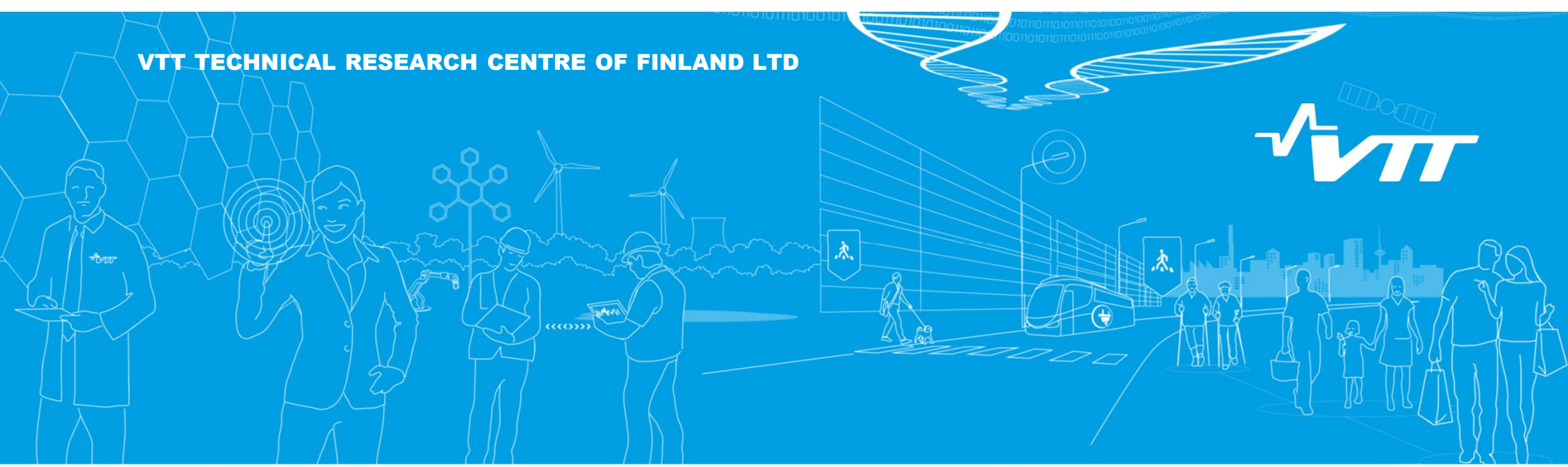

Hedging the climate sensitivity risks of the 2°C target

International Energy Workshop 2015

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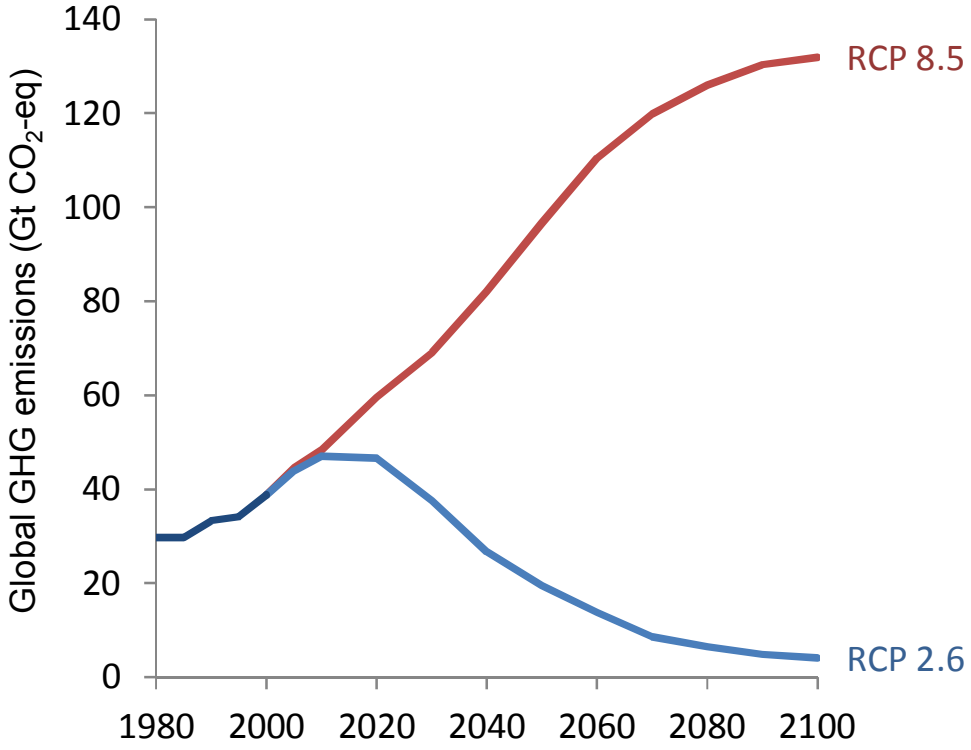
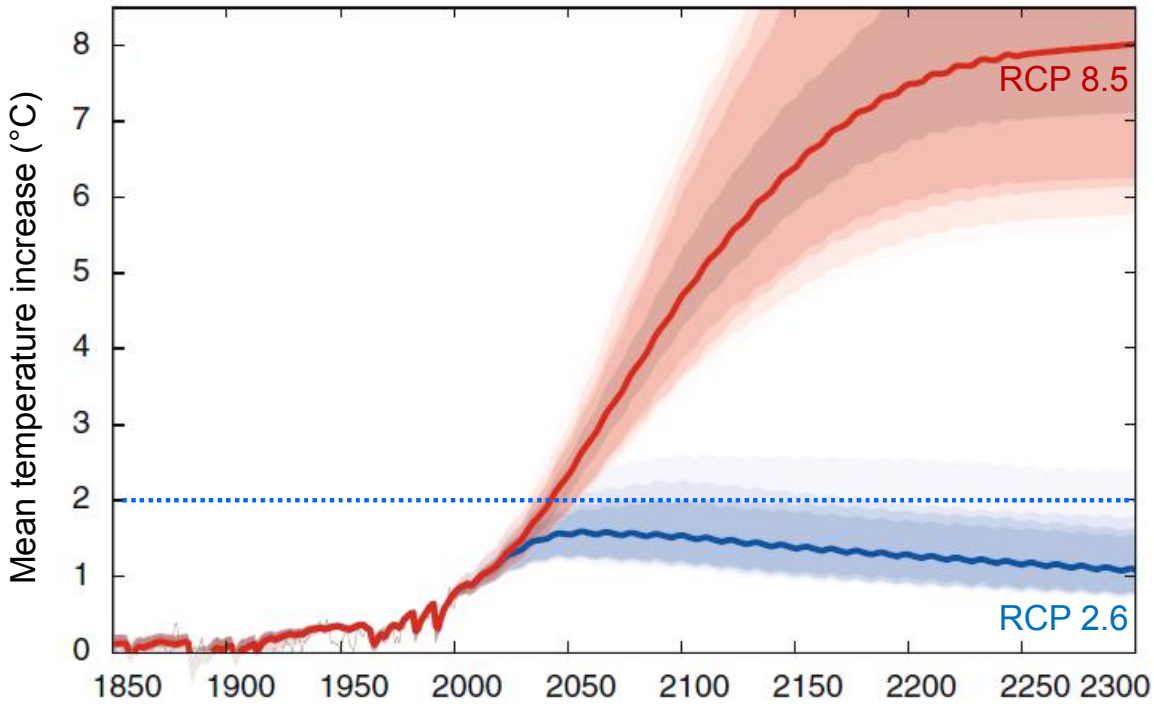
Paper:
Ekholm 2014, Hedging the climate sensitivity risks of a temperature target, Climatic Change 127, pp. 153-167.

The 2°C limit and climate sensitivity (Cs)



Uncertainty in climate sensitivity (Cs)
⇒ uncertainty in future temperature
⇒ 2°C target cannot be met with certainty



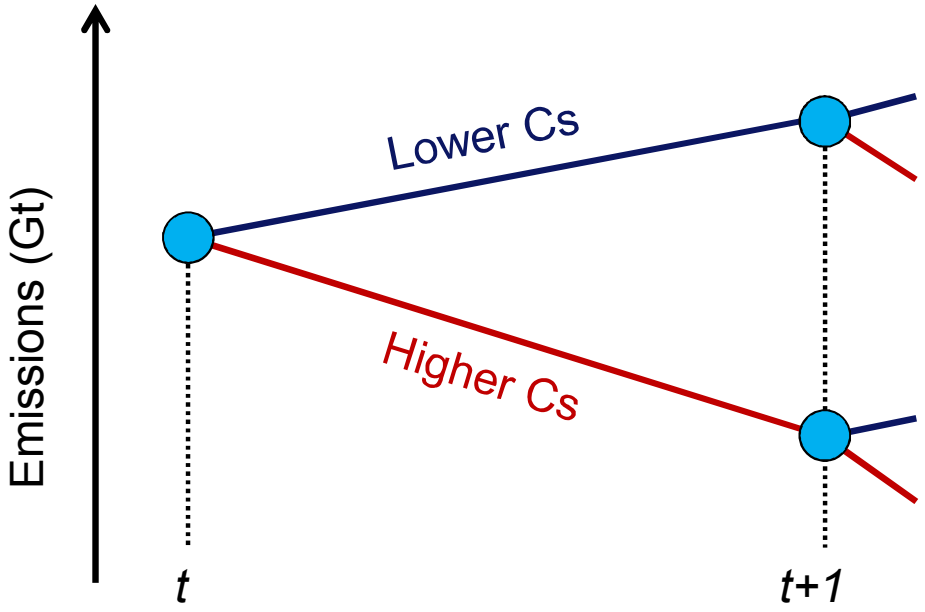
Source: Meinshausen et al. (Climatic Change 109, 2011)

Learning and sequential decision making

- Uncertainty over Cs decreases gradually through learning
  - new observations over time
  - improved modelling

- Emission pathways can be sequentially readjusted to adapt to this new information

- In principle, possible to meet the 2°C target with certainty



Intertemporal cost-efficiency problem, – a recursive formulation

Cost efficiency problem
for a temperature limit under uncertainty:

$$\min_r \left\{ E_t \left[\sum_{\tau=t}^{\infty} \beta^{\tau} c_{\tau}(r_{\tau,s}) \right] \middle| \begin{array}{l} T(x_{\tau,s}) \geq 0, \\ x_{\tau+1,s} = f_s(x_{\tau,s}, r_{\tau,s}), \\ \forall s, \tau \geq t, \\ r_{\tau,s_1} = r_{\tau,s_2} \quad \text{if } S(\tau, s_1) = S(\tau, s_2) \end{array} \right\},$$

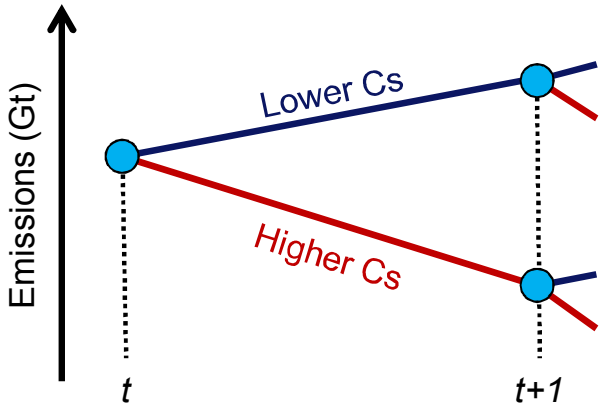
Minimize expected mitigation costs

ΔT limit

State transfer function

Scenario-tree structure (non-anticipativity constraints)

Recursive formulation:
Minimize the current period's and the expected future costs' sum



$$V_t(x_t) = \min_{r_t} \{ c_t(r_t) + \beta E_t \left[V_{t+1,s}(f_s(x_t, r_t)) \right] \mid T(f_s(x_{t,s}, r_{t,s})) \geq 0, \forall s \}$$

Evolution of expected carbon price

- Solution through the recursive reformulation (see the paper) yields an equation for the expected evolution of carbon price:

Current marginal abatement cost

Future marginal abatement cost

Reductions' marginal impact to the 2°C limit

$$c'_t(r_t) = \beta E_t \left[c'_{t+1,s}(r_{t+1,s}) \frac{\sum_{\tau=t+1}^{\infty} \left(I_s(t,\tau) \beta^{\tau-t-1} \lambda_{\tau,s} \right)}{\sum_{\tau=t+2}^{\infty} \left(I_s(t+1,\tau) \beta^{\tau-t-1} \lambda_{\tau,s} \right)} \right]$$

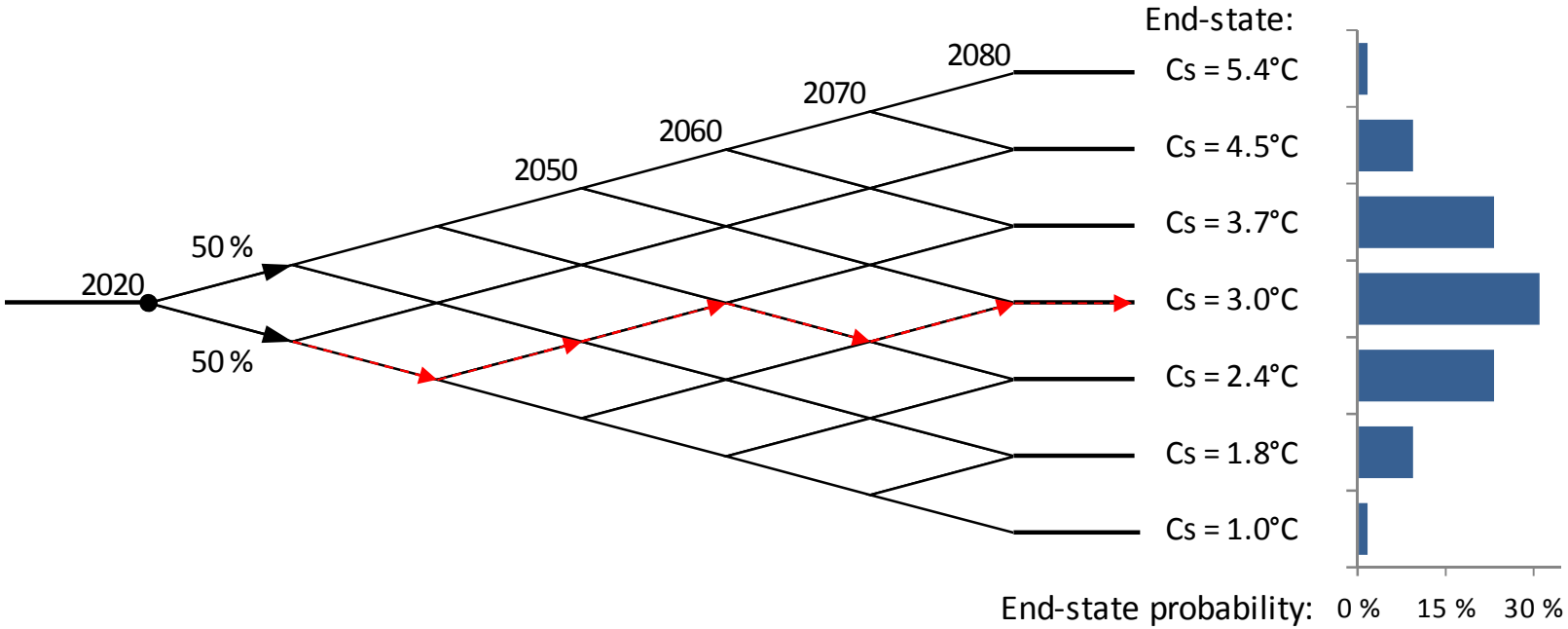
Discount factor

The numerical model

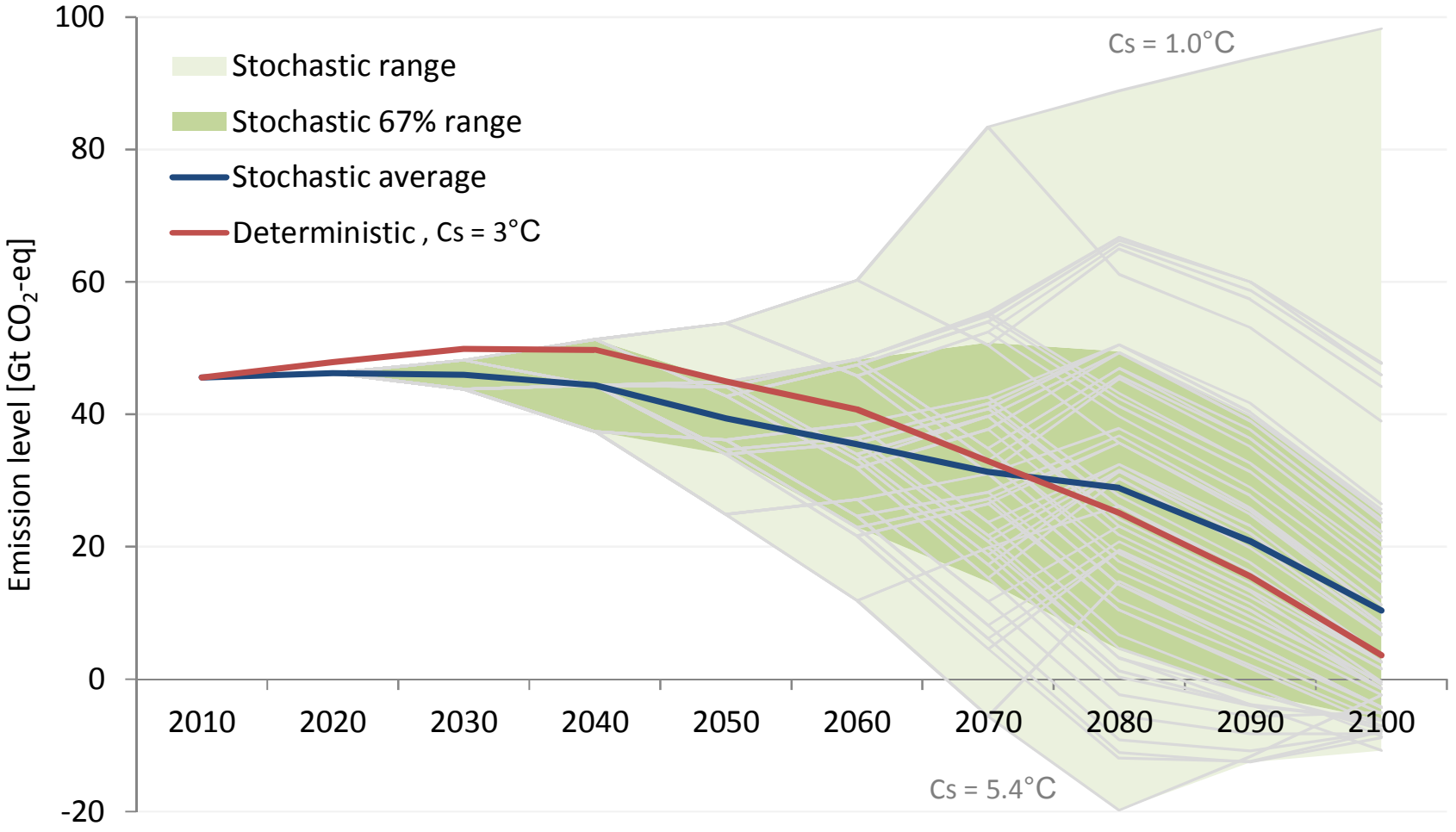
- **SCORE**: Stochastic Cost Optimization for Reducing Emissions
  - Marginal abatement cost (MAC) curves estimated from literature (for simplicity, no path-dependency assumed)
  - Simplified climate module for calculating ΔT (from DICE)
  - A stochastic information process describing learning on Cs, sequential decision making on emission reductions
  - 10 year time-steps, model runs up to 2200

Learning on climate sensitivity

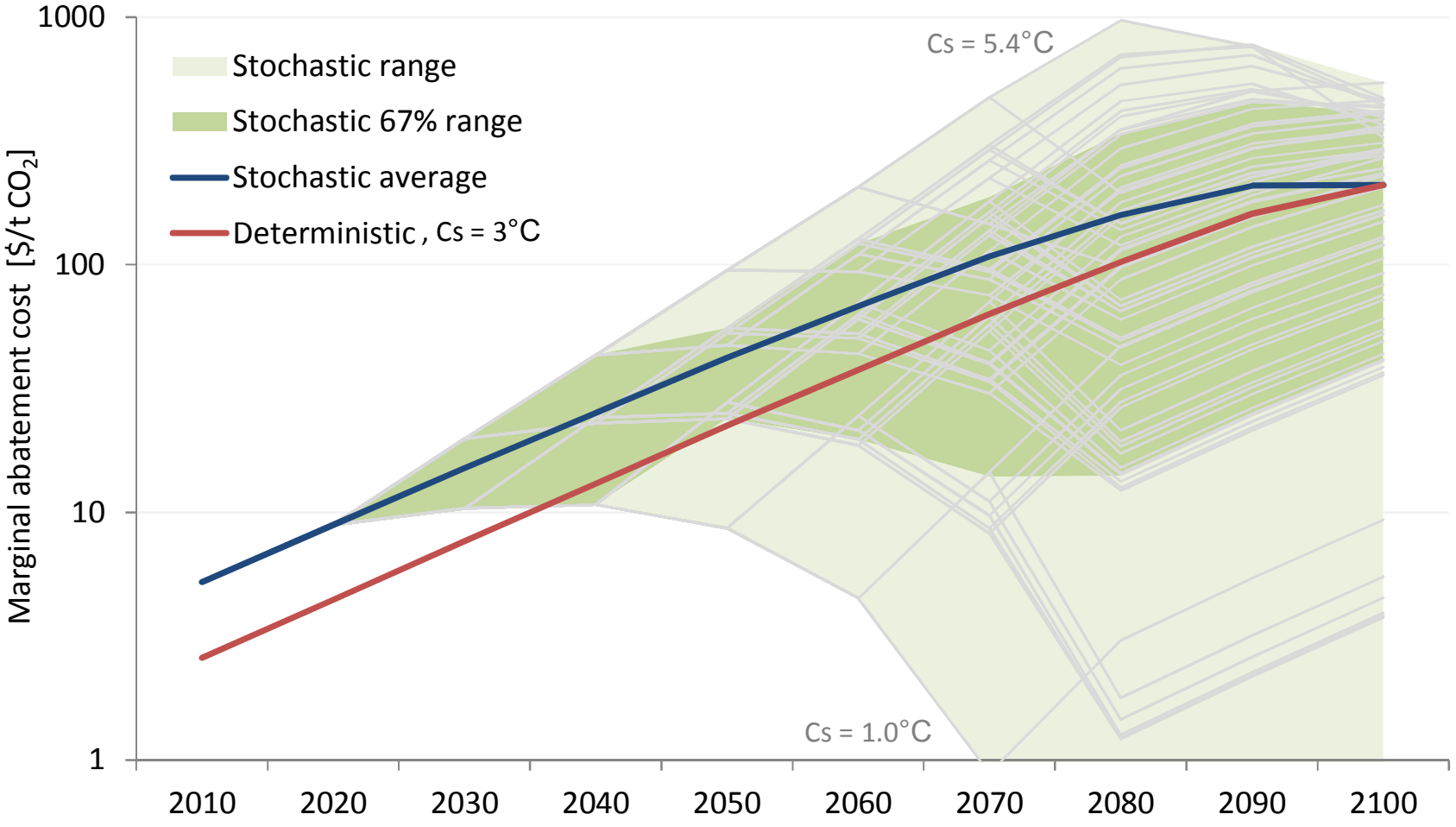
- **Binomial lattice:**
  - 10 year time periods, the true value of Cs known in 2080
  - 7 end states corresponding to a distribution from Knutti and Hegerl (Nat. Geosci., 2008), 64 paths through the lattice
  - assumed to be exogenous



Emissions under sequential decision making

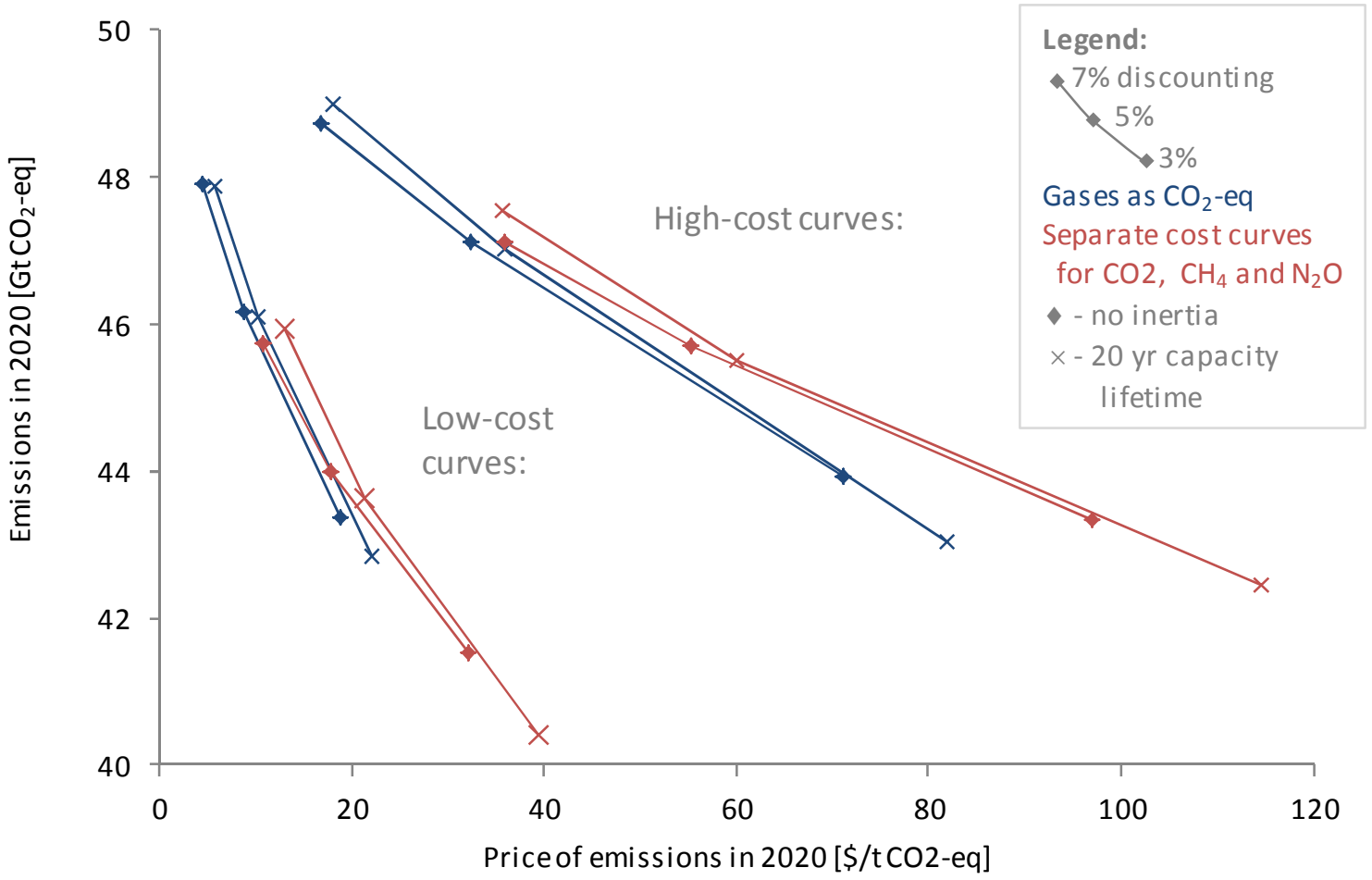


Carbon price under sequential decision making



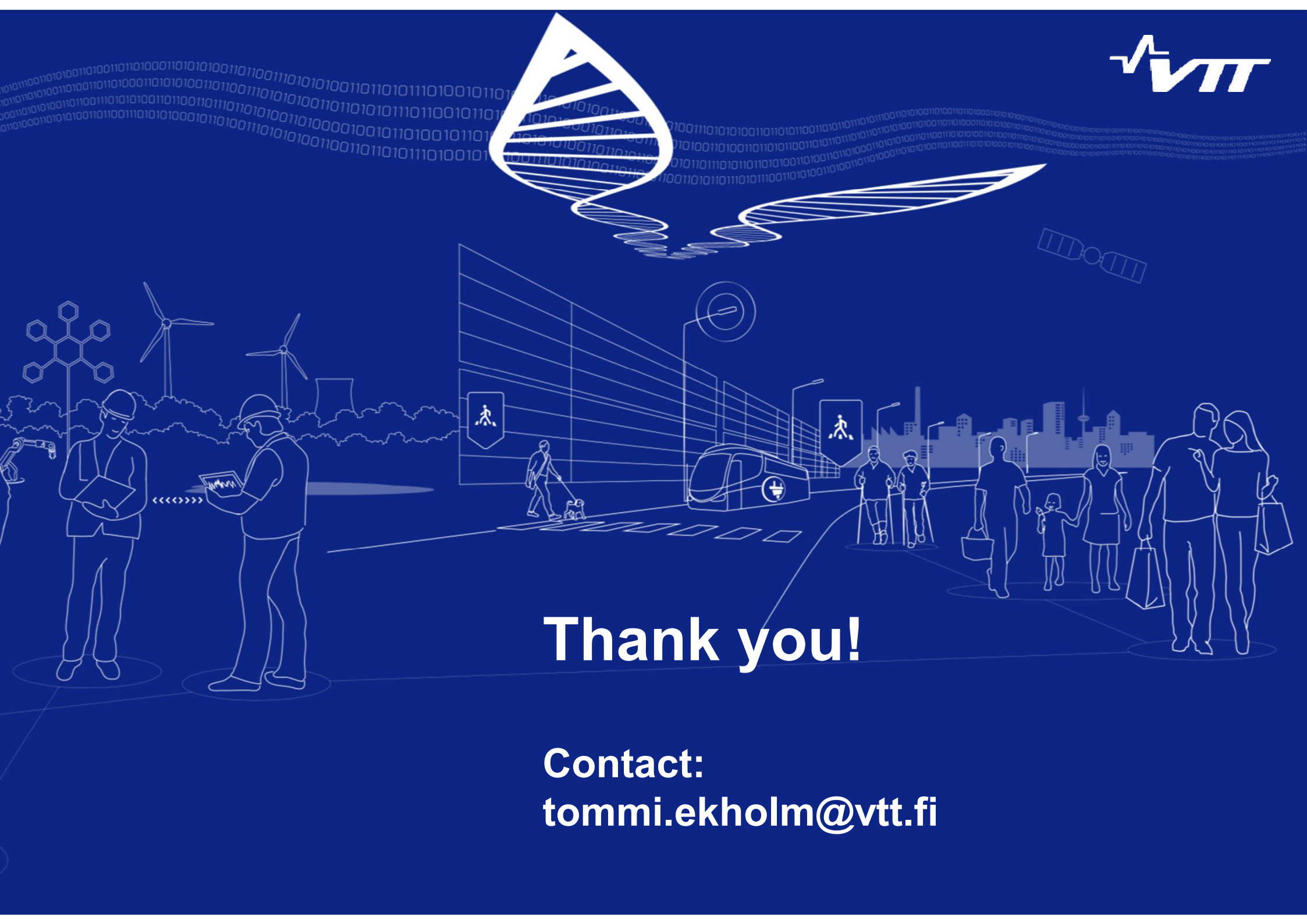
Sensitivity analysis on the results for 2020

- Sensitivity of 2020 prices / emissions with regard to:
  - Discount rate
  - Cost assumptions
  - Inertia of capital for emission reductions
  - Treatment of non-CO_2 emissions



Main conclusions

- 2°C limit met with certainty through sequential decision making, although some of the tail-risk of Cs uncertainty is not captured
- Uncertainty in Cs warrants more ambitions early action than what a deterministic case exhibits
- Near-term policy guidance dependent on uncertain assumptions
- Cs is a notable risk-factor for long-term carbon prices: annual volatility of optimal carbon prices around 10-20%



Thank you!

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