50 km<br>Fuel used: 50 L |

# Closing thoughts

# The rebound dilemma (from an economic perspective)




(Hilty, 2012) Why energy efficiency is not sufficient – some remarks on "Green by IT"

# Energy sufficiency

"**Energy sufficiency** goes beyond **energy efficiency**: it's about having enough but not using too much. It's about doing things differently; about living well, within the limits."

- Cycle to a nearby destination instead of using car.
- Reduce thermostat by 1 degree.
- Shower less.

| Enforcing policy | Enabling policy | Implicit policy |
| --- | --- | --- |
| "No cars allowed." | Provide public infrastructure. (e.g. bikelanes) | Social pressure. |

Quote source : https://www.energysufficiency.org/

# Downshifting


Source: Paramount pictures

# Higher income ⇒ Higher GHG emissions

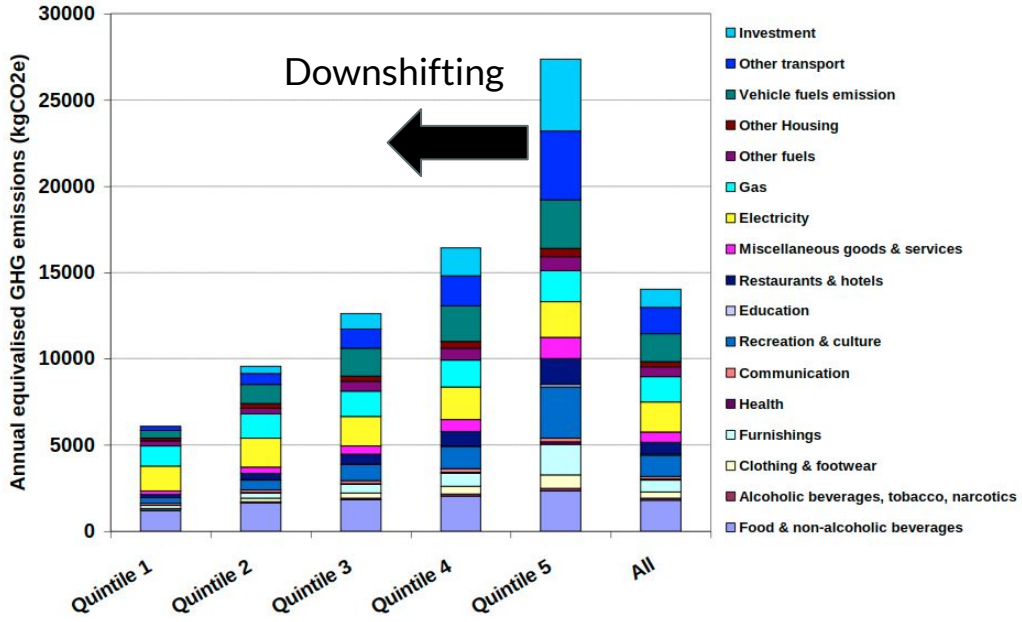



**Figure 7. Estimates of GHG emissions for different income groups in the UK**
*Source: Chitnis et al Figure 4*

# Thank you :-)

# References (1 / 3)

[1] Lorenz M. Hilty. Why energy efficiency is not sufficient – some remarks on "Green by IT", Proceedings of the 26th Environmental Informatics Conference (EnviroInfo), pp. 13-20, 2012

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[3] Verena Tiefenbeck, Lorenz Goette, Kathrin Degen, Vojkan Tasic, Elgar Fleisch, Rafael Lalive and Thorsten Staake. Overcoming Salience Bias: How Real-Time Feedback Fosters Resource Conservation, Management Science, 64 (3), pp. 1458-1476, 2018

[4] Masahito Takahashi and Hiroshi Asano. Japanese Vending Machine and Display Cooler Energy Use Affected by Principal-Agent Problem, In: Quantifying the Effects of Market Failures in the End-Use of Energy, pp. 108–119, International Energy Agency, 2006

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[6] Coleman, J. Japan's vending machines not as upright as they look, The Sunday Gazette, 1997

[7] Hischier R and Hilty L. Environmental impacts of an international conference. Environmental Impact Assessment Review 22, 543–557, 2002

[8] Lapillonne B, Pollier K and Samci N. Energy efficiency trends for households in the EU. Report, ODYSSEE-MURE, ADEME, 2015

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[10] Diekmann A, Meyer R, Mühlemann C and Diem A. Schweizer Umweltsurvey 2007—Analysen und Ergebnisse (Swiss environmental survey—Analyses and results). Report to the Swiss Federal Statistical Office (BFS) and to the Federal Office for the Environment (BAFU). Technical report, ETH Zurich, 2009

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