PAUL SCHERRER INSTITUT

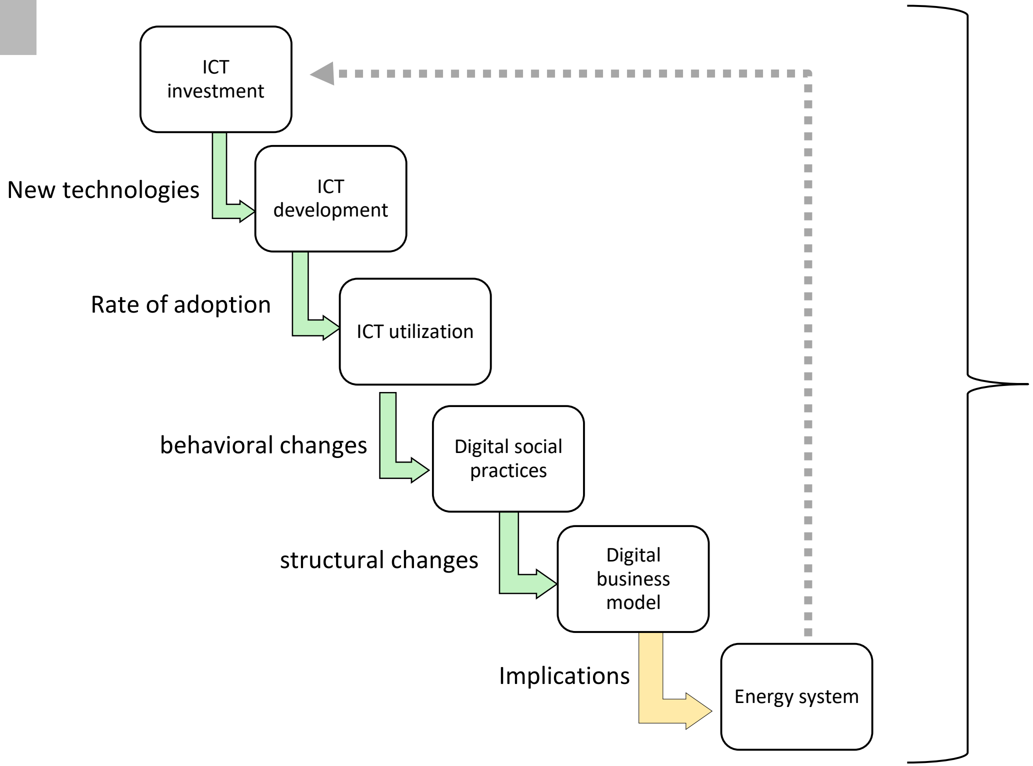
Stermieri Lidia:: PhD student :: Paul Scherrer Institut :: Energy Economics Group

DIGITAL ENERGY TRANSITION: DIFFUSION OF NEW SOCIAL PRACTICES AND THEIR IMPACT ON THE ENERGY SYSTEM

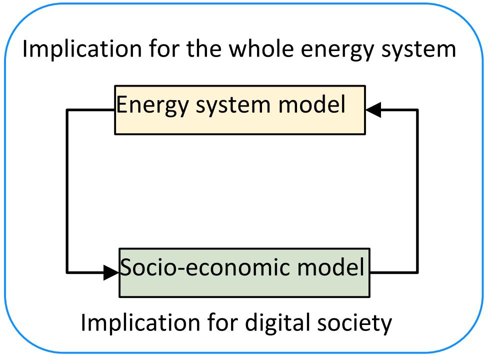
IAEE Conference, 2021, Digital event

Digitalization and Digital society

Digitalization: the increasing application of information and communication technology (ICT) throughout the economy and society.

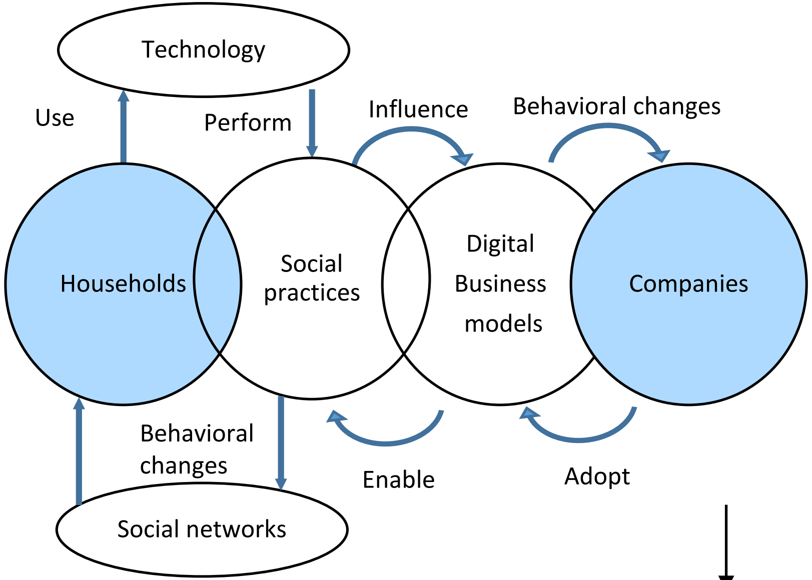


New framework



Work in progress- please do not cite

Agent-based socio-economic model



- Heterogeneous agents: Households, Companies
- Time period :from 2020 to 2050, annual based
- Dynamic over time horizon
- Transport, Residential, Service sectors
- Decision process based on maximize utility, considering:
  - **Cost/Benefit analysis**
  - **Behavioral preference**
  - **Infrastructure development**

Output:

- Impact of new social practices on energy service demand
- Rate of diffusion of technologies, practices, policies
- Digital level of society

Work in progress- please do not cite

Decision processes and indexes

Decision process of households for social practices and technology adoption:

$$y_{i,t} = \max(U_{i,p,t})$$

$$U_{i,p,t} = \alpha_{pre,i,p}\, preferences_{i,p,t} + \alpha_{ben,i,p}\, benefit_{i,p,t} + \alpha_{inf,i,p}\, infrastructure_{i,p,t}$$

Where:

i= Heterogeneous households

p= practices or technologies

t= time (year)

α_n, n∈N:{be,ben,inf} are the weights (from model calibration)

$\alpha_n \in [0,1]$

Decision process of companies based on benefit:

$$Benefit_{c,p,t} = \Delta GVA_{c,p,t} - \Delta Transition\_Cost_{c,p,t}$$

c= companies of service sector

p= digital business model and related practices

t= time (year)

GVA=Gross Value Added

Work in progress- please do not cite

PAUL SCHERRER INSTITUT

Households decision process: Social component and social networks

$$U_{i,p,t} = \alpha_{be,i,p}\, \boldsymbol{preferences_{i,p,t}} + \alpha_{ben,i,p}\, benefit_{i,p,t} + \alpha_{inf,i,p}\, infrastructure_{i,p,t}$$

$$\boldsymbol{preferences_{i,p,t}} = 1 - \frac{\left(\sum_{k=1}^{n}\left(v_{p,k} - v_{i,k,t}\right)^2\right)}{n}$$

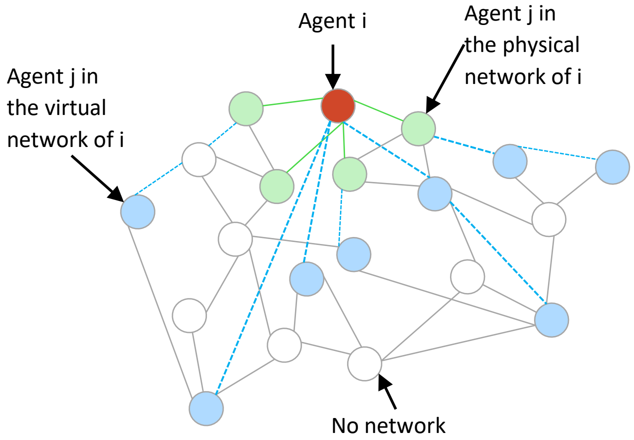
v_i: Household preferences
v_p: Technology attributes

Example:
1 single attributes
K="environment"
Households i: $V_{i,k} = 1$

	Input	Output
Technology	Vp,k	Calculation preference
P1	0.4	0.64
P2	0.6	0.84

v_i: Household preferences change over time due to social interactions:

Social networks



sn_m, m∈M:{vir,phy} are the social networks
$sn_{phy,i}$ = set of agents j in the physical network of agent i
$sn_{vir,i}$ = set of agents j in the virtual network of agent i

Social opinion dynamic:

For each i, and for each sn_m, and for each j, and for each k:

$$v_{i,k,t+1} = v_{i,k,t} - \mu_i * \frac{1}{|sn_m(i)|}\left[\sum_{j\in sn_m(i)} \left(v_{i,k,t} - v_{j,k,t}\right)\right]$$

s.t. $\left|v_{i,k,t} - v_{j,k,t}\right| \leq trust_{sn_m,i}$

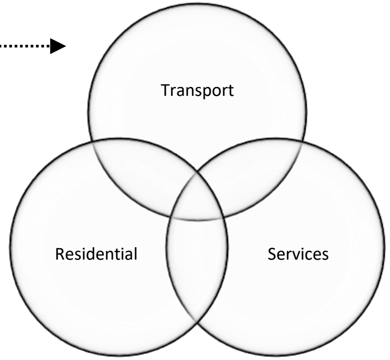
Where: μ_i (speed of preferences change), $trust_{sn_m,i}$(trusting interval for sn_m) ∈[0,1]

Work in progress- please do not cite

Households decision process: Economic component and infrastructure development

$$U_{i,p,t} = \alpha_{be,i,p}\, preferences_{i,p,t} + \alpha_{ben,i,p}\, \boldsymbol{benefit_{i,p,t}} + \alpha_{inf,i,p}\, \boldsymbol{infrastructure_{i,p,t}}$$

[Cross-sectoral analysis](#)



$$\boldsymbol{benefit_{i,p,t}} = \frac{budget_{i,t} - ANPV_{i,p,t}}{budget_{i,t} + ANPV_{i,p,t}}$$

s.t. $budget_{i,t} \geq \sum_p ANPV_{i,p,t}$

$$\mathrm{ANPV}_{\mathrm{i,p,t}} = \mathrm{f}(\mathrm{d}_{i,p}, CAPEX_{i,p,t}, OPEX_{i,p,t}, LT_p)$$

Where:
$\mathrm{ANPV}_{\mathrm{i,p,t}}$ = Annualized Net Present Value

$d_{i,p}$= discount rate per agent and per technology

Using input from Energy system model

$\boldsymbol{infrastructure_{i,p,t}}$=

residential sector: $\mathrm{infrastructure}_{i,p,t} = \begin{cases} 0 \ \ if\ no\ infrastructure \\ 1\ if\ infrastructure \end{cases}$

transport sector: $infrastructure_{i,p,t} = infradepl_{p,t} * \dfrac{1}{1 + exp^{(0.5 * \frac{km_{trip,i,t} - \overline{\overline{km_{trip,t}}}}{10^4})}}$

Work in progress- please do not cite

Decision process of companies

$$\boldsymbol{Benefit_{c,p,t}} = \Delta GVA_{c,p,t} - \Delta Transition\_Cost_{c,p,t}$$

if $Benefit_{c,p,t}$ > 0 or ($Benefit_{c,p,t} \leq$ 0 and willingness to perform practice >= 0.4):

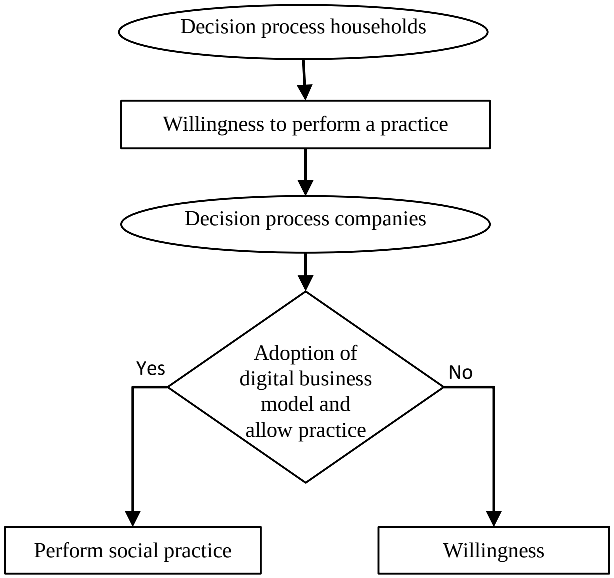
investment in digital business model, increase in the digital level

Else

no investment, practice related to business model not allowed, no evolution of digital level

$$emp\_willingness_{c,p,t} = \frac{\#\ employees_{c,t}\ willing\ to\ perform\ practice\ p}{\#\ empoyees_{c,t}}$$

For each t:

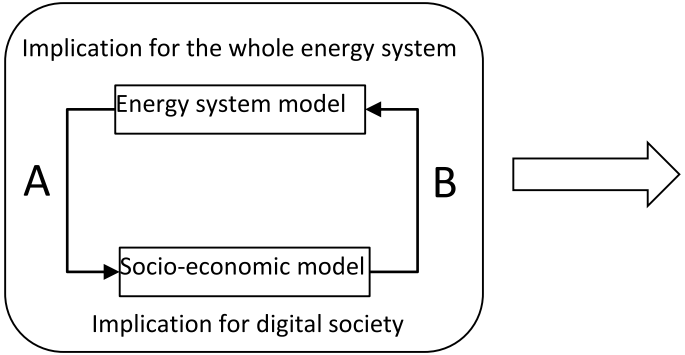


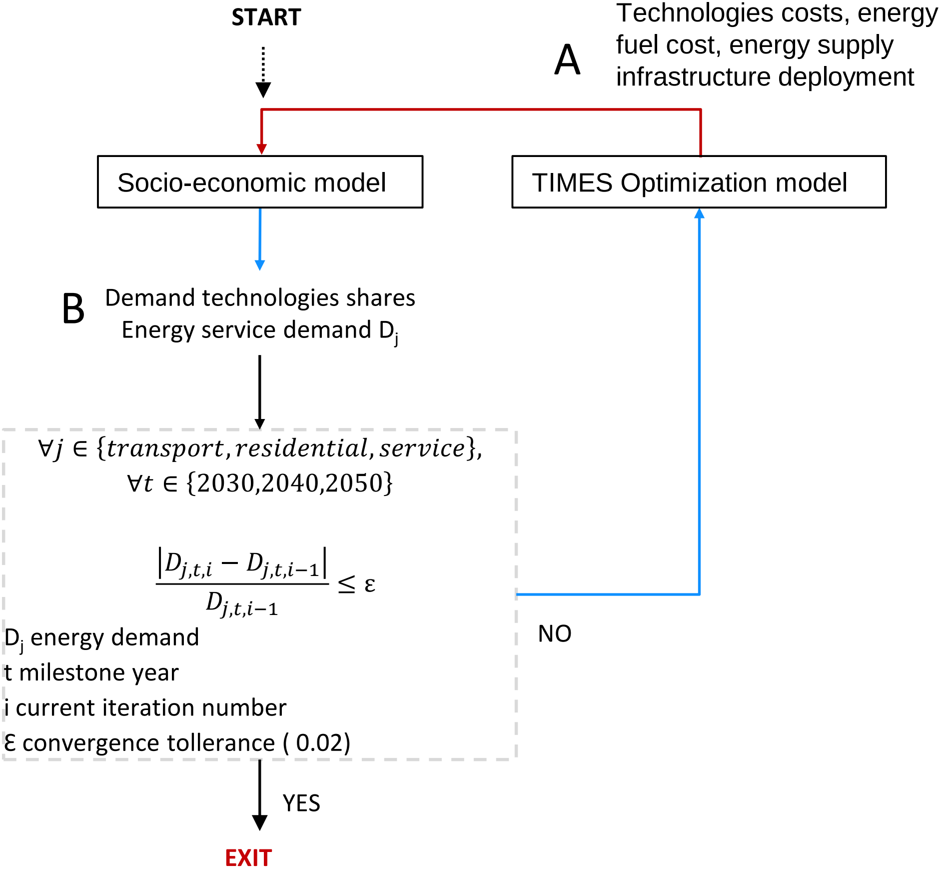
Example: “teleworking” practice

- Cost/benefit analysis:
  - TransitionCost(t)= ICT_cost + trainings + network_infrastructure + Energy_cost + administrative_cost
- Only sectors that can adopt the business model are considered

Work in progress- please do not cite

Soft-link between models





1. Energy system model:
   TIMES framework (Optimization model)
2. Soft-link
3. Iterative process

Work in progress- please do not cite

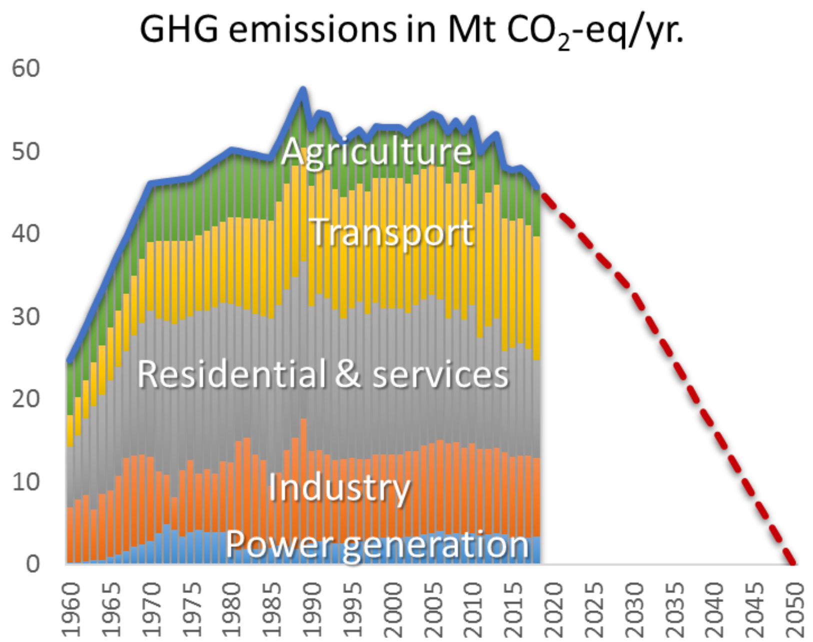
Switzerland: challenges of the energy transition

Objectives of Swiss Climate and Energy Strategy:

- Net-zero climate target 2050
- Withdrawal from nuclear energy (35% of Switzerland's electricity generation)
- Promotion of renewable energy resources
- Promotion of energy efficiency

Challenges:

- Maintain a clean power generation sector
- Limited renewable energy resources
- Security of supply (intermittent generation from renewables)



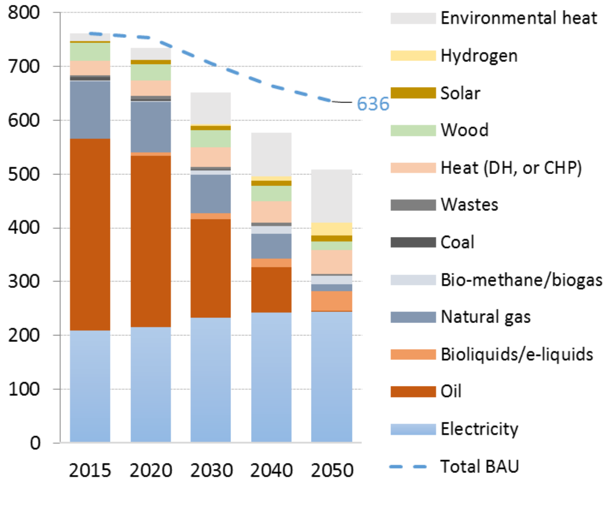
Work in progress- please do not cite

Current net-zero scenarios do not explicitly include digital strategy

LONG-TERM ENERGY TRANSFORMATION PATHWAYS[1]

JASM Joint Activity Scenarios and Modelling

Final energy consumption by fuel, PJ/yr.



Key messages:

- Solar PV, electric and hydrogen cars, heat pumps, energy savings measures
- Hydrogen, biofuels and synthetic fuels
- Capture, utilization and storage of CO_2

+

Digital Switzerland Strategy[2]:

Development of digital business models

Improving the digital empowerment of people

Development of infrastructures

?

Net-zero scenario including opportunities and challenges identified in the digital strategy

Work in progress- please do not cite

1. Scenarios, J. A., Panos, E., Kober, T., Ramachandran, K., & Hirschberg, S. (2021). I NTEGRATED SCENARIO ANALYSIS WITH THE SWISS TIMES ENERGY SYSTEM MODEL

2."Swiss Federal Office of Communication. (2018). *"Digital Switzerland strategy." September*, 19. https://www.bakom.admin.ch/bakom/en/homepage/digital-switzerland-and-internet/strategie-digitale-schweiz.html

Switzerland and the opportunity of digitalization

Favorable conditions for digital transformation:

Economic structure:

- 74% of Swiss GDP is generated by the service sector
- Most Swiss firms are small- and medium-sized enterprises
- 75% of population works in the service sector

Market and political context

- Stable political system
- Attractive economic policy
- Flexible employment market
- Legal basis for the data economy

Digital transformation enables the sustainable development of the country:

- Increase resource and process efficiency(Lack of natural resources)
- Ensure value creation, growth and well-being

Work in progress- please do not cite

PAUL SCHERRER INSTITUT PSI

The Switzerland framework for digital social practices

Databases

SHEDS survey and Sinus Milieus
To initialize socio-demographic attributes and behavior of Swiss population

Microcensus and SHEDS
To calibrate transport sector

STEM technology dataset
Current and future technology cost and efficiency
Energy cost
Used in the cost/benefit analysis

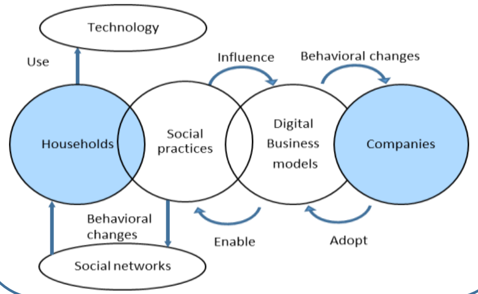
Time Use Survey
To parametrize the diffusion of social practices

SFOE statistics
To calibrate and validate the model

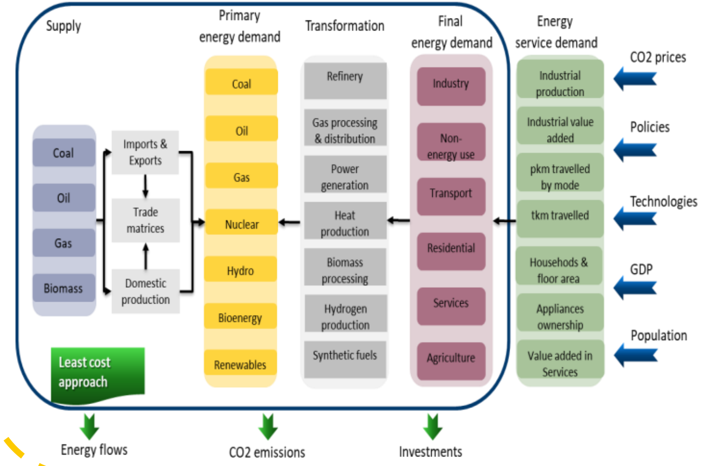
Output

Transition pathways and energy system configuration to achieve Swiss long-term climate target

Swiss Agent-based socio-economic model



Swiss Times Energy system Model (STEM)*



- High level of technology detail
- Long time horizon(2050+)
- High temporal resolution

Output

- Impact of new social practices on energy services demands
- Rate of diffusion of technologies, practices
- Digital level of society

Work in progress- please do not cite

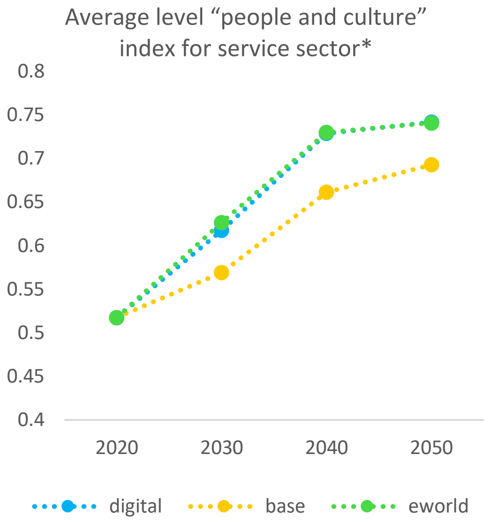
* Switzerland Energy Transition Scenarios : Development and Application of the Swiss TIMES Energy System Model (STEM), Final Project Report December 2014, Ramachandran Kannan, Hal Turton

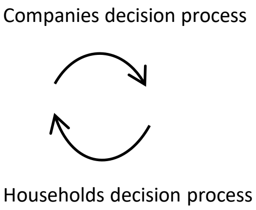
Case study for Switzerland:
-net-zero climate target
- social practice “teleworking”

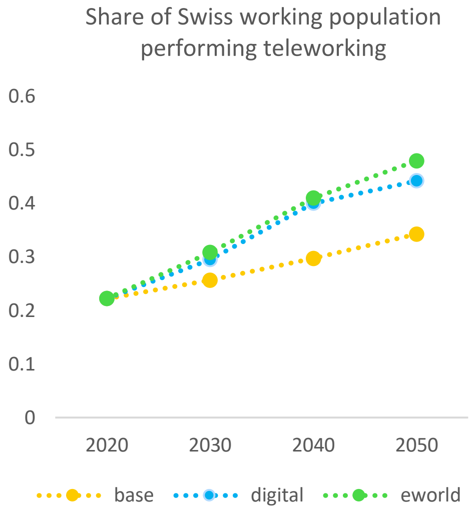
Scenario	BASE	Digital	E-world
Digital society	• ICT development annual growth rate: 0.28% • ICT intensity usage: 30% Example: «teleworking» People who do telework will work from home 30% of their annual working hours and 30% of their meetings will be online meetings	• ICT development annual growth rate: 1.40% • ICT intensity usage: 60% Example: «teleworking» People who do telework will work from home 60% of their annual working hours and 60% of their meetings will be online meetings	• ICT development annual growth rate: 1.85% • ICT intensity usage: 100% Example: «teleworking» People who do telework will work from home 100% of their annual working hours and 100% of their meetings will be online meetings
Climate target	0 Mt CO_2 in 2050 CO2 tax: 336 CHF/Mt in 2030 360 CHF/Mt in 2040 2917 CHF/Mt in 2050		

Work in progress- please do not cite

Preliminary results: Adoption of a practice and business model







Conclusions:

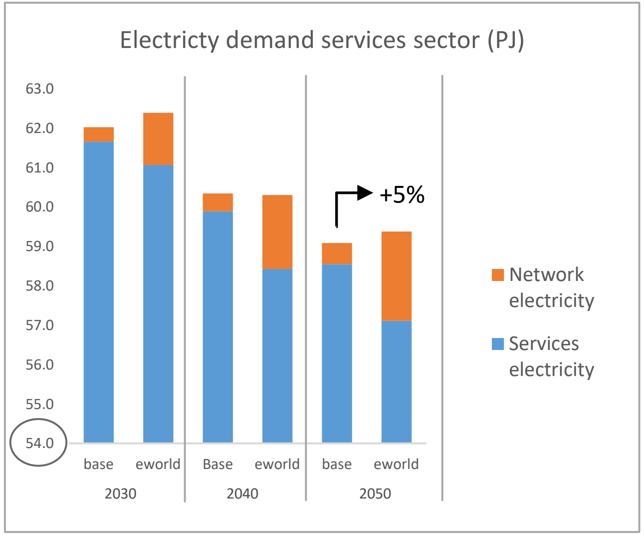
- Social network influence maintains the growth in teleworking after the saturation of the number of companies doing the practice
- Companies need to facilitate the spread of teleworking practice to mobilize the working population towards the practice

Work in progress- please do not cite

Energy services demand: base and eworld

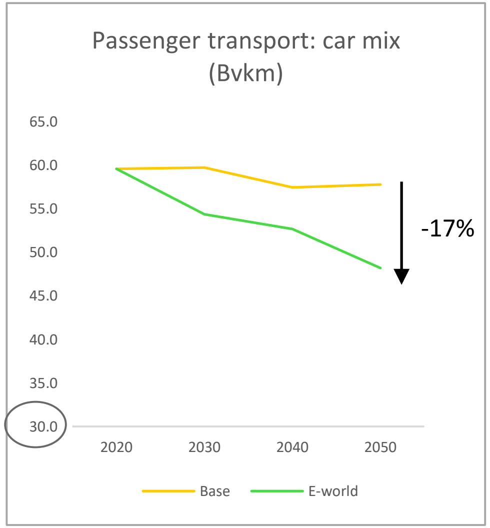
Work in progress- please do not cite

Services sector



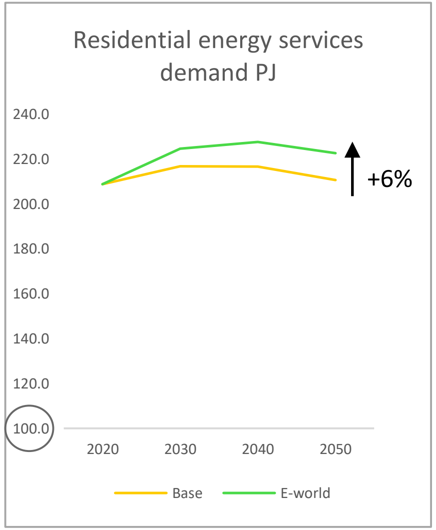
Electricity demand connected to internet data for online meetings (network infrastructures and data center)

Transport sector



Reduction in demand for commuting but without decreasing car ownership rate

Residential sector



Increase in heat and electricity demand

! Small variations, only one practice analyzed!

Conclusions: Implication for the energy system

1. Agents choice is suboptimal from a system perspective:

- Lower transport demand does not favor the renovation of the cars fleet
- If clean technologies are not supported, their rate of penetration is slower

Teleworking alone does not guarantee less emission from transport, clean technologies need to be attractive

2. **Energy system reacts reducing the emission in other sectors:**

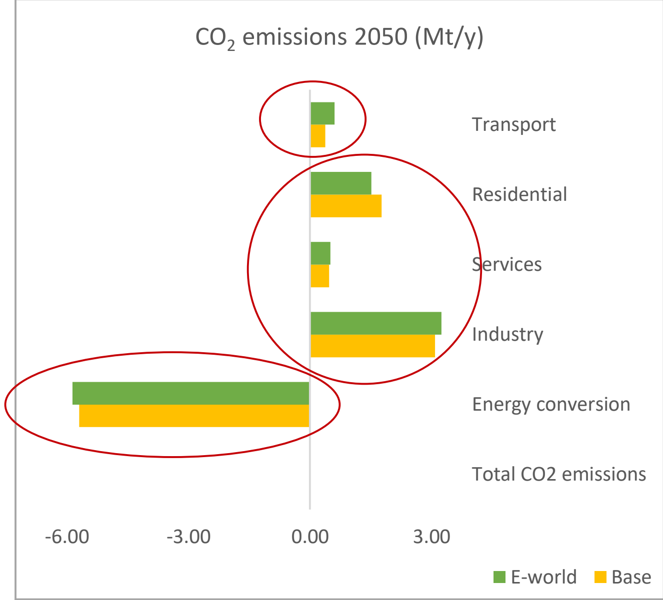
- It shifts renewable resources from industry to reduce emission in residential and transport sectors
- It increases the burden on the energy conversion sector to offset the emissions

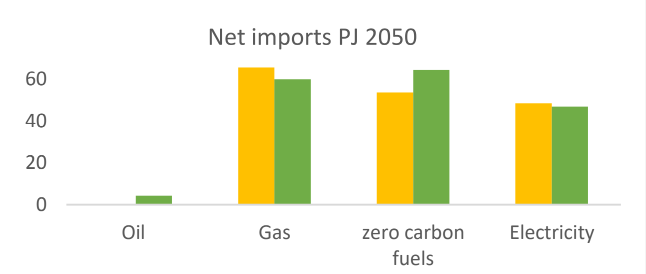
3. **More zero carbon fuels are used in transport and residential:**

- Due to limited resources, additional imports are needed

Total annual cost increase of 1 BCHF/y_{2050} due to additional import of zero carbon fuels

Need to identify social practices and digital business models that impose obstacles or that help accelerating the energy transition





Work in progress- please do not cite

Wir schaffen Wissen – heute für morgen

My thanks go to Dr. E. Panos and Dr. T. Kober for their support in my research