

# Genetic multi criteria optimization for existing buildings holistic retrofit



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# Introduction and context

- France & Western Europe :  
Priority for existing building stocks energy retrofit
  - 43% of final energy consumptions (FR) [SOeS, 2010]
  - Existing buildings retrofit : < 1% / year [Meijer et al, 2009]
- Building retrofit design process
  - Definition of decision criteria
  - Energy audit of the existing building
  - Pre-selection of relevant elementary retrofit measures
  - Identification of efficient building retrofit strategies.

# Building energy retrofit measures



# Criteria for existing building retrofit

## Objective functions (on life cycle)

### *Environment*

- Cumulated primary energy consumption [MJ] [Frischknecht & al, 1996]
- Climate change potential [kg CO<sub>2</sub> eq.] [Guinee et al., 2001] [IPCC, 2007]
- Abiotic resources depletion [kg Sb eq.] [Guinee et al., 2001]
- Air acidification potential [kg SO<sub>2</sub> eq.] [Guinee et al., 2001]
- Other LCA indicators

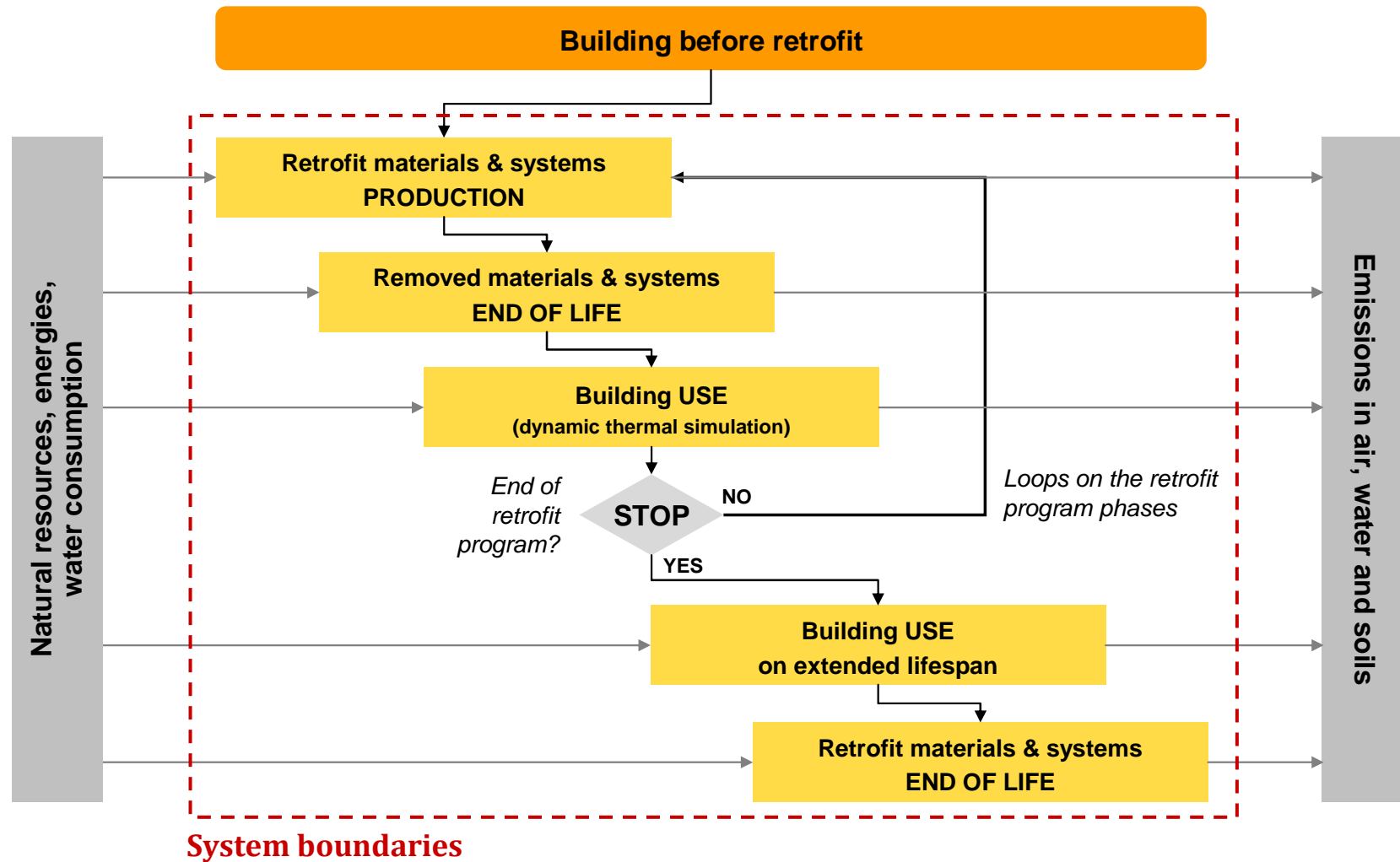
### *Economy*

- Investment cost [k€]
- Global cost on life cycle [k€]

### *Occupant comfort*

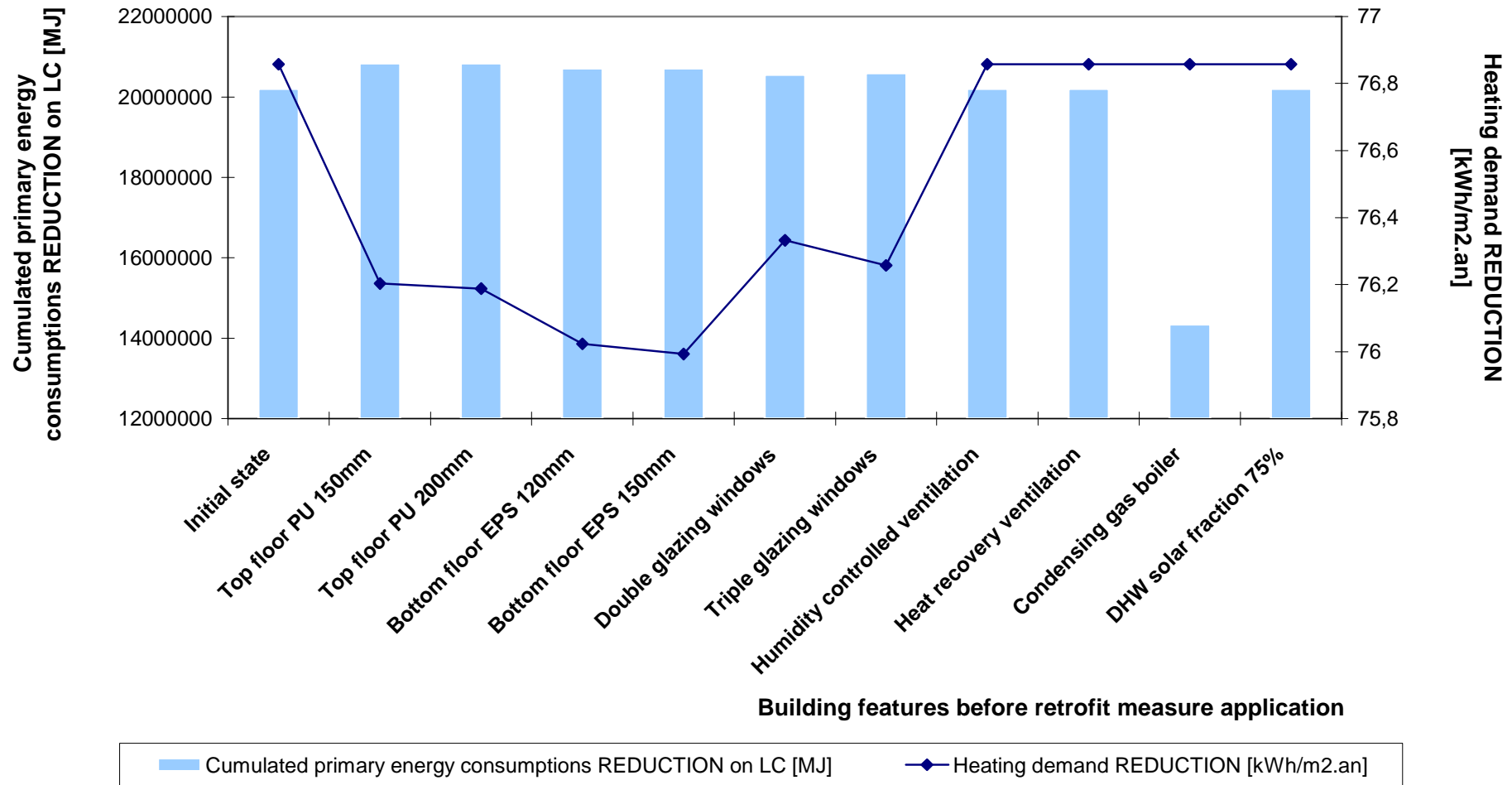
- Adaptive summer thermal comfort indicator [degree.hours]

# Solutions' performances evaluation



# Interactions & system complexity

**Influence of façades external thermal insulation (ETI)  
mineral wool 200mm, in function of building state before retrofit measure application**



# Genetic representation of retrofit programs

- 1 retrofit program = 1 solution = 1 individual
- Represented by 2 chromosomes

## CONTENT Chromosome

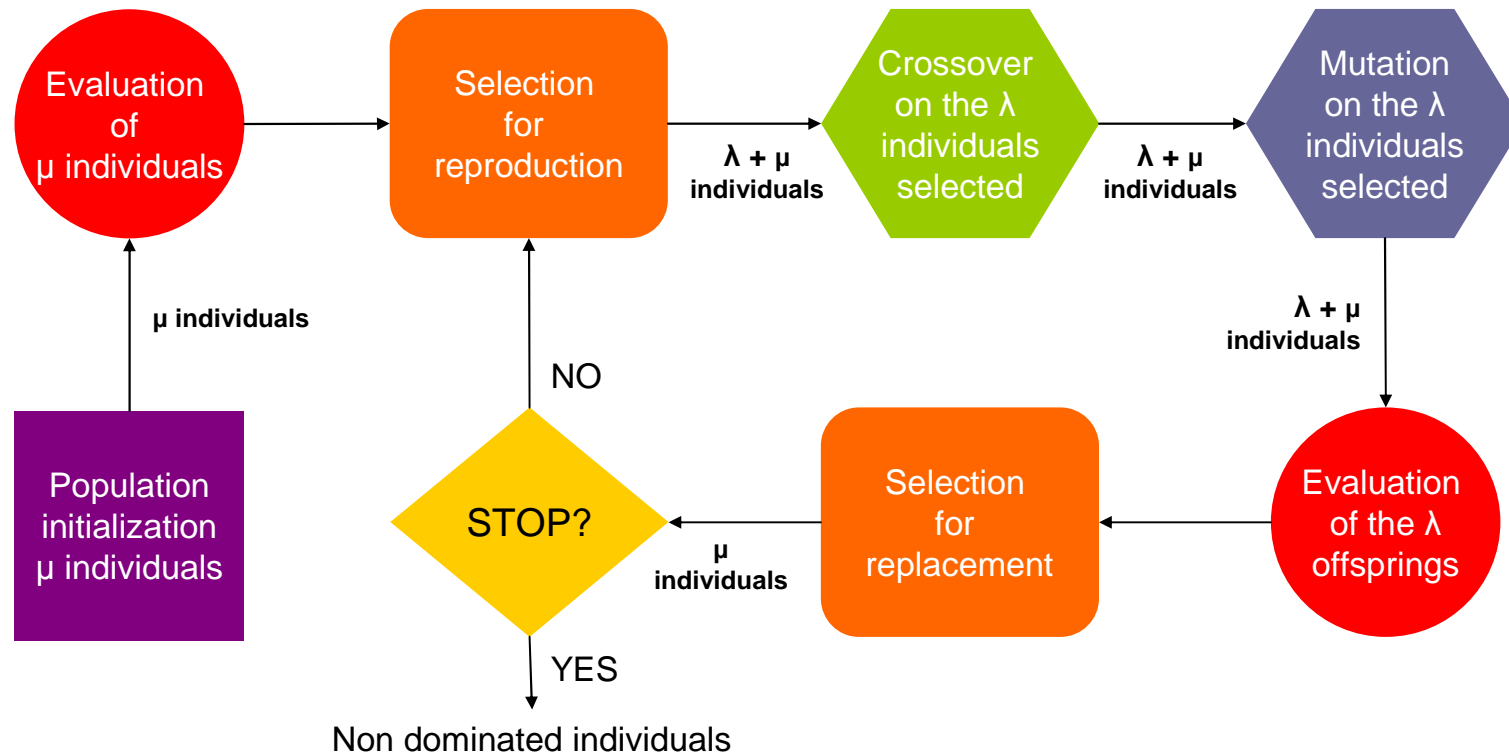
Thermal insulation thickness, NOTHERN façade  
...  
Window type, NOTHERN façade  
Window dimensions, NOTHERN façade  
...  
HVAC equipment  
Type of boiler  
Solar factor for DHW production



## PLANNING Chromosome

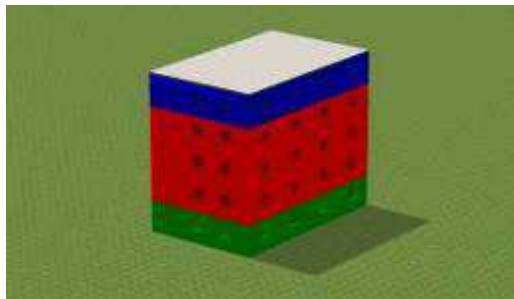
# Phase : Th. insulation thickness, NOTHERN façade  
...  
# Phase : Window type, NOTHERN façade  
# Phase : Window dimensions, NOTHERN façade  
...  
# Phase : HVAC equipment  
# Phase : Type of boiler  
# Phase : Solar factor for DHW production

# Genetic algorithm (NSGA – II) approach





# “Barre grimaud” case study



- **Barre Grimaud** (Multi family R+4, 792 m<sup>2</sup>, before 1974)
- **Constructive elements BEFORE energy retrofit**

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External walls	Concrete walls filled in with concrete
Bottom floor	Concrete slab (200mm)
Terrace roof	Concrete slab
Windows type	PVC double glazing
Ventilation	Non modulated mechanical ventilation
Heating system	Collective fuel boiler, installed before 1988
DHW production	Individual gas boilers

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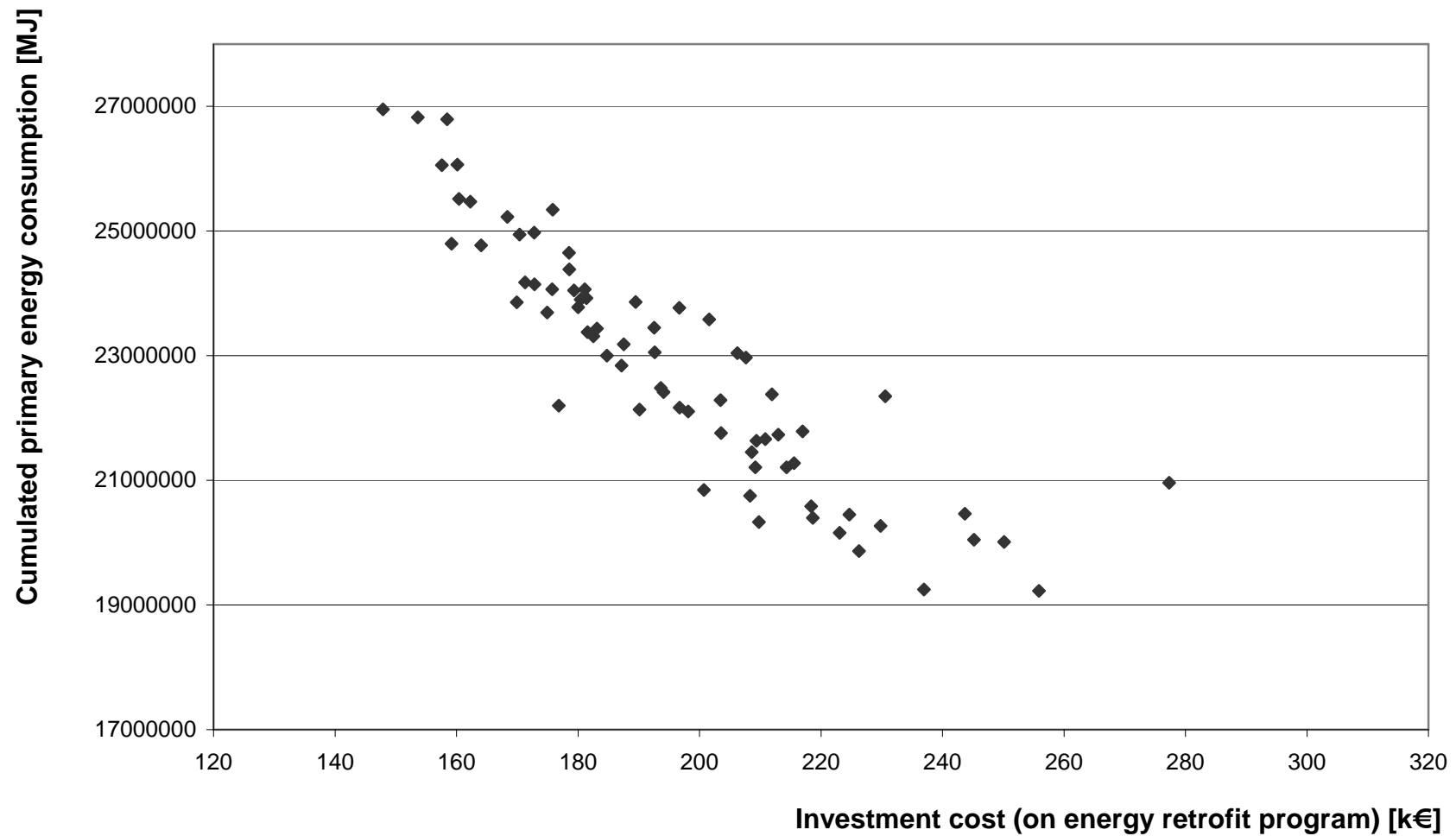
- **Heating energy needs BEFORE energy retrofit** : 178 kWh/m<sup>2</sup>.an
- **Energy retrofit options**

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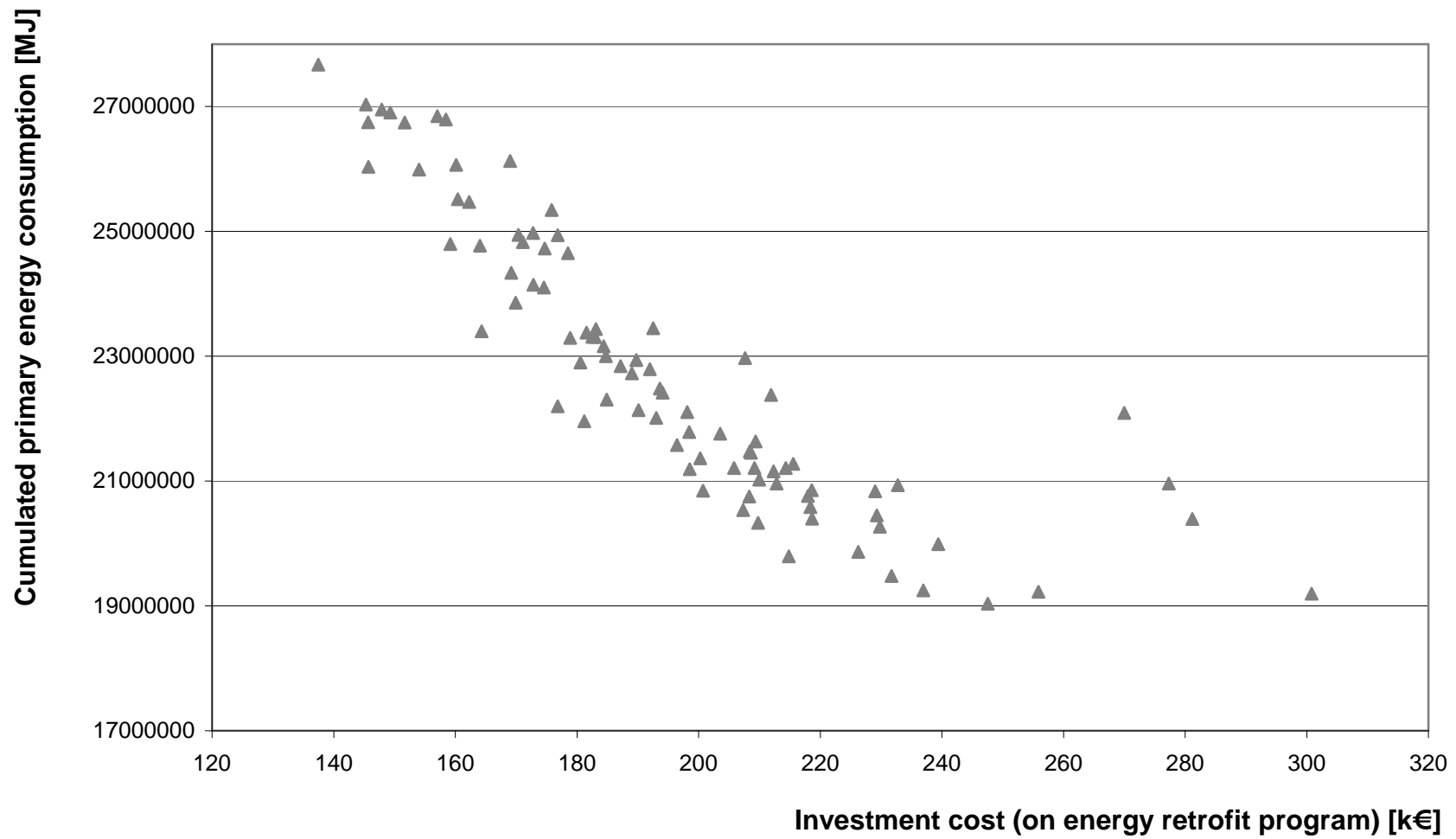
External walls	Mineral wool exterior insulation (10, 12, 15, 18, 20, 25 or 30cm)
Bottom floor	Polystyrene exterior insulation (10, 12, 15, 18, 20 or 25cm)
Terrace roof	Polyurethane exterior insulation (10, 15, 20, 25, 30, 35 or 40cm)
Windows type	Low-e double glazing (DG) or triple glazing (TG), with wooden frames
Ventilation	Heat recovery (HR) or humidity controlled (HC)
Heating system	Low-temperature condensing gas boiler
DHW production	Solar thermal fraction of DHW needs: 35%, 55% or 75%

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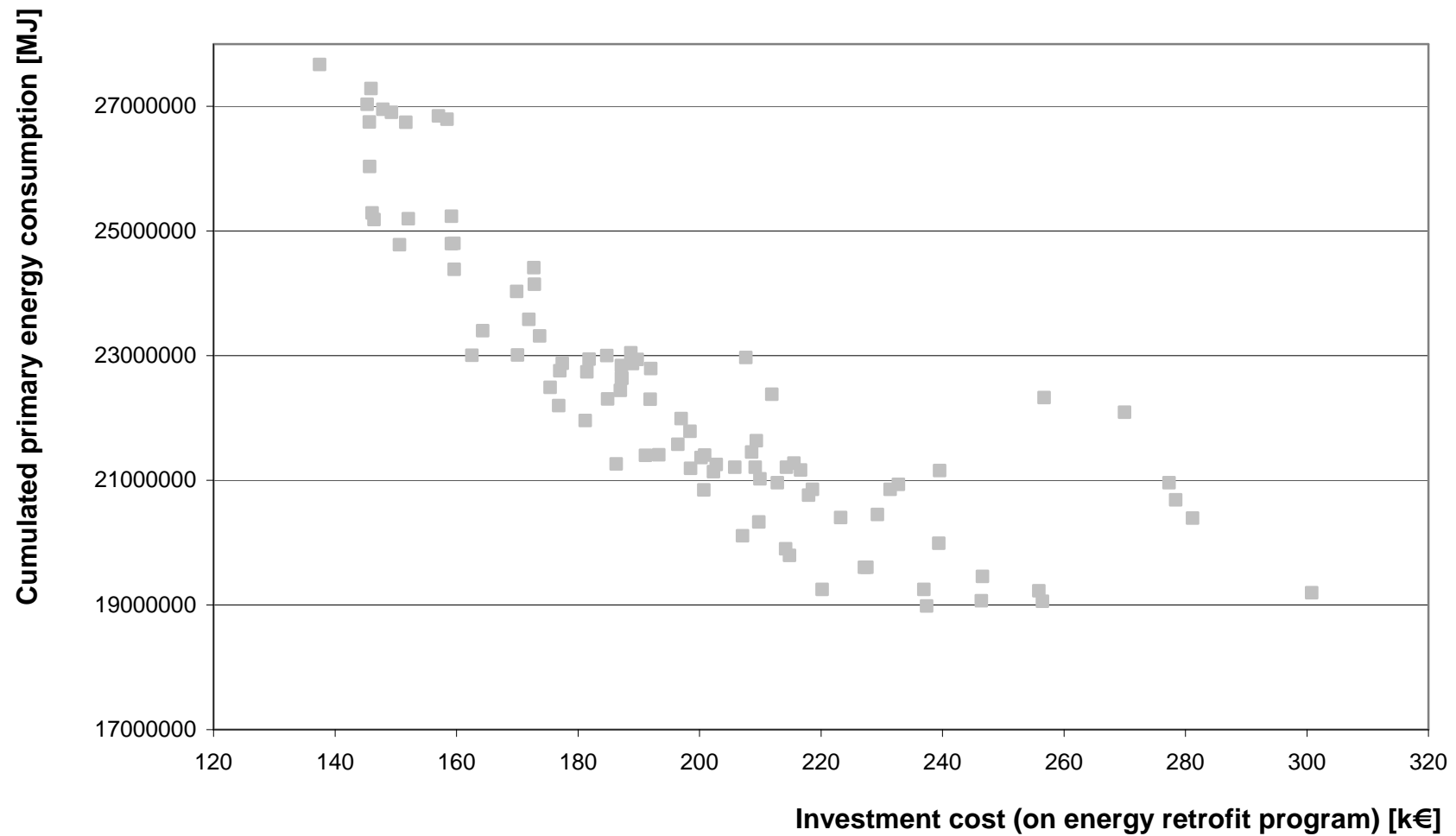
# Front génération 1



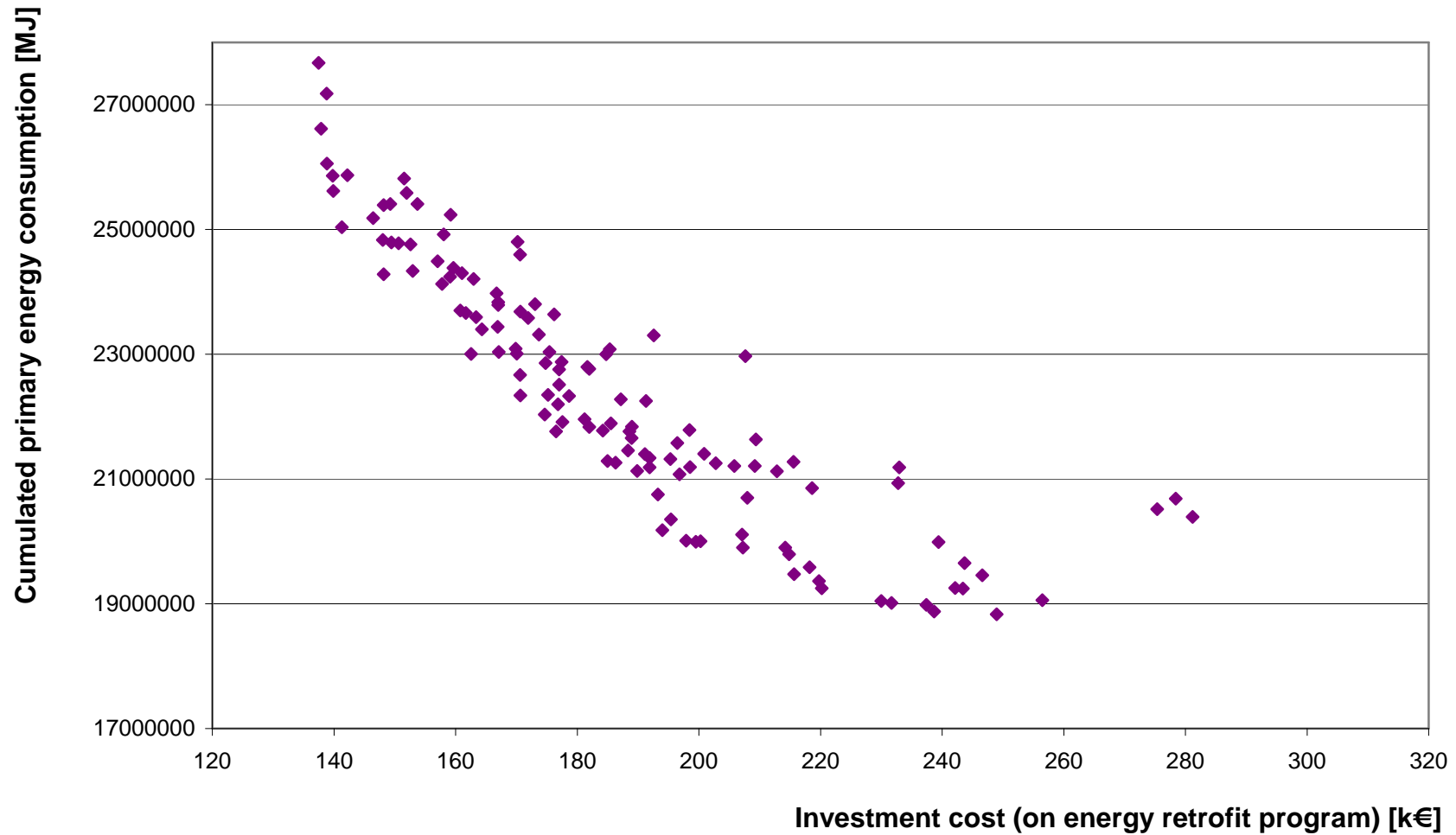
# Front génération 2



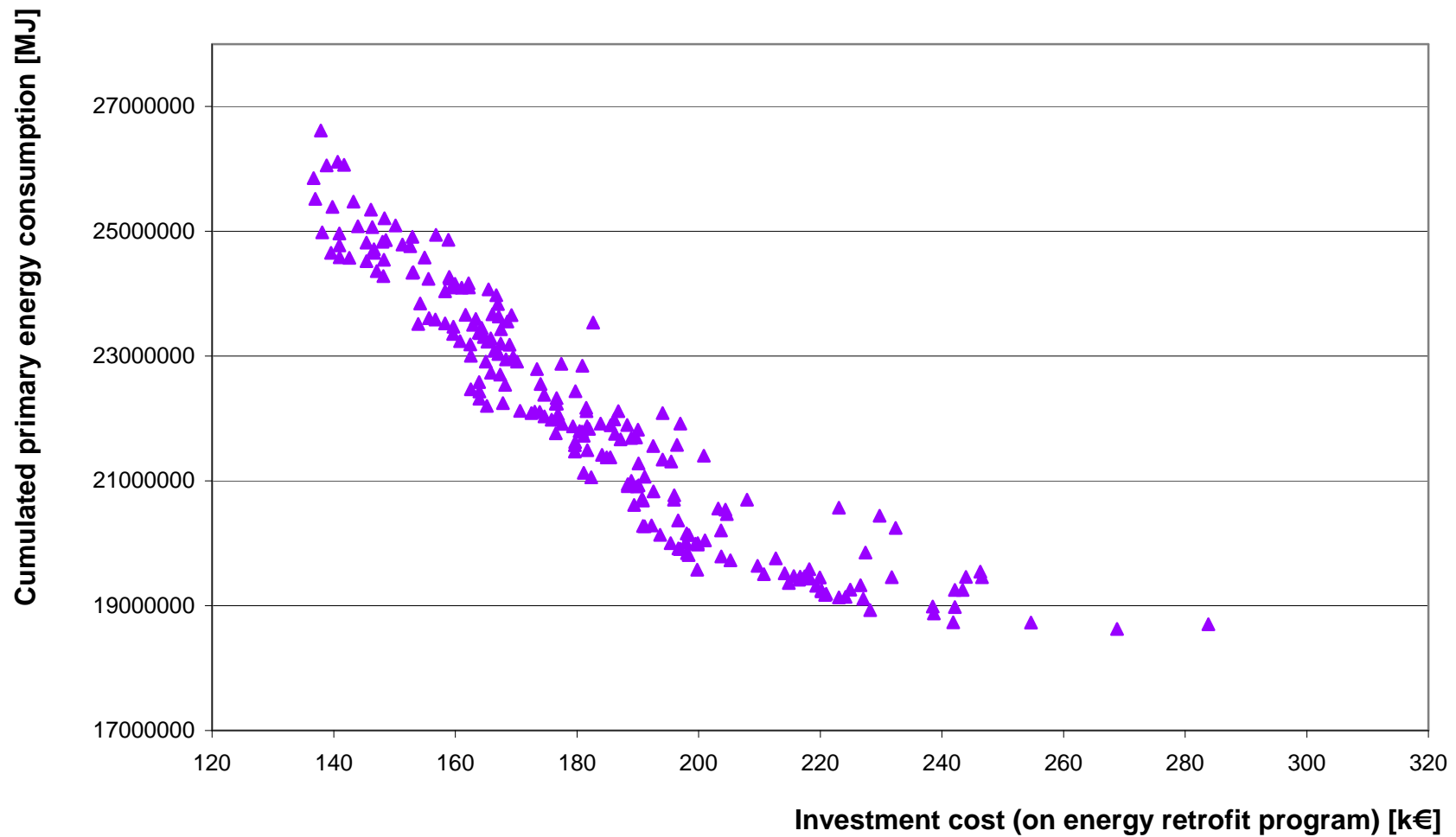
# Front génération 3



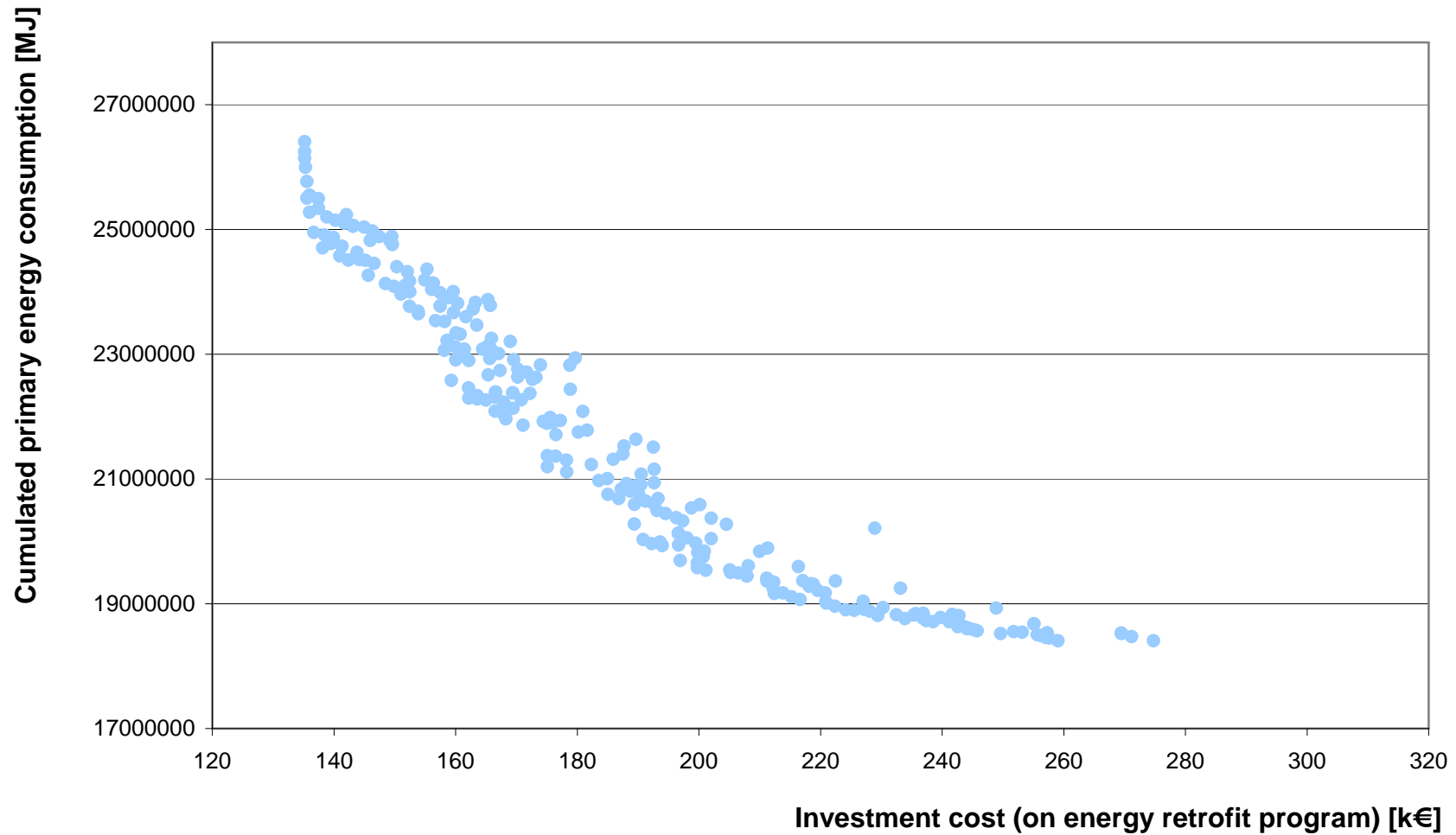
# Front génération 5



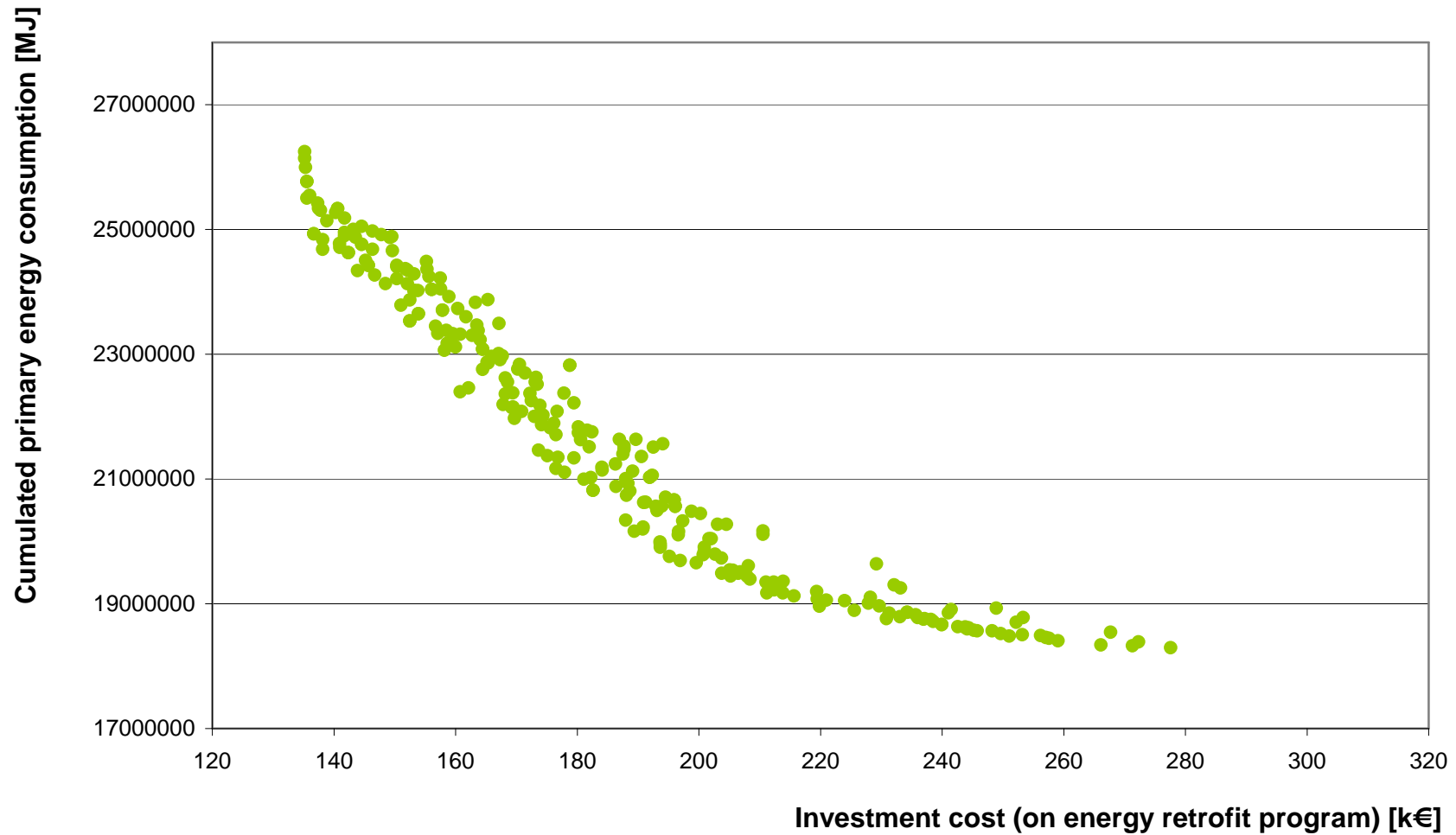
# Front génération 10



# Front génération 40

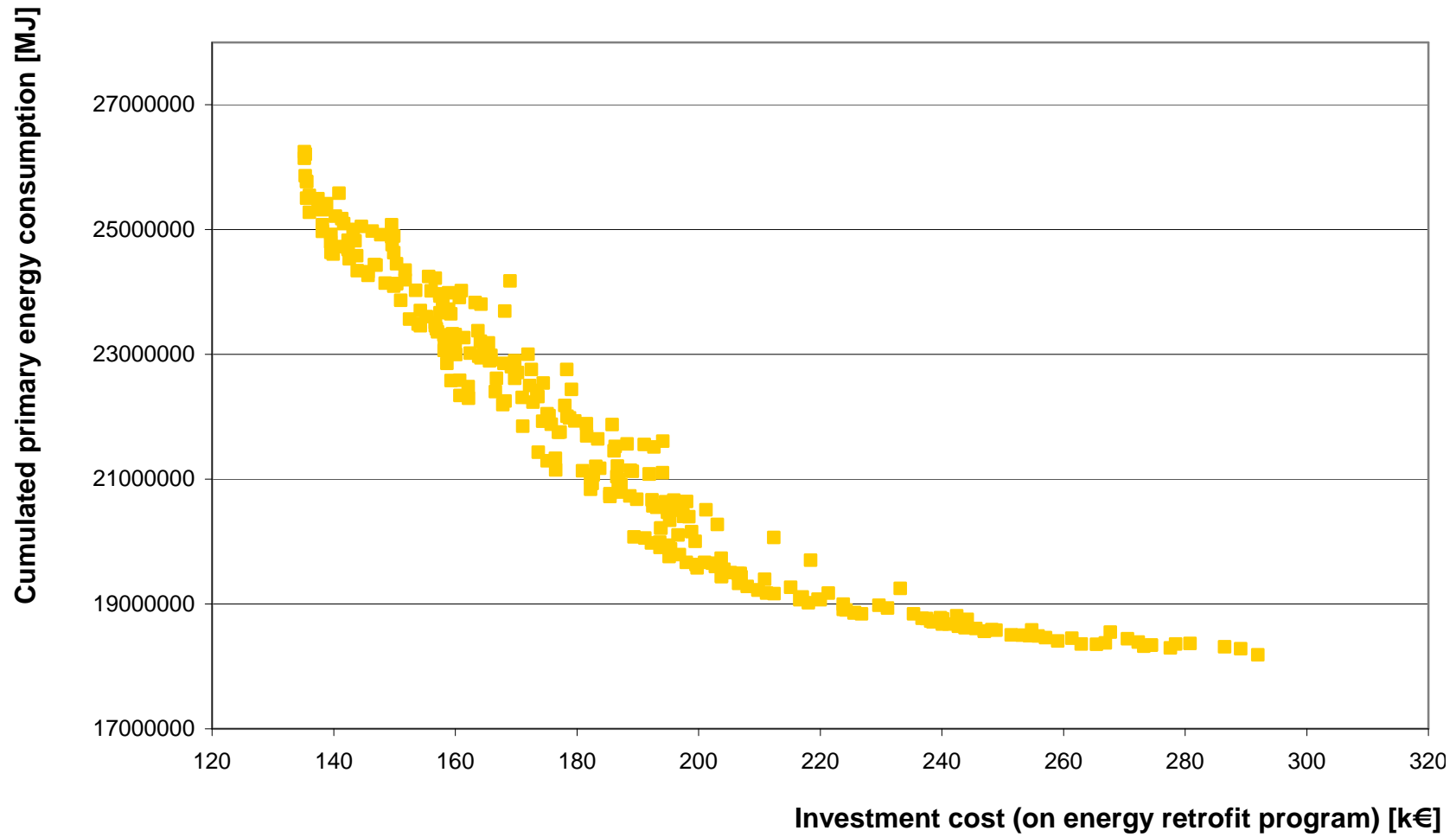


# Front génération 50

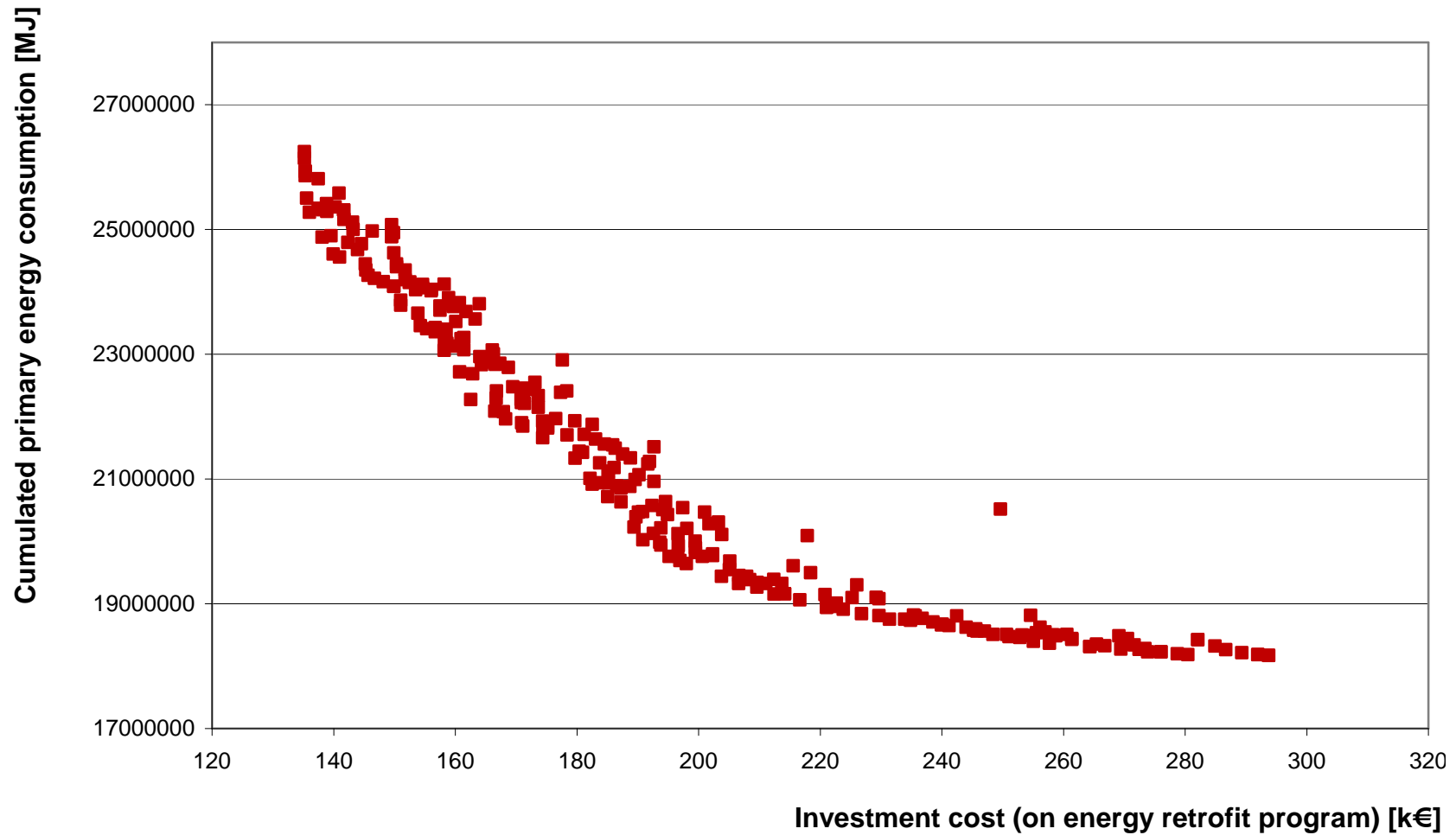




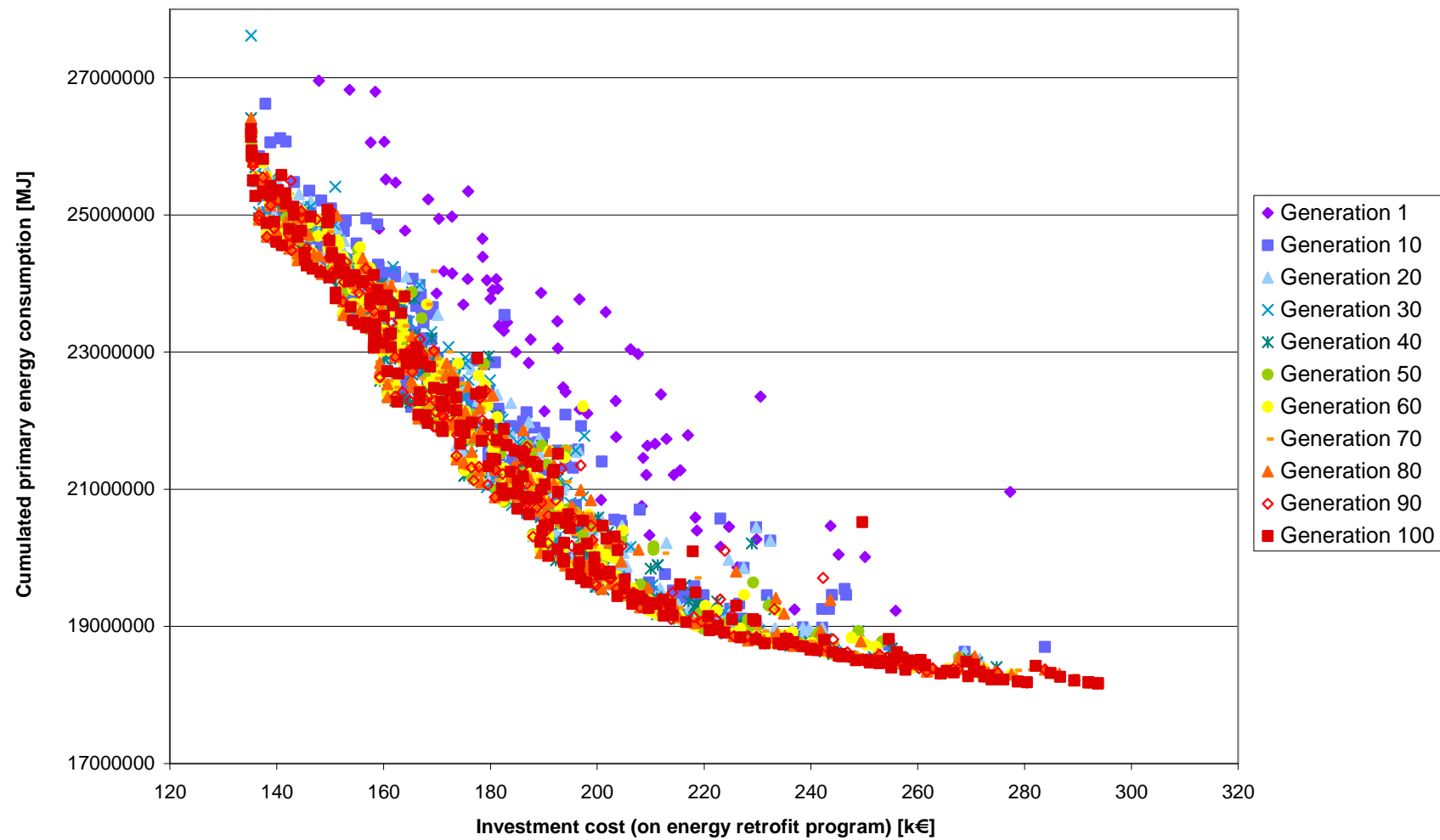
# Front génération 70



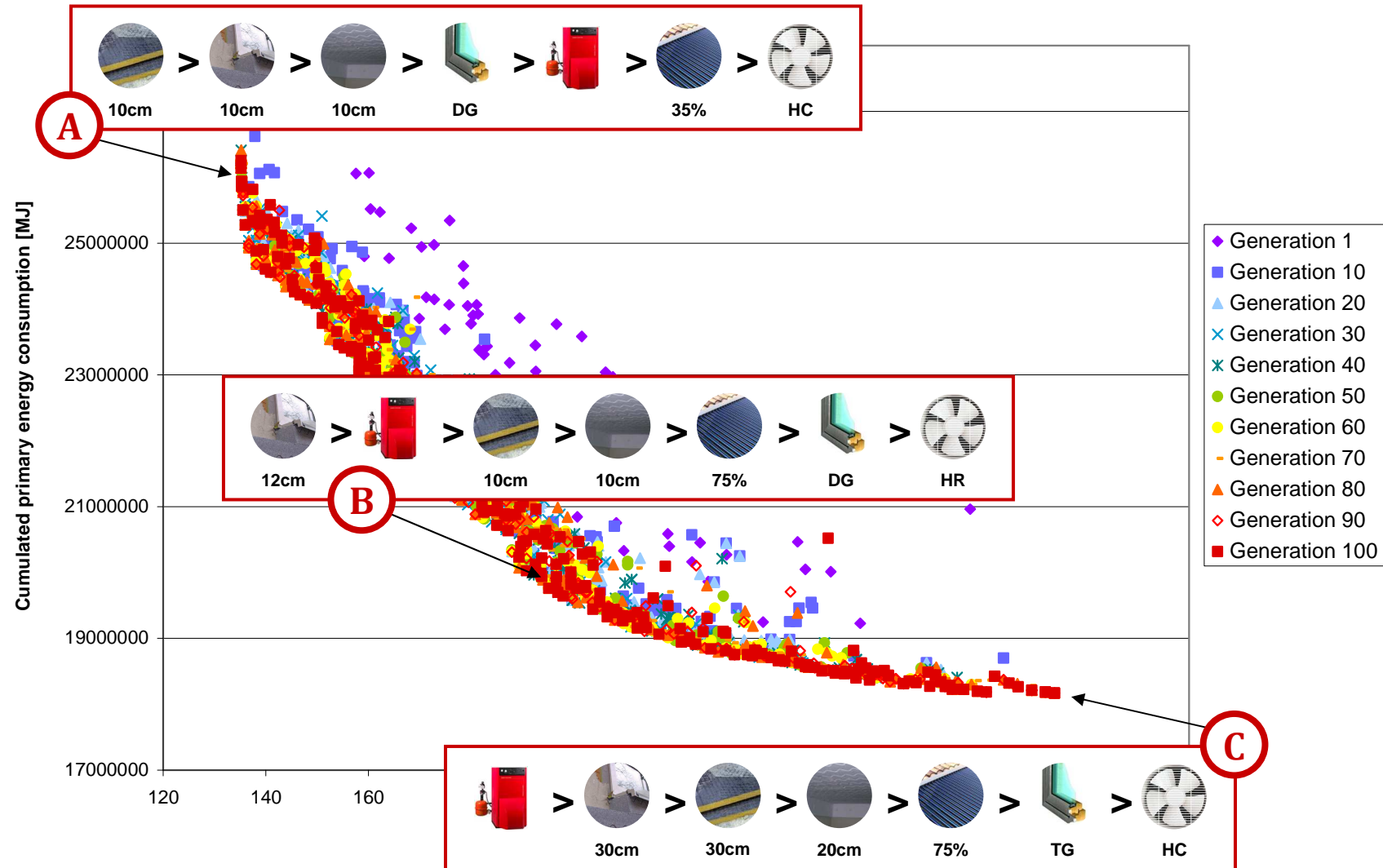
# Front génération 100



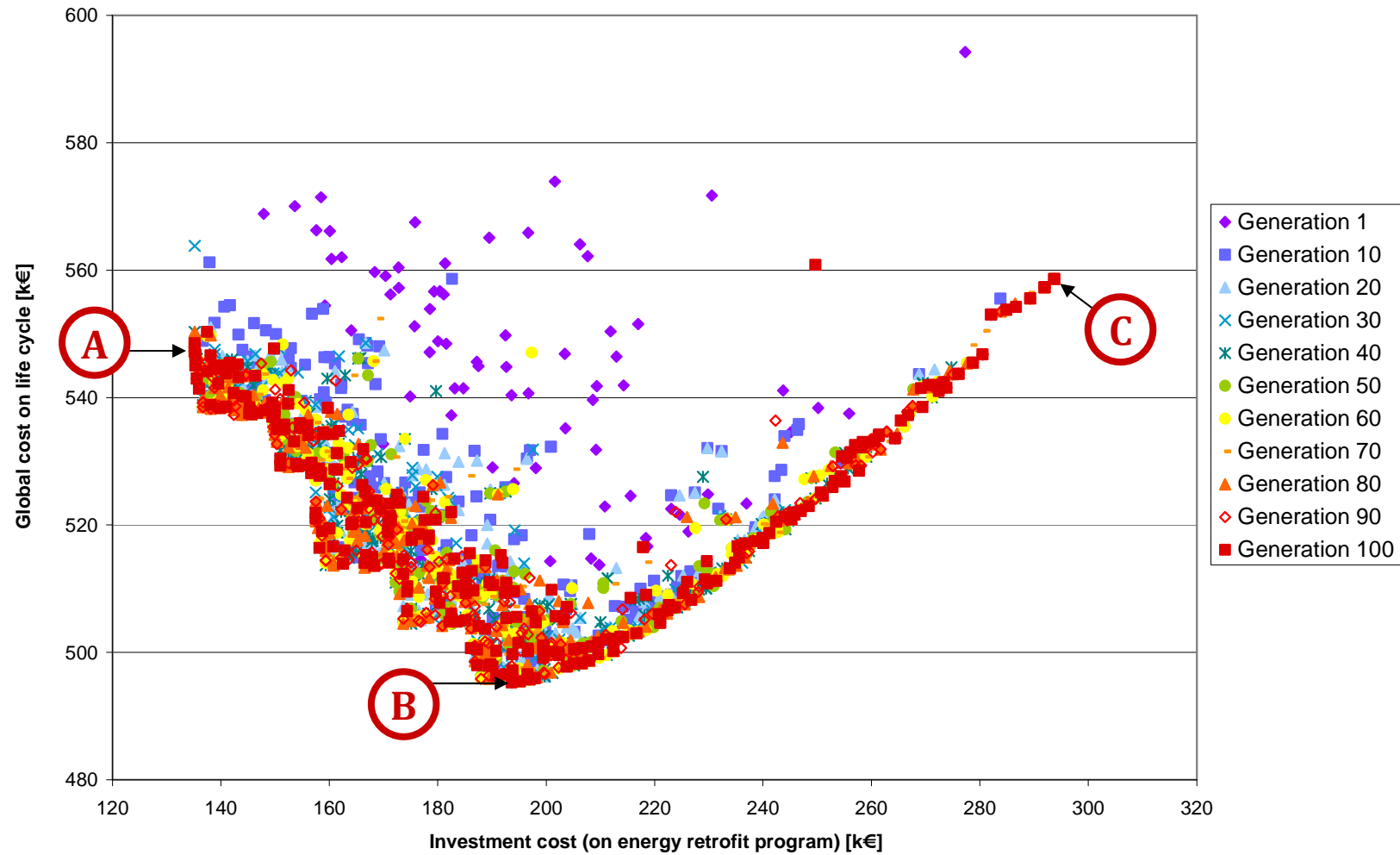
# Compromise between investment and energy conservation



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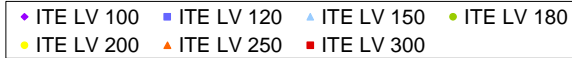
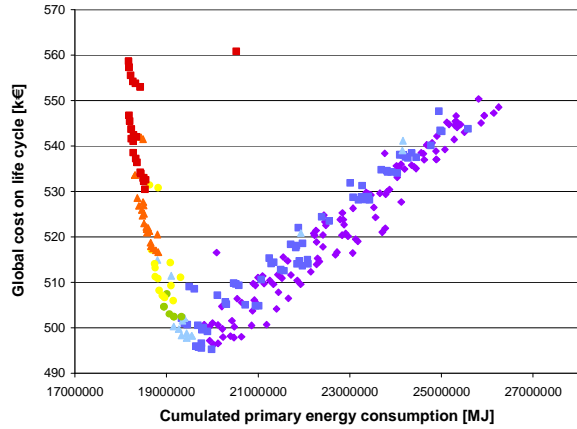


# Most energy efficient solutions are not paid off on 50 y.

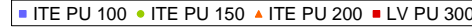
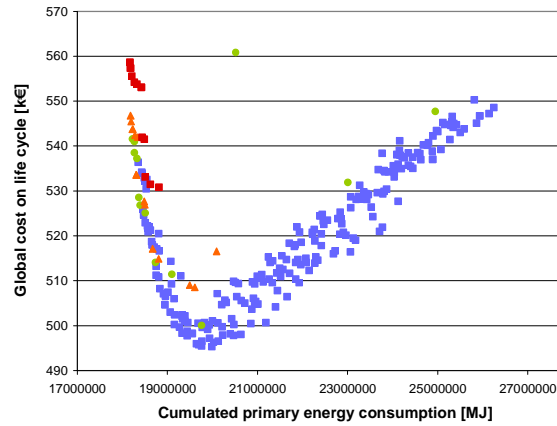


# Results analysis

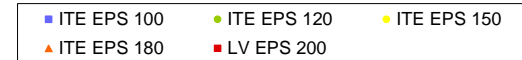
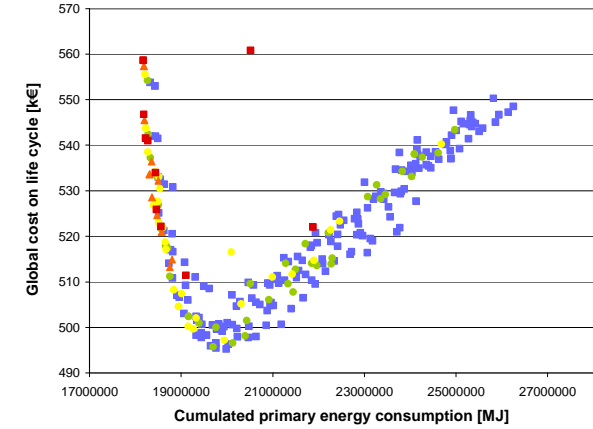
### Façade thermal insulation



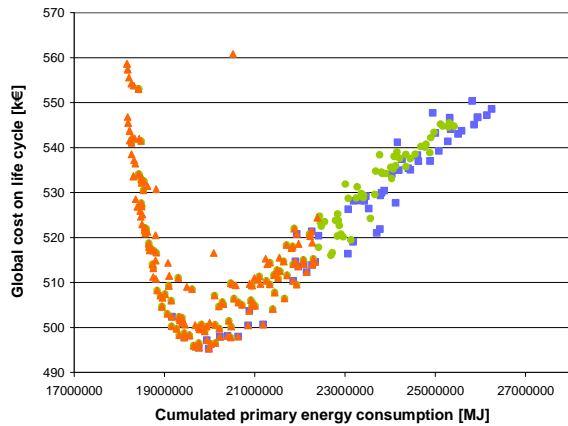
### Top floor thermal insulation



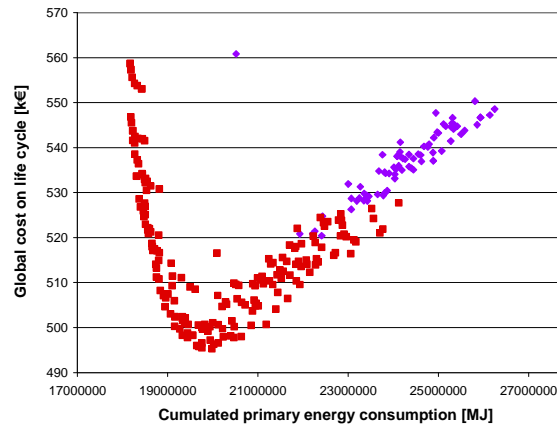
### Bottom floor thermal insulation



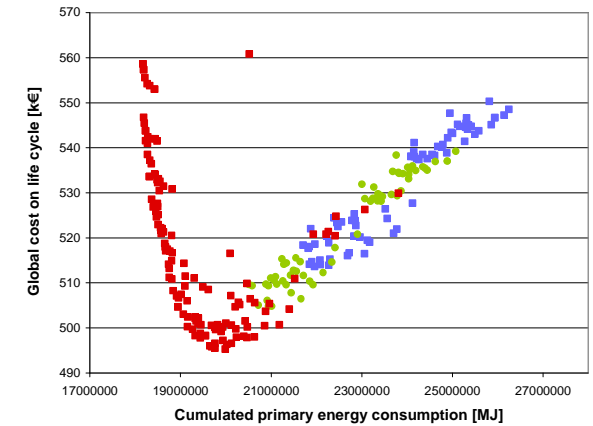
### Windows



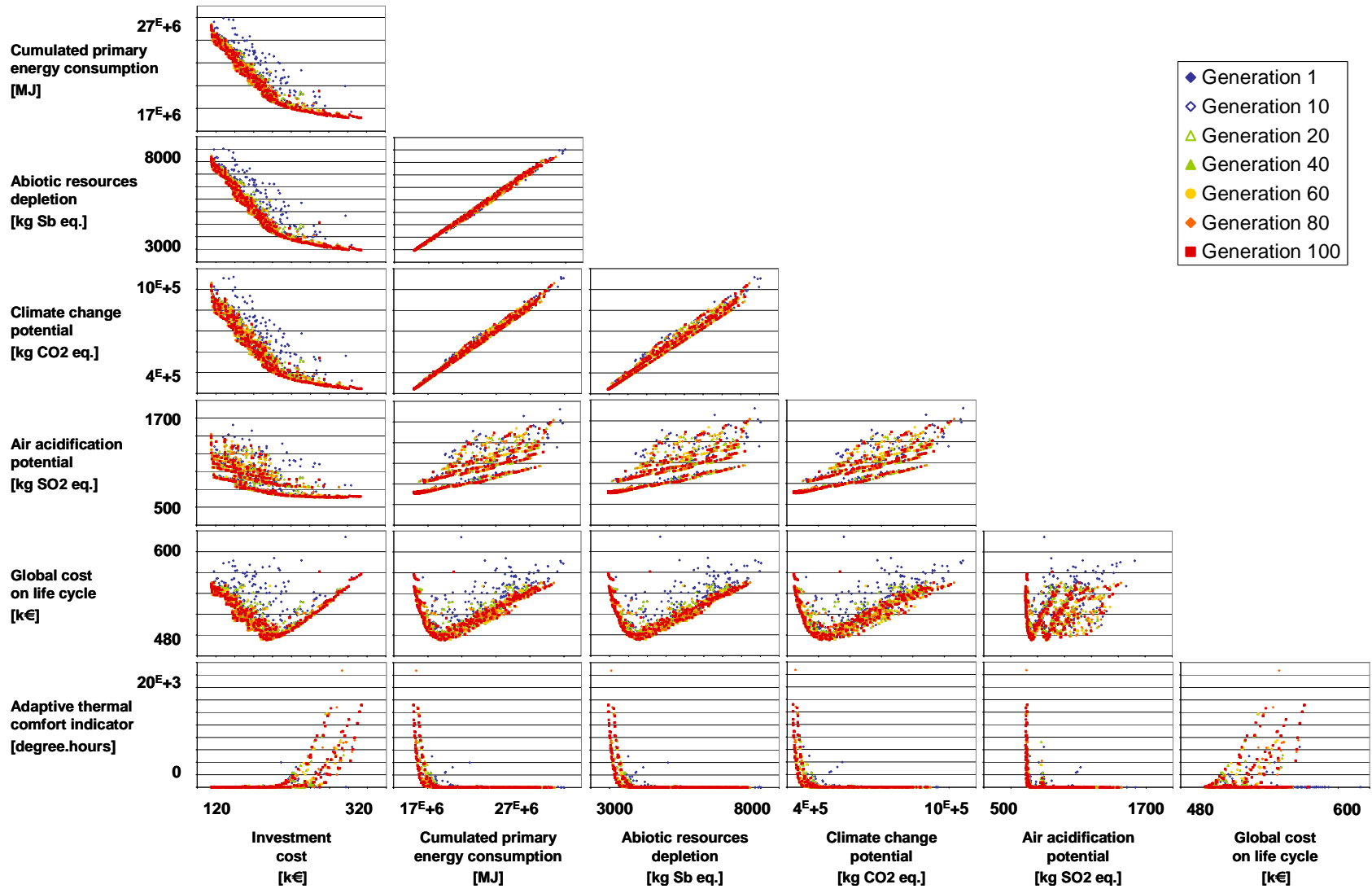
### Ventilation



### DHW production, solar factor



# Pareto fronts & trade-offs in between decision criteria



# Conclusion

- MCDA approach based on multi criteria optimization
  - Identification of Pareto frontiers exhibiting efficient retrofit programs
  - Genetic algorithms : efficient exploration of the search space
  - Trade-off in between investment and environmental impacts mitigation
  - The most energy efficient solutions are not optimal on global costs
  
- Perspectives
  - Qualification of approximate optimization, compared to exact approaches
  - Integration of investment constraints
  - Towards building stocks retrofit management



# Energy retrofit and sustainable modernization



# Thank you for your attention

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