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Experience curves and Building Envelopes: The Swiss case and some European outlook

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Content

Methodology

- Peculiarity of building envelope
- Definition of reference EE level
- Understand innovation process and anticipate future developments

The Swiss case

- Façade insulation
- Glazing / windows

European perspective

- Window glazing

Conclusions and recommendations

References

Methodological issues

Experience curves: general methodological issues (1)

Goal and application

- Forecast of costs and competitiveness of new & innovative products
- Energy modelling and Policy analysis

Method

- (Statistical) description of relation between costs (prices) and cumulative market volume

$$C = f(Q)$$

Advantage

- Relatively simple approach, quantitative results

Drawback

- Weak theoretical background
- Low explanatory power of innovation process and drivers of costs and deployment
- Very new technologies, technolog. break throughs cannot be included

$$C = f(Q) = aQ^{-b}$$

Experience curves: methodological progress needed

- More explanatory power of innovation process and drivers of costs and deployment needed

Estimation Method

$$C \text{ (or Price)} = f(Q(d_1, d_2, d_3 \dots), M, P, L, B \dots)$$

d1, d2, d3...	drivers of deployment, e.g. M, P, Price (Cost)
M	market structures and situation [prices of input factors]
P	Policy action
L	Quality of product
B	Business cycle

=> Understanding techno-economic progress, diffusion process, barriers and successful policy measures as important as knowing the exact progress ratio

Drivers and Types of Innovations

Scope and goals of innovations

- Technical (Energy efficiency, architecture, lifetime)
- Economics (costs, cost-effectiveness)
- Quality (architecture, durability, maintenance, environm. impact)
- Marketing, commercial exploitation

Gradual Innovations (GI)

Expercience Curves ok

- Improvement and simplification of work processes (WP)
- Improvement of materials and techniques (MT)

“Leapfrog” Innovations (LI)

Exp. Curves n.a.

- Fundamental alteration of work processes
- New materials and techniques (e.g. pre-fabrication instead of manual ass.)

The building envelope

Peculiarities of energy efficiency of the building envelope

- Multi-functional character of building envelope:
 - provision of (thermal) comfort and light
 - protection against weather impacts, noise, burglary
 - energy saving
- Add-on character of energy
- Energy efficiency (EE) / energy saving rather than generation/supply
- Gradual character of EE
- Economics of EE in buildings is not only determined by usual parameters (energy prices, interest rates, lifetime), but also by choice of EE level, Willingness to Pay for housing attributes (cf. Banfi et al. 2006)

Experience curves and the building envelope (1)

Adaptation of experience curve (EC) concept to building EE:

	Electricity generation technologies	Building envelope EE measures / technologies
Output	Electrical capacity (more or less homogenous good, independent of technical characteristics and of stage of development of the plant)	m ² of applied insulation or windows, energy performance depending technical characteristics, reference, stage of development
Cumulative output	Cumulative installed capacity kW _{el}	Applied m ² @ technical characterist. Cumulative kWh _{conserved}
Specific costs	CHF/kW _e CHF/kWh _{produced}	CHF/m ² @ technical characteristics CHF/kWh _{conserved}

Experience curves and the building envelope (2)

Methodological peculiarities and challenges of empirical estimation

- Reference energy efficiency (EE) standard needed
- Reference standard changing over time
(codes and standards, energy prices, common practice)
- **Distinguish between standard EE levels and enhanced EE**
- Costs (prices) depending on Quality
- Quality changing over time due to consumer needs, product differentiation or regulation
(e.g. window frame, lifetime of materials, mechanical fixings)
- High degree of division of labour: **EC effects on all levels**
- Availability of consistent time series of P and Q often a problem

Experience curves and the building envelope (2)

- Single companies vs. sector of a country
- Individual Countries vs. Europe
- Individual production step, products (e.g. glazing, insulation material)

vs.

Whole envelope element (complete façade insulation incl. skin, installed window)

=> depends relevance, i.e. on cost structure

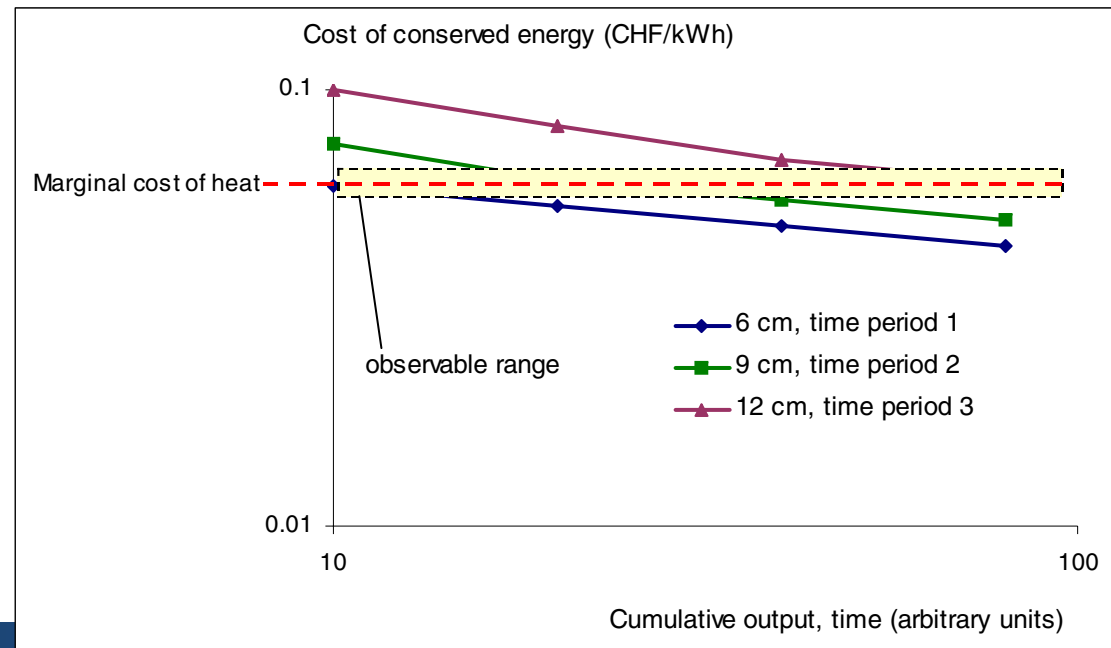
Examples

- Standard façade insulation: 2/3 labour cost, 1/3 material cost, but labour cost depends on insulation thickness
- Standard window: glazing 25% of window cost
- Triple glazed window: glazing 40% of window cost
- Windows installing: 25% of final cost

Marginal costs of EE: Empirical challenge of estimating techno-economic progress

$$\text{Average Costs (AC) of EE} = \frac{\text{Construction Add-on Costs} \rightarrow \text{Insulation}}{\text{Energy Efficiency Gain} \rightarrow \text{Conservation of space heating}}$$

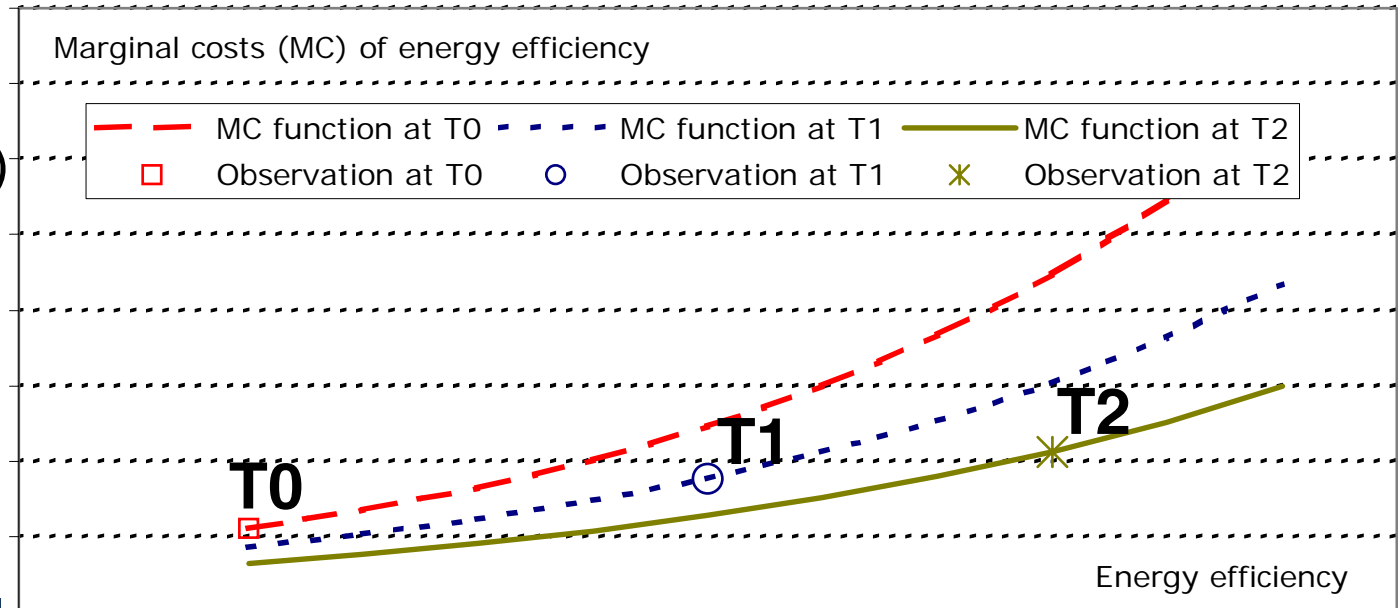
Peculiarity:
Observing constant AC of EE despite of techno-economic progress
Reason:
insulation thickness (and hence AC of EE) is chosen as a function of energy prices



Marginal costs of EE: Empirical challenge of estimating techno-economic progress

$$\text{Marginal Costs (MC) of EE} = \frac{\text{Marginal Construction Add-on Costs} \rightarrow \text{Improved Insulation}}{\text{Marginal Energy Efficiency Gain} \rightarrow \text{Add. conservation of space heating}}$$

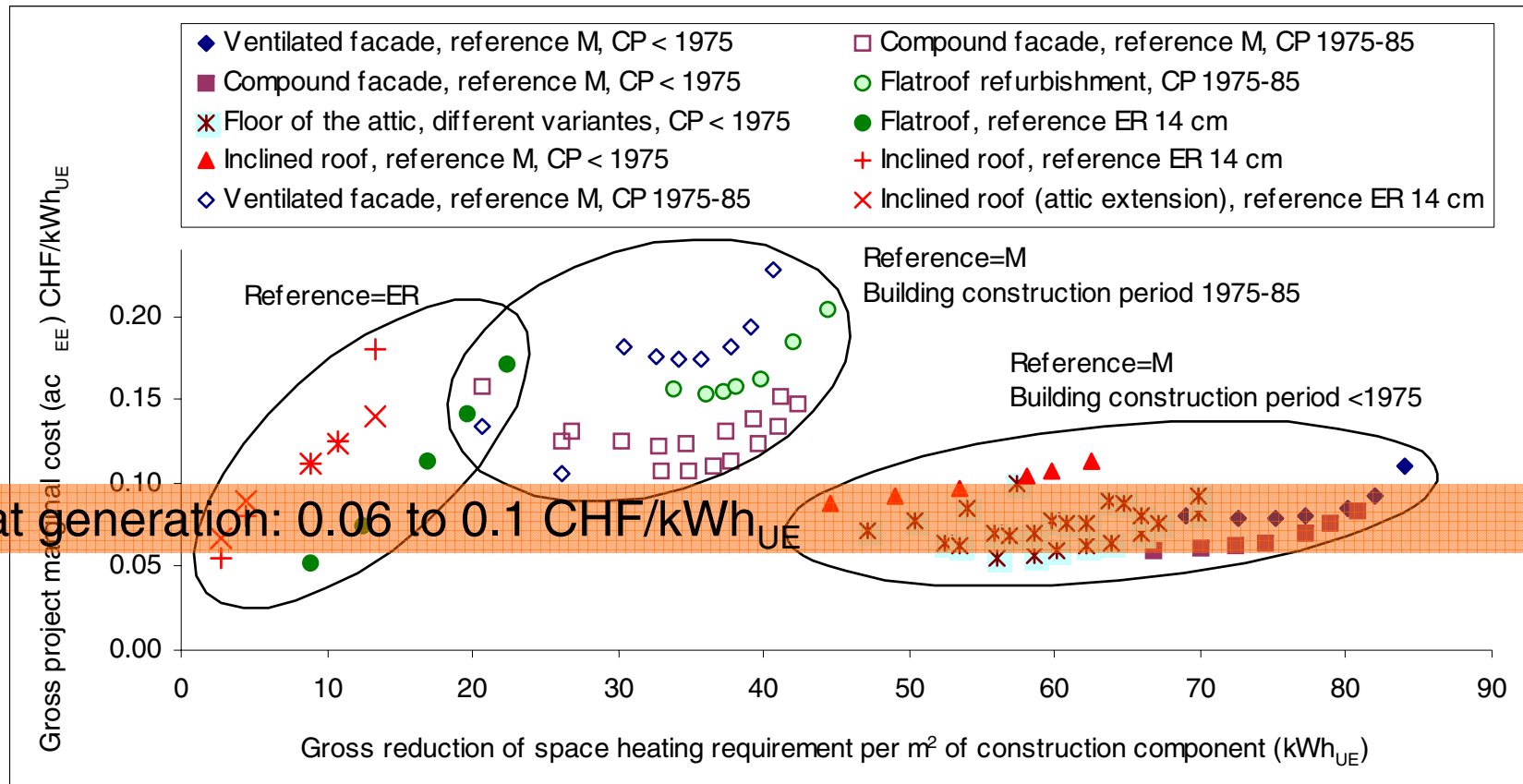
Peculiarity:
Observing higher MC (e.g. at T2 vs T0) despite of techno-economic progress (i.e. MC curves are getting lower and „flatter“)



Marginal costs of EE

Standard EE level economically viable (or close to)

=> Policy and EC discussion should focus on enhanced EE levels



1 CHF =
0.6 Euro

Innovation goal: Energy Efficiency, Utility

	Innovation-Typ
<p>Lower lambda, lower insulation thickness (at equal U-Value)</p> <p>Insul. materials: „grey“ EPS, Phenol“harz“, Aerogel,...</p> <p>New insul. materials : Vacuum insul. panels (VIP)</p>	<p>GI, LI</p> <p>LI</p>
<p>Thermal bridges:</p> <p>(Geklebte) gekeilte Platten (auch Redukt. Schadensrisiko)</p> <p>Anschlussdetails allgemein (in CH bereits relativ gut)</p> <p>Insulated solar blind „boxes“</p>	<p>GI</p> <p>GI</p> <p>LI</p>
<p>Lifetime, maintenance intervalls</p> <p>Pollution facade surface: chemical, physical</p> <p>Glue, Gewebe/Netze</p>	<p>GI, LI</p> <p>??</p>

Innovation goal cost reduction

	I.Type	Approach
Spritzverfahren (Klebemörtel, Deckputz)	GI	MT->AP
Integration von Bohren, Dübeln und Setzen	GI	MT->AP
Anschlussdetails (in CH bereits relativ gut)	GI	MT->AP
Dämmmaterialien mit geringeren λ (Archit., Bauland)	GI, LI	MT, AP
Selbstklebende Dämmplatten und Netze	LI	MT->AP
Neubau: Vorgefertigte Wandelemente (Beton, Holz, u.a.) mit WD, Fenstern, Erschliessung (Elektro, Medien, Lüftung)	LI	AP
Erneuerung: Lasergestützte Vermessung und Vorfertigung Verzicht auf Gerüst	LI	AP
Integrierte Planung (von Planung direkt in Vorfertigung)	LI	AP

The Swiss case

Legal, Institutional and economic framework

The Swiss case

Drivers of past cycle:

- Energy crises and price increases/high levels (or expectations)
1973, 1979-1986, 2004 - and concern on energy / environment
- Standards set by professional association SIA
building elements: 70ies; whole building 1988 / 2001 / 2007
- Codes by cantonal authorities: mainly 1980ies, harmonisation
1990ies, reinforcements 2001 and 2008
- (Autonomous) technical progress (competition)
- Voluntary Standards and Labels (MINERGIE as from 1997)

Long-term technical progress of insulation

- Continuous increase of insulation thickness (cf. table)
- Easier “Verarbeitbarkeit”
- Development of insulated elements (window sill / breast / reveal)
- Reduction of thermal bridges (e.g. fixings)
- More recently: lower λ (thermal conductivity):
compound materials: 0.03 W/mK, vacuum insulation: < 0.01 W/mK

Example: Rock wool insulation in Switzerland

	< 1960	1961-1965	1966-1970	1971-1975	1980	1985	1990	1993	1995	1997	2000	2003	2007
Incl. roof			50	75	90	100	105	117	129	129	135		160
Façade					60-80	75	84		91	96	108	120	140
Flat roof	30	40	50	60-80	80-100		110		120		140		
Basement ceiling				20	30		40						

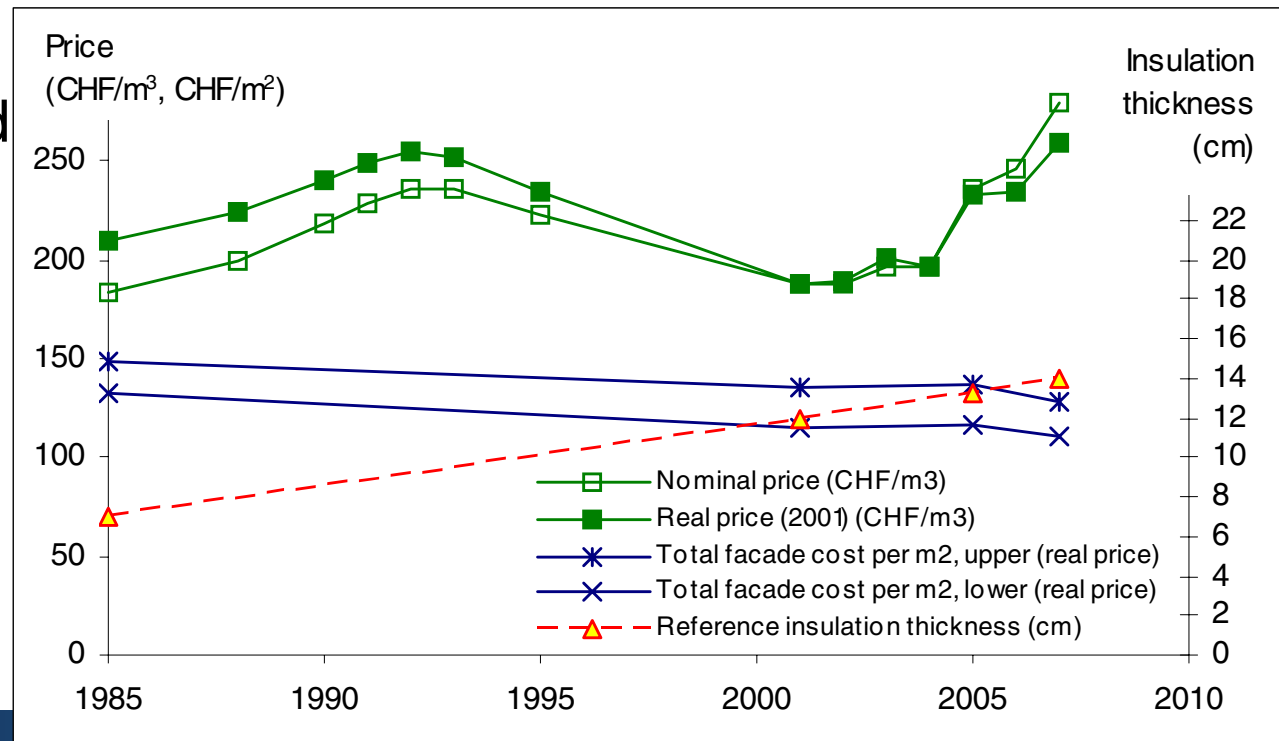
Standard facade insulation (PS)

Development since 2001:

- Increase of material costs (per m³, and even more per m²) since 2005
- No (or low) progress regarding installing time
- Nevertheless constant nominal prices
- Installing is more and more outsourced => quality problems

1 CHF =
0.6 Euro

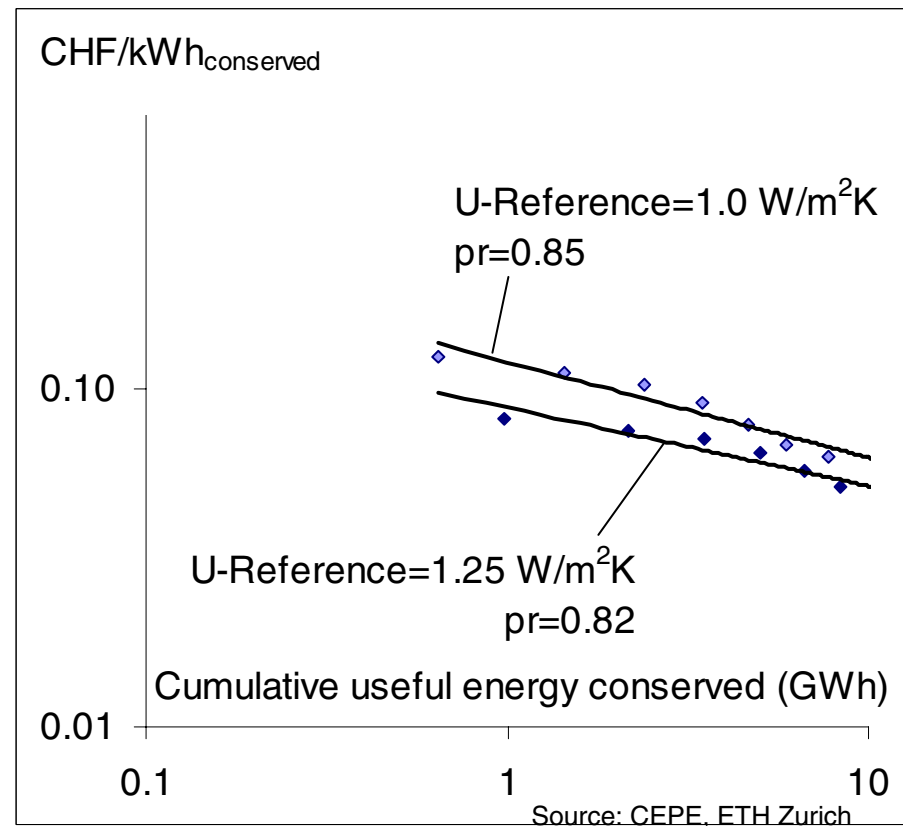
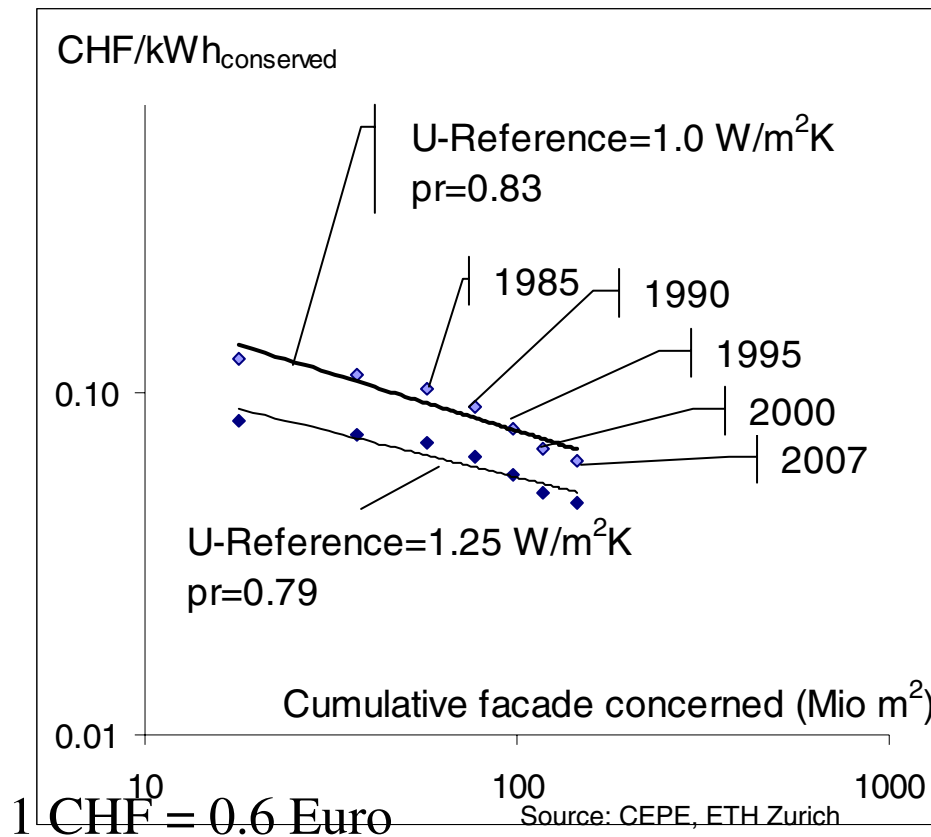
Source:
marmoran maxit, Switzerland
CEPE, ETH Zurich



Progress ratio of standard façade insulation (PS)

Development since 2001:

- Most recent updates confirm results of Jakob and Madlener (2004)

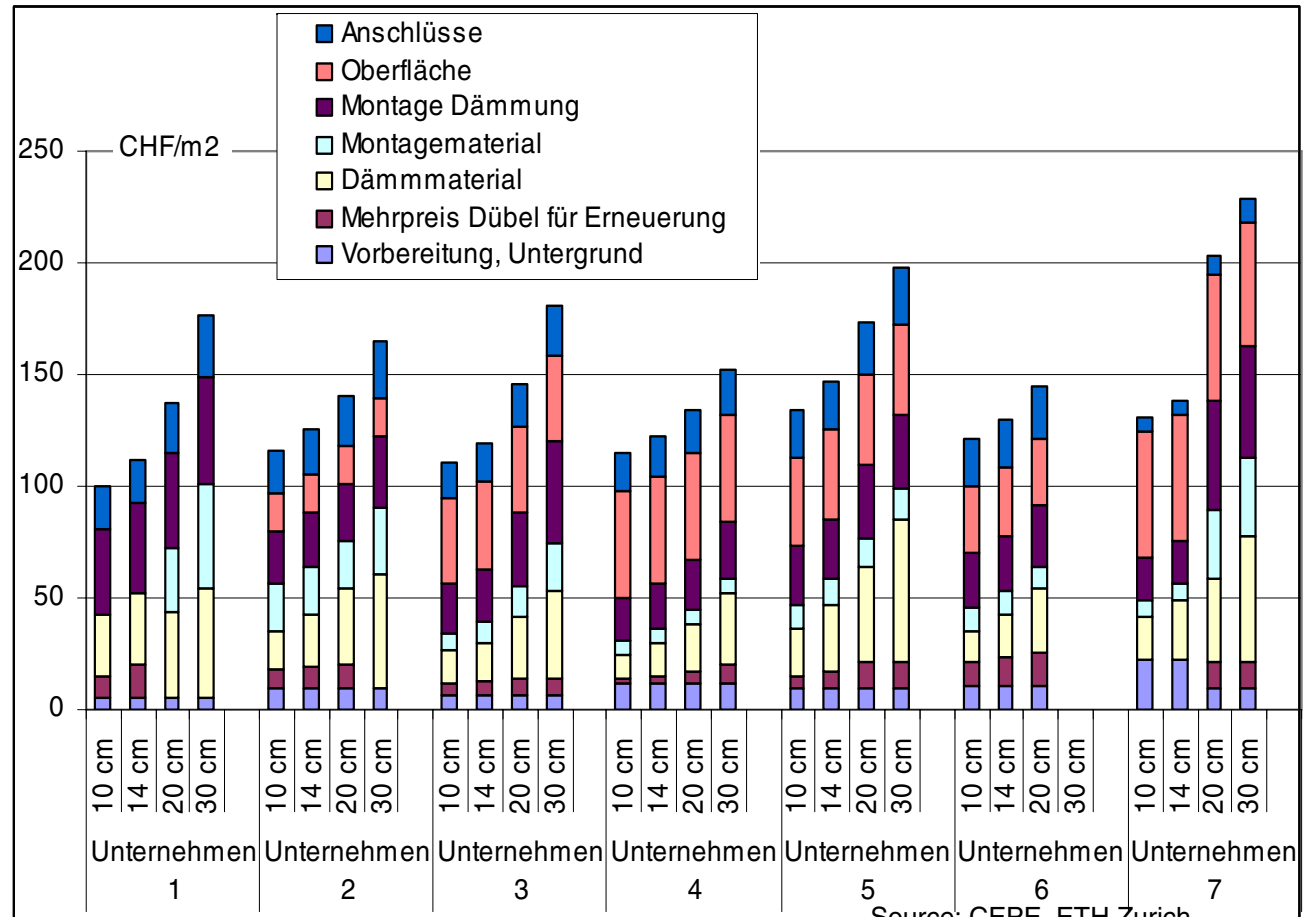


Enhanced energy efficiency standards (1)

Cost structure

- Labour: 2/3
- Material:
Total: 35-50%
Insulation panels:
ca. 25%-30%)

1 CHF =
0.6 Euro



Source: CEPE, ETH Zurich

Market and cost structure of standard compound façade insulations (example EPS in Switzerland)

Cost share (CHF/m²)

- Material resource (Styrol), depending on oil price 1-3
few European producers w/o transportation: 1-2
- Insulating panel: few Swiss producers (3 EPS, 1 Rock Wool) 15-20
- Insulation system (adhesive mortar, plaster, adjacent elements etc.):
about ten Swiss suppliers 20-30
- Mechanical fixing (mainly existing buildings): few Swiss suppliers 6-10
- Scaffolding: large number of small and medium enterprises (SME) 6-10
- Pre-treatment (only existing buildings) 10-15
- Assembling, plastering, painting: large number of small enterprises,
some medium ones, increasingly sub-contracting 40-60
- Planning: large number of small enterprises,
few medium and large ones (e.g. integrated companies) 5-10

Innovation since about 2000

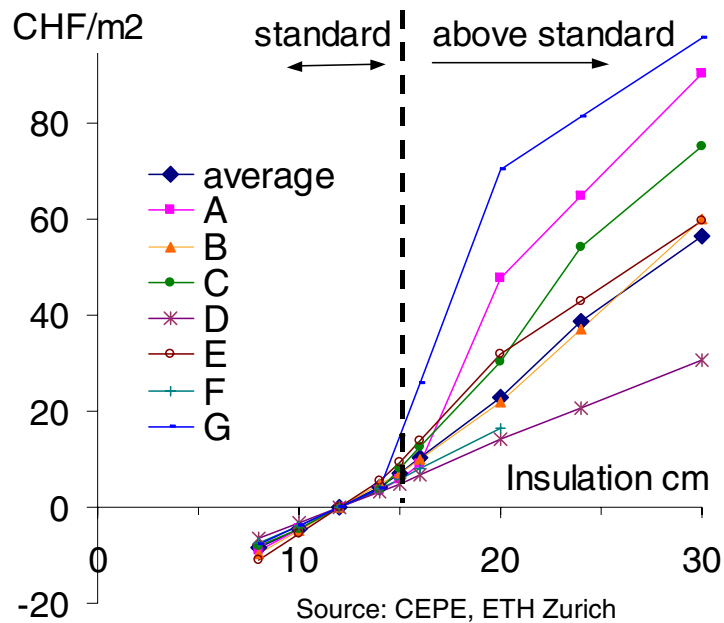
- Versenken von Dübeln (Vermeidung von Abzeichnung)
- Dämmplatte mit Hochleistungsdkämmkern: ca. 30% Verbesserung
- Graues EPS (Lambda): ca. 10% Verbesserung
- Spezielle Kantenausbildung bei hohen Dämmstärken zur Q-Sicherung
- Minergie-Eco, Eco-Devi (Sachliche Entscheidungsgrundlage)
-

Expected innovations as from 2007

- Anschlusselemente (z.B. Storenkasten) mit Vakuum-Dämmung
- Kontroll- und Instandhaltungskontrollvertrag Bauherr - Systemhalter
-

Enhanced energy efficiency standards (2)

Survey 2001/2002



2007

?

Figure: Add-on Investment Cost of Facades with Insulation as compared to Reference 12 cm (CHF/m²)

- No official price statistics => costly surveys
- Pioneer market surcharges?
- Few experience: Risk surcharges?

1 CHF = 0.6 Euro

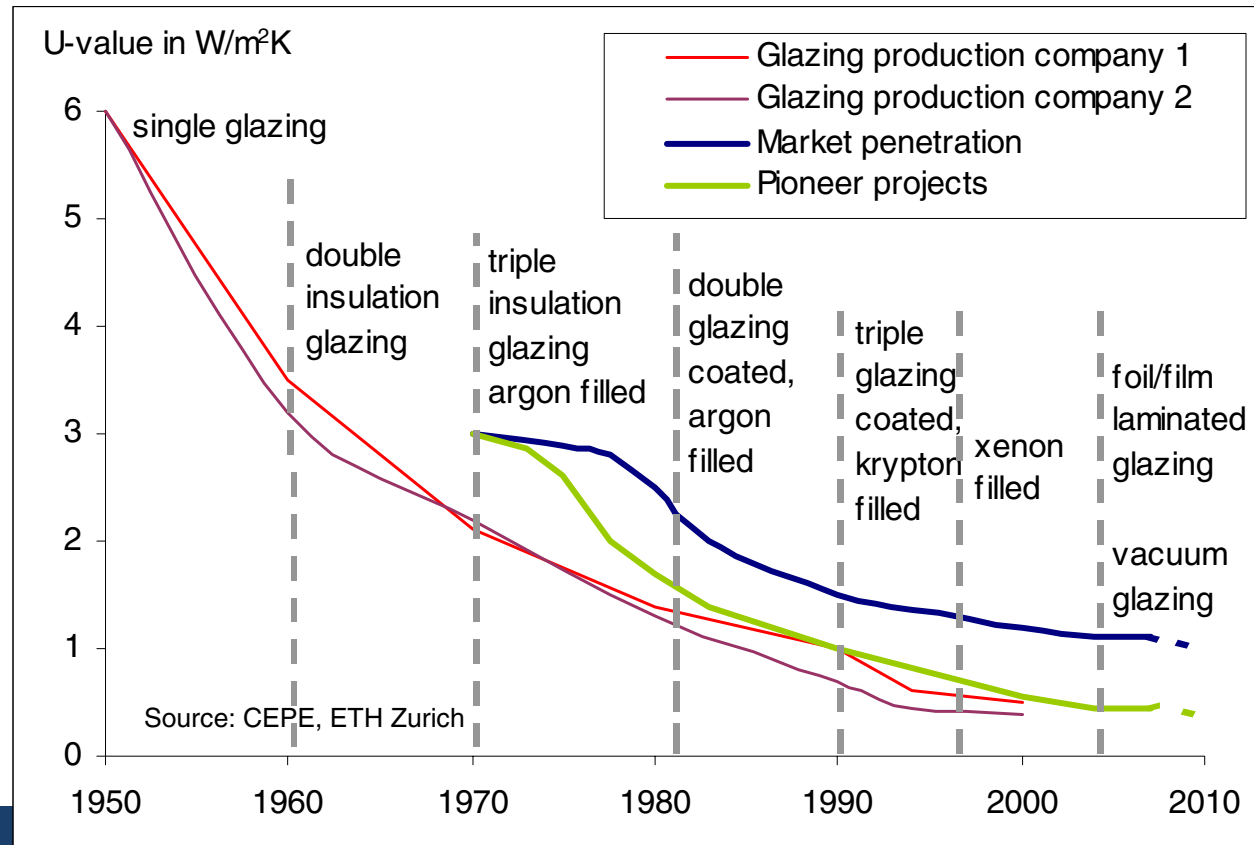
Cost/price development depends on market structure, economic and policy framework, cultural background

- Material resources: Polystyrol: oil product, Mineral wool: energy intensive
Pyrogene Kieselsäure (Silica) for vacuum insulation panels: semi-conductor
 - Codes and standards: mechanical fixing will become mandatory
 - Cultural background: traditionally small structured, large division of labour vs. industrial approach (e.g. pre-fabrication of elements)
- => Impact on development of final costs (prices) depends on relative importance (cost share)

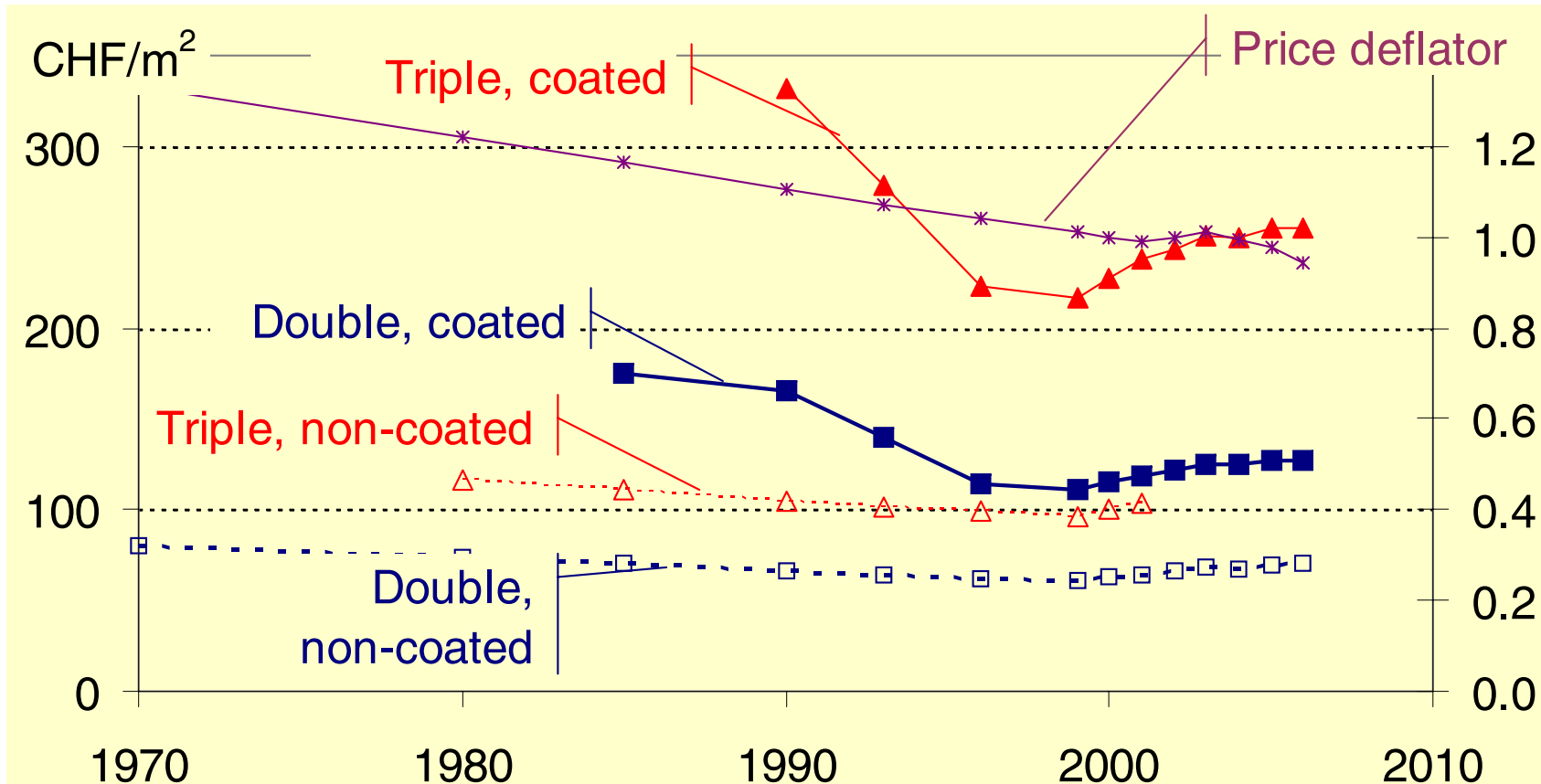
Technical progress of window glazing

Development since 2001:

- Further progress on U-value (but only moderate)
- Progress on Solar heat gain coefficient (partic. triple glazing)



Cost/price development of glazing



Source:
Leading Swiss glazing company,
BFS, CEPE ETH Zürich

Decreasing U-Value & Price
=> Learning & Experience

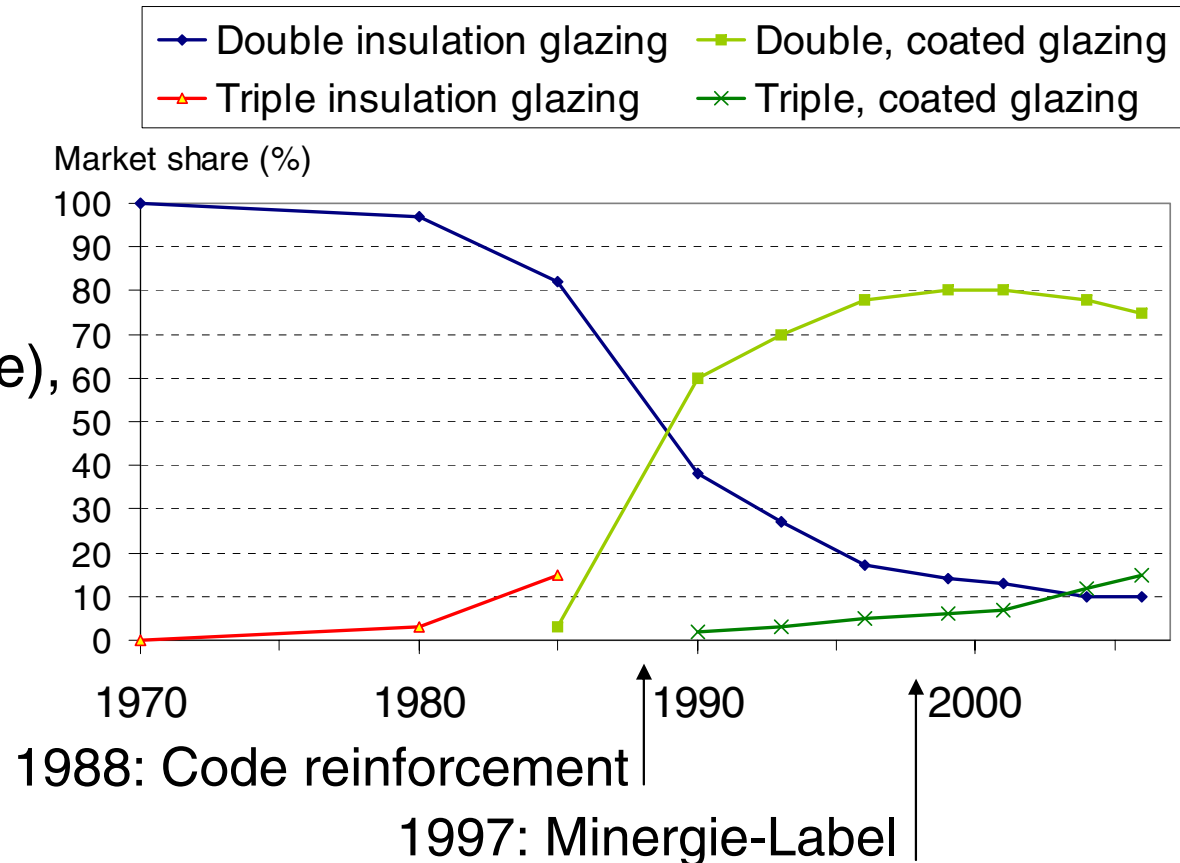
Price increase
Still learning?

1 CHF =
0.6 Euro

Diffusion of glazing efficiency standards

Development since 2001:

- Non-coated glazing fading out
- Diffusion of triple glazing increasing steadily (despite price increase), but only slowly



Source:
Leading Swiss glazing company
CEPE, ETH Zurich

Market and cost structure of windows (Swiss case)

Cost share (CHF/m²)

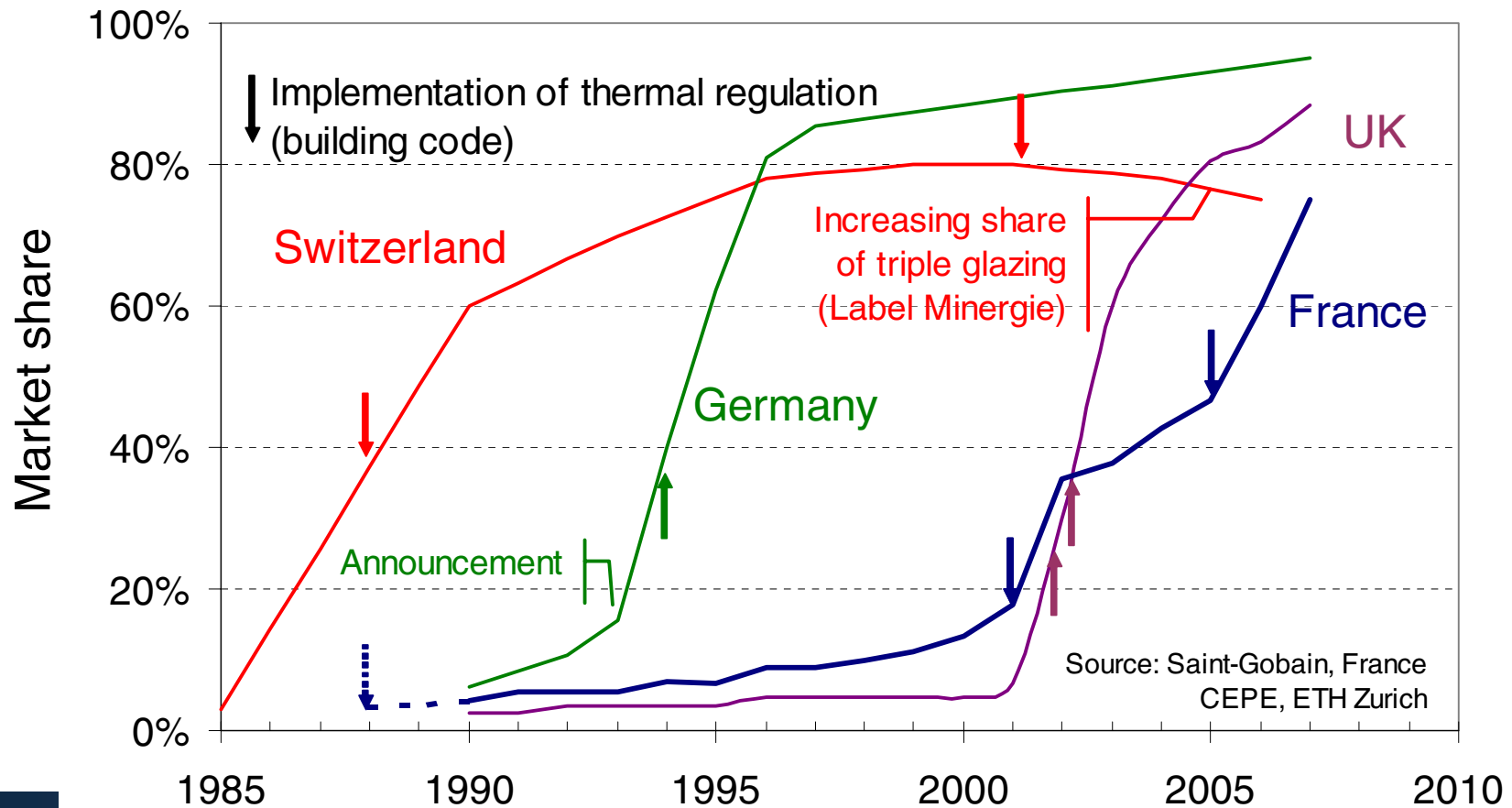
- Float glass production: 100% imported, 1 Swiss company prod. abroad, few European producers
.....
- Coating and inert gas filling: 1 Swiss producer, few European producers
.....
- Window producing:
 - Wood: few large companies, many SME
.....
 - Plastic:
.....
- Final mounting on building: large companies, many SME
.....

Some Outlook to Europe

To be completed (final version on CD and web)

Diffusion of coated (double) glazing

- Ambitious codes and standards enable rapid diffusion



Conclusions and recommendations

Conclusions

- Be aware of peculiarities of EC of EE (general, build. env.)
- Considerable techno-economic progress (TEP) in the past
- Slow-down of TEP apparent in recent years, also due to BC and price increases of input factors (energy)
- Interpretation of progress ratio related to used definition!
- Drivers and successful diffusion policies (rather than exact pr or buy-down costs)
- High relevance of codes and standards for market transf.
- Further research on building envelope EC needed

Policy recommendations: Aiming at market transformation

- Raise awareness (population, involved sectors)
- Ambitious codes and standards (cf. glazing in F, GE, UK, CH)
- Promotion programmes (e.g. tax incentives, tariffs, labels, subsidies) conditional on advanced EE standards
- Attractive research competitions to foster techn. break throughs (cf. fixings with low thermal bridges in CH)
- Combine different policy measures (cf. Heat pump promotion in CH, White certificates)

References

- Jakob and Madlener (2004): Riding down the experience curve for energy-efficient building envelopes: the Swiss case for 1970–2020. *Int. J. Energy Technology and Policy*, Vol. 2, Nos. 1/2, 153-178
- Jakob (2006): Marginal costs and co-benefits of energy efficiency investments - The case of the Swiss residential sector. *Energy Policy* 34, 172–187.
- Banfi, S., Farsi, M., Filippini, M., Jakob, M. (2006). Willingness to Pay for Energy-Saving Measures in Residential Buildings. *Energy Economics* xx (2006) xxx–xxx (accepted 8 June 2006, in Press, available online).