Vermieter:

$$\min_{x_V} \sum_t \beta_t \cdot \text{Kosten}_t \quad \text{with } \beta_t = \frac{1}{(1+i)^t}$$

s.t. $-\text{Mieteinnahmen}_t + \text{Investitionskosten}_t = \text{Kosten}_t$

$$\text{Miete}_t \times \text{Fläche} = \text{Mieteinnahmen}_t$$

$$\text{Spezifische} \times \text{Anlage} + \text{Zuschuss}^{INV} = \text{Investitionskosten}_t$$

Parameter

Mieter:

$$\min_{x_m} \sum_t \beta_t \{\text{Kosten} + \text{Slack}_t \times \text{Slack-Preis}_t\} \quad \text{with } \beta_t = \frac{1}{(1+i)^t}$$

s.t. $+\text{Mietausgaben}_t + \text{Energieausgaben}_t = \text{Kosten}_t$

$$\text{Miete}_t \times \text{Fläche} = \text{Mietausgaben}_t$$

$$(\text{Menge}_t - \text{Slack}_t) \times \text{Preis}_t - \text{Zuschuss}^{HK}_t = \text{Energieausgaben}_t$$

$$\frac{\text{Mietausgaben}_t + \text{Energieausgaben}_t}{\text{Einkommen}_t} \leq \text{Anteil}_t$$

Staat:

$$\min_{x_S} \sum_t \beta^{Staat}_t \{\text{Zuschuss}^{INV}_t + \text{Zuschuss}^{HK}_t\}$$

s.t. $\sum_t \beta^{V}_t \cdot [(\text{Miete}_t - \text{Miete}^{0}) \times \text{Fläche} + \text{Zuschuss}^{INV}_t] \ominus$

$$\sum_t \beta^{M}_t \, \text{Zuschuss}^{HK}_t$$

Governance (Leader)

decision variables: sub_t^{inv} ... heating system investment subsidy

sub_t^{hc} ... heating cost subsidy

$rent_t$ ... rent price

parameters: β_t^g ... governant's discount factor

$area$ ... rented area

$\overline{rent}$ ... initial (current) rent price

β_t^t ... tenant's discount factor

β_t^l ... lessor's discount factor

$$\min_{x^s} \sum_t \beta_t^g \left(sub_t^{inv} + sub_t^{hc} \right)$$

$$s.t. \quad \sum_t \beta_t^l \left[\left(rent_t - \overline{rent} \right) \cdot area + sub_t^{inv} \right] = \sum_t \beta_t^t \, sub_t^{hc}$$

Lessor: (Follower)

decision variable: c_t^{hs} ... heating system capacity

parameters: $rent_t$ ... rent price

$area$ ... rented area

σ_t ... specific heating system investment costs

$$\min_{x^l} \sum_t \beta_t^l \, costs_t \quad \text{with} \quad \beta_t^l = \frac{1}{(1+i)^t}$$

$$s.t. \quad costs_t = -rent_t \cdot area - sub_t^{INV} + \sigma_t^{inv} \cdot c_t^{hs}$$

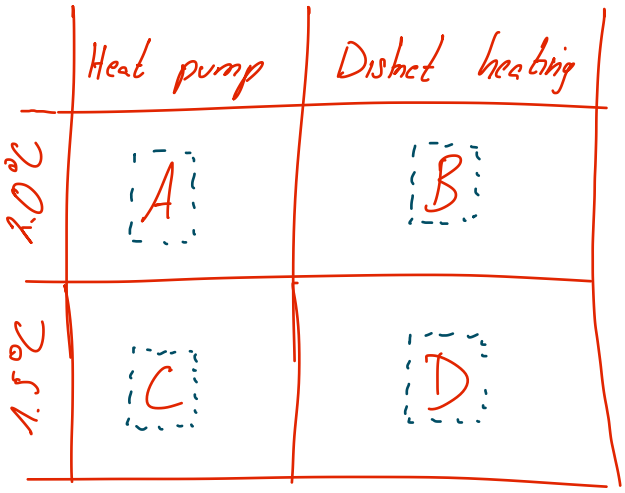
Tenants: (Follower)

decision variable: $slack_t$ ... heat demand reduction (demand elasticity)

$$\min_{x^t} \text{ total costs} = \sum_t \beta_t^t \left(costs + slack_t \cdot p_t^{slack} \right)$$

$$\text{s.t. } \underbrace{rent_t \cdot area}_{\text{rent costs}} + \underbrace{\left(q_t - slack_t\right) \cdot p_t - sub_t^{hc}}_{\text{energy-related costs}} = costs$$

$$\frac{costs_t}{income_t} \leq share_t$$



Entscheidungsvariablen: → Investitionsförderung für den Vermieter ($sub_{inv,y,m}$)
→ Heizkostenzuschuss für die Mieter ($sub_{heat,y,m}$)
→ Mietobergrenze für Mieter/Vermieter ($rent_{y,m}$)

$$\min_{x} \quad \underbrace{sub_{inv}}_{lessor} + \sum_{y}\sum_{m} \frac{1}{(1+i)^{y}} + \underbrace{sub_{heat,y,m}}_{tenants}$$

$$\underbrace{q_{load,y,m}}_{\text{Total heat demand}} \leq q_{init,y,m} + \underbrace{q_{alt,y,m}}_{\text{District heating or heat pump}}$$

$$q_{alt,y,m} \leq \hat{q}_{alt} \quad : \forall y,m$$

Investment costs of the lessor: Heizsystem + Bauarbeiterkosten

$$costs_{inv} = costs_{inv,hs} + costs_{inv,con} - sub_{inv}$$

$$= \hat{q}_{alt}\left[c_{alt,hs} + c_{alt,con} \cdot \underbrace{n_{ten}}_{\text{number of tenants}}\right] - sub_{inv}$$

operational revenues of the lessor:

$$revenues_{y,m} = \left(\overline{rent} + rent_{y,m}\right) \cdot area \cdot n_{ten}$$

net present value constraint of the lessor:

$$-costs_{inv} + \sum_{y}\sum_{m} \frac{1}{(1+i)^{y}} \cdot revenues_{y,m} \geq 0$$

$$-\hat{q}_{alt}\left[c_{alt,fix}+c_{alt,con}\cdot n_{ten}\right]-sub_{inv}+\sum_{y}\sum_{m}\frac{1}{(1+i)^{y}}\left(\overline{rent}+rent_{y,m}\right)\cdot area\cdot n_{ten}\geq 0$$

tenants:

initial spendings of all „n_{ten}" tenants:

$$\underbrace{S_{y=0}}_{\text{initial}}=n_{ten}\cdot\left(\overline{rent}\cdot area+\sum_{m}q_{load,y=0,m}\cdot p_{init,y=0}\right)$$

$$S_{total}=-\sum_{y}\frac{1}{(1+i)^{y}}S_{y=0}$$: net present value of the total spendings in the time horizon.

alternative spendings of all „n_{ten}" tenants:

$$S_{alt}=n_{ten}\cdot\left[\sum_{y}\sum_{m}\frac{1}{(1+i)^{y}}\left(\overline{rent}+rent_{y,m}\right)\cdot area+q_{alt,y,m}\cdot p_{alt,y,m}-sub_{heat,y,m}\right]$$

$S_{total}\leq S_{alt}$: greater net present value for the tenants

$$sub_{inv}\doteq n_{ten}\left(\sum_{y}\sum_{m}\frac{1}{(1+i)^{y}}sub_{heat,y,m}\right)$$: subsidy - parity of landlords and tenants