Balmorel investments with various decision horizons and uncertainty

This presentation was adapted and shortened
for day 2 of the wholeSEM workshop
to not elaborate on points made day 1

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Part 1
Balmorel

Balmorel modelling ideas and principles

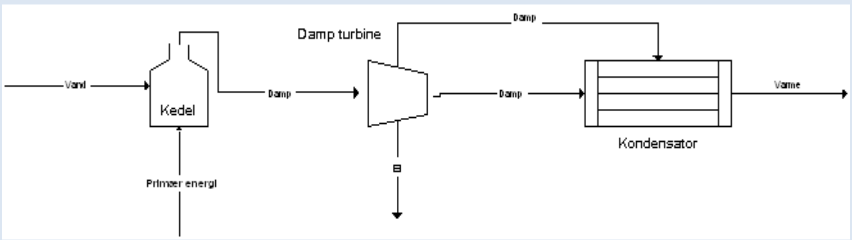
The ambitions:

- To model a wide-stretched geography and a long time perspective, and with possibilities to emphasize selected topics
- Flexibility in modelling (we will not make make a one-size-fits-all model)
- An open source model – sharing of knowledge, and transparency in decisions

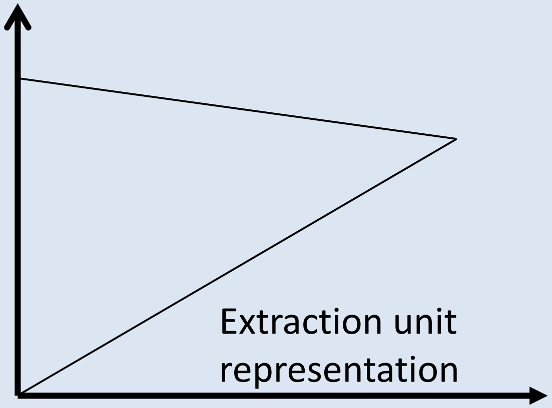
The implementation

- Application of a modelling language (GAMS)
- Transparent data structures
- Linear modelling (base version)
- Thorough documentation s
- The model (GAMS code) and documentation available as open source at the internet (www.balmorel.com)

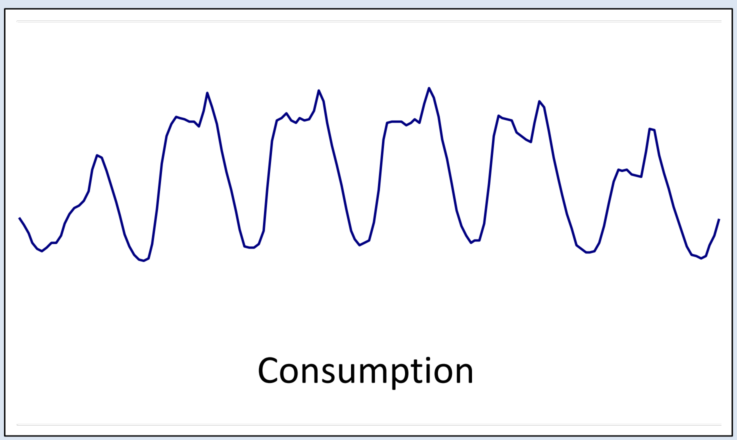
Mainly bottom-up: typically based on technical description of production units, transmission, consumption, ..



Electricity and heat production



Extraction unit representation



Consumption

Electricity transmission system

.. but with some top-down elements, possibilities for calibration, ..

Focus on electricity and district heating

Represents

- A number of technology types
- Fuels types
- Electricity transmission with capacities, losses and costs
- Electricity and heat distribution costs
- Electricity and heat demand (price responsive)
- Taxes, subsidies
- Environmental restrictions, penalties and incentives
- Endogenous investment possibilities (technologies, transmission)

Solution principle (1)

The Balmorel model determines for each time period and each geographical entity:

- generation of electricity and heat, distinguished by technology and fuel
- consumption of electricity and heat
- electricity transmission
- distribution of electricity and heat
- emissions
- investments in production and transmission
- prices

such that ….

Solution principle (2)

Social welfare is maximized

(i.e., maximizing consumers' utility minus producers' cost)

Thus, a partial equilibrium model, with:

- Equilibrium between regional electricity prices according to transmission constraints
- Equilibrium between time periods according to storage possibilities
- Equilibrium between short and long term marginal costs according to capacities, costs and investment possibilities
- Equilibrium between electricity and heat prices according to technical characteristics of production units
- Equilibrium between consumers' and producers' marginal utilities according to demand and supply characteristics

Additional comments

for today

- Geography, time: fully scalable. Applications that I know of typically use around 50 geographical entities; 300-8760 time slices per year
- Same model for investment and operation (only difference is whether investment options are present or not)
- LP, but with possibility to apply MIP (e.g. for unit commitment, discrete size investments, ...)
- Investments in Balmorel were originally myopic, now flexible rolling horizon
- Investments: investment cost is distributed (annuity) over the years of the lifetime of the investment (technology, geography and year specific)
- Decision makers for technology investments and dispatch are thought of as companies (TSO/DSO for transmission/distribibuition) ; framework conditions are thought of as set by politicians

- The rolling horizon version of Balmorel will be available at www.balmorel.com in about a month (preliminary version)

Part 2
Investments and decision horizons

Example of rolling planning idea

Year	2010	2015	2020	2025	2030	2035	2040	2045	2050
Planning interval 1	2010	2015	2020	2025	2030				
Planning interval 2		2015	2020	2025	2030	2035			
Planning interval 3			2020	2025	2030	2035	2040		
Planning interval 4				2025	2030	2035	2040	2045	
Planning interval 5					2030	2035	2040	2045	2050

Planning horizon: 2010 through 2050, with representation of every fifth year
Planning intervals: 20 years in each (represented by 5 years in each interval)
Planning intervals: 5
Investments during previous planning intervals
- are kept if they were before the start of current planning interval
- otherwise they are discarded to permit replanning

Objective function (indication)

$$\min OBJ = \sum_{y=2010}^{2030} \frac{\sum_{y}\sum_{r} C_y}{(1+I)^{(y-2010)}}$$

The composition of the objective cost *C* main components includes :

The Investment cost for new generators and transmission lines:

$$INV_y = \sum_r \sum_g (Vgkn_{g,r,y} \cdot Cap_g \cdot Annuity_g + \frac{\sum_{r'} Vtkn_{r,r',y} \cdot CapT \cdot Annuityt}{2}) \cdot (1 + \sum_{y_t \in N_y} \frac{1}{(1+d)^{y_t - y}})$$

Comments on investment cost:

- *d*: discount rate (society's perspective)
- N_y: remaining years in current planning interval (in this case 2010, .. , 2030)
- *Annuity*: annuitized capital and financing cost, risk (investors' perspective)
- takes investments life time into consideration

Geographical extenion of a Case

Data and analyses by Weiming Xiong

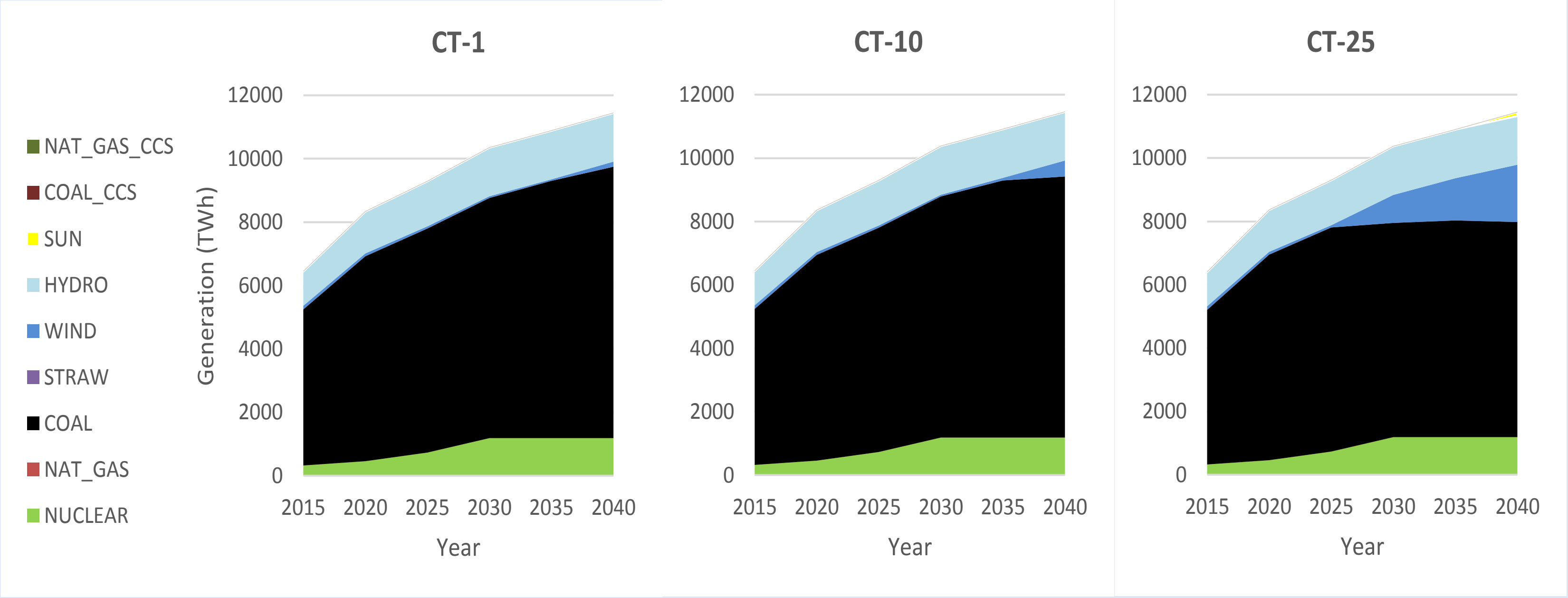
Scenarios

Scenario group	Scenario name	Scenario description
Carbon Tax change	CT-1	1-year prediction period. Fuel cost keeps consistent with initial year. Carbon tax is implemented as 50 RMB/ton from 2030. From then on, carbon tax will increase 5% annually towards 2040.
	CT-10	10-year prediction period. The rest of assumption is same with RS-CT.
	CT-25	Perfect prediction. The rest of assumption is same with RS-CT.
Fuel cost change	FC-1	1-year prediction period. Fuel cost will increase 30% in 2030. From then on, fuel cost will increase 2% annually towards 2040.
	FC-10	Perfect Prediction methodology. The rest of assumption is same with RS-FC.
	FC-25	The rest of assumption is same with RS-FC.

Idea:

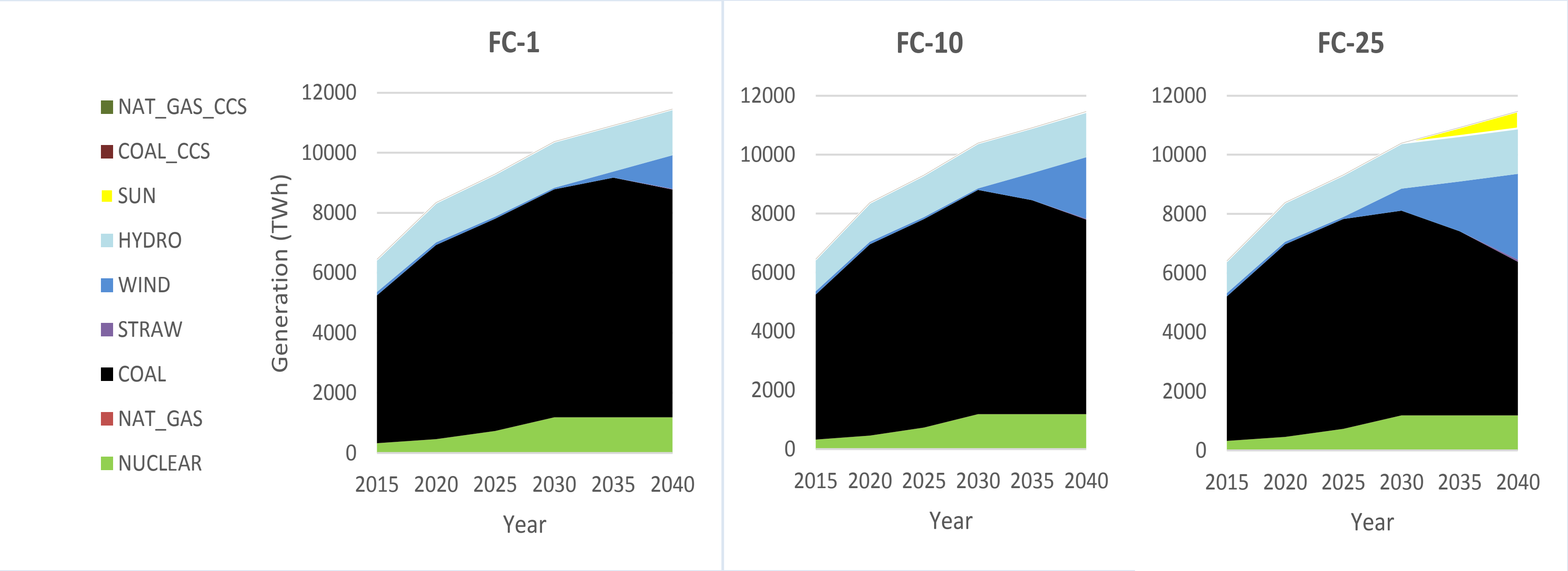
- model years 2015 through 2040, represented by every fifth years
- apply an abrupt change in carbon tax (CT) or fuel cost (FC) in 2030, and increase gradually from then on
- analyse results using rolling horizon with various length of intervals

Electricity generation mix with carbon tax change



'-1': one-year intervals; '-10': ten-years intervals; '-25': 25-years interval

Electricity generation mix with fuel cost change



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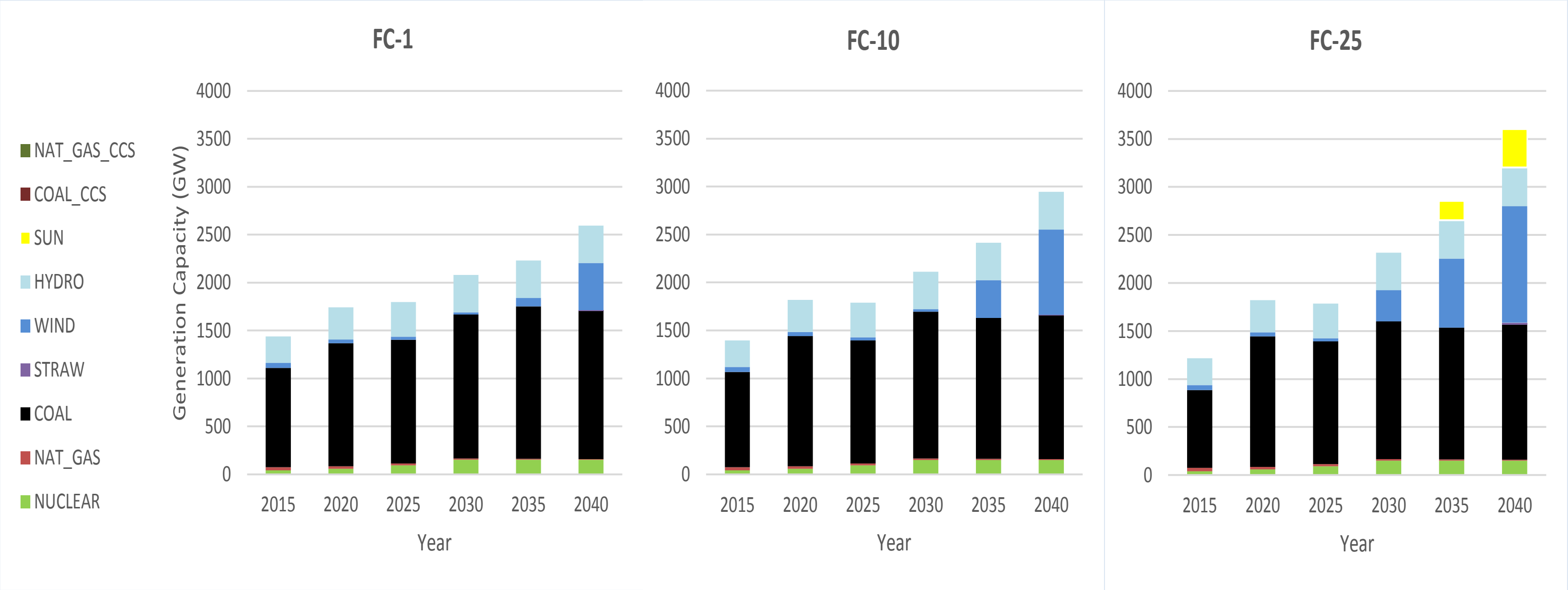
Generation capacities with fuel cost change



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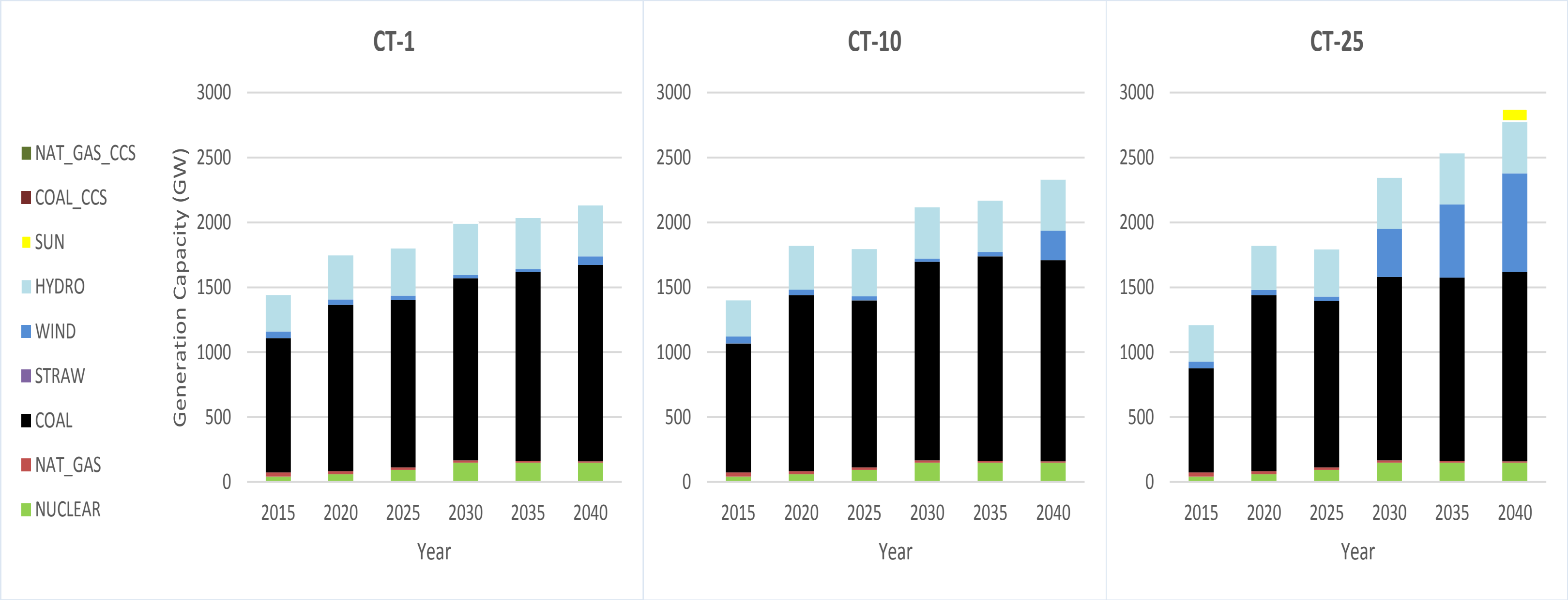
Generation capacities with carbon tax change



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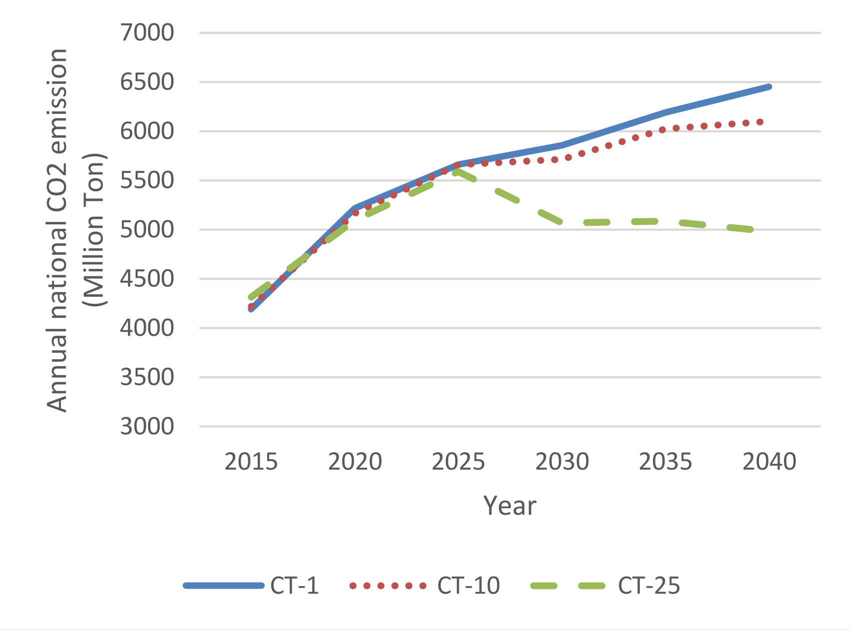
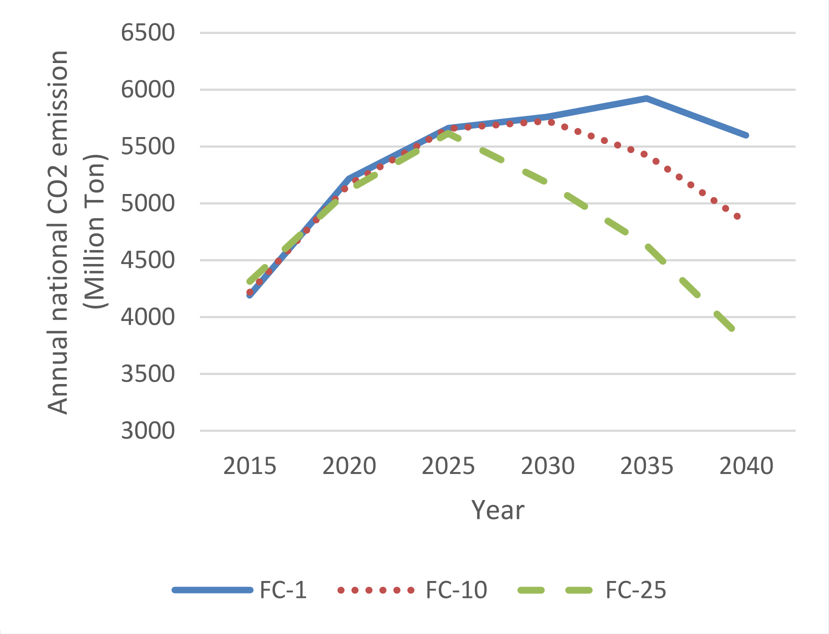
CO_2 emission with carbon tax and fuel cost changes





'-1': One-year intervals; '-10': ten-years intervals; '-25': 25-years interval

Part 3
Uncertainty

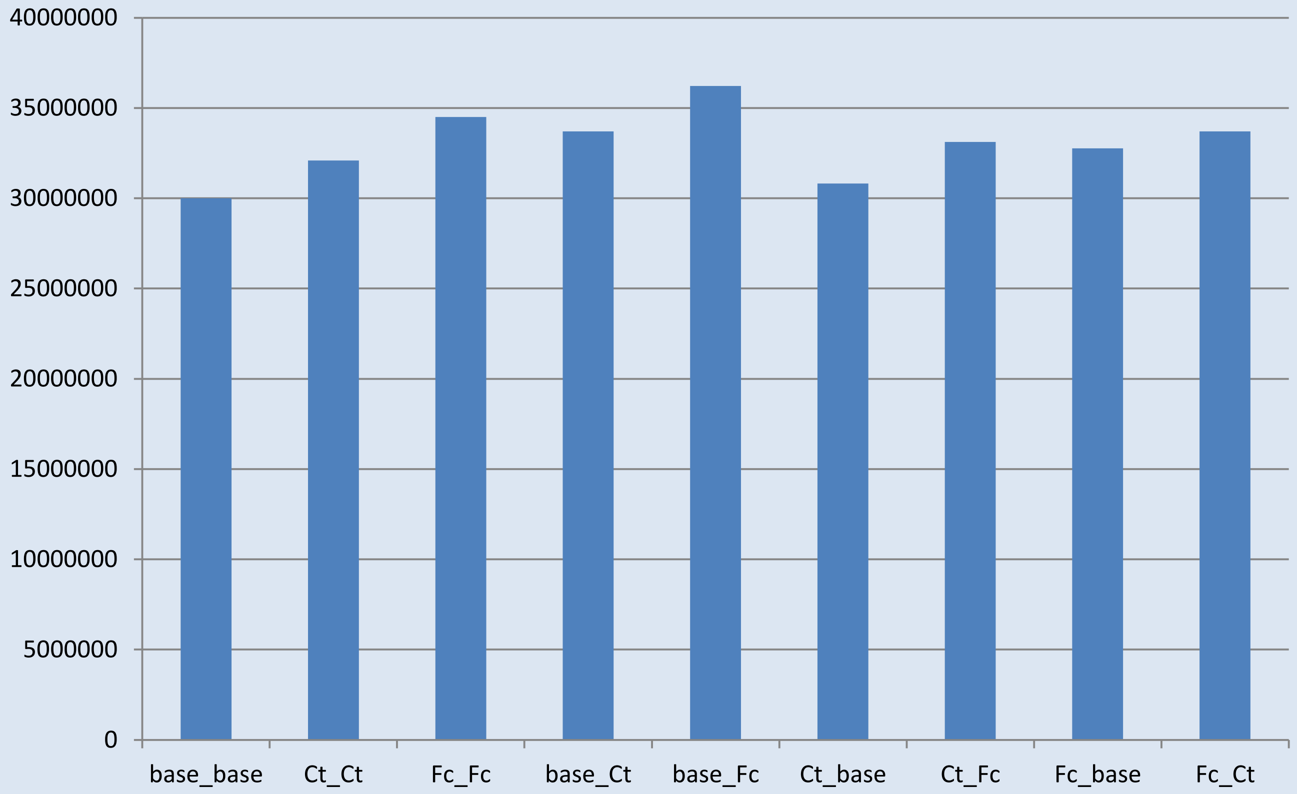
Uncertainty

- Only partial knowledge wrt. future energy policies, fuel prices, growth, wind energy availability, ...
- Analyst/decision-maker may find it
  - Acceptable to use probabilities with e.g. wind, solar and hydro power variations
  - Not acceptable to use probabilities with e.g. future fuel prices, energy policies
- Using the rolling structure to analyse the consequences of change of planning assumptions
- With posibility to revise not-implemented decisions

Analysis example

- Planning horizon 2015 – 2040
- Considering the same three scenarios as above: base, high Carbon tax from 2030 (Ct), high Fuel cost from 2030 (Fc)
- Method for calculation:
  - For each scenario Si: Find optimal investment decision
  - Define three Decisions Dj: optimal investment corresponding to Sj
  - For each combination (Si, Dj) of scenario and decision:
    - Keep Dj for 2015 (decided and implemented investments)
    - Discard Dj after 2015 (decided but not implemented investments)
    - Find optimal investment decision 2020-2040 for Scenario Si

Cost graph



40000000
35000000
30000000
25000000
20000000
15000000
10000000
5000000
0
base_base
Ct_Ct
Fc_Fc
base_Ct
base_Fc
Ct_base
Ct_Fc
Fc_base
Fc_Ct

Cost matrix
Minimax

		Scenario			
		base	Ct - Carbon Tax	Fc – Fuel Cost	Max(row) Maxcost per Scen
	base	29	33	36	36
Decision	Ct - Carbon Tax	30	32	33	33 Minimax
	Fc – Fuel Cost	32	33	34	34

Values are results *E-6

Cost matrix
Minimax regret

		Scenario			
		base	Ct - Carbon Tax	Fc – Fuel Cost	
	base	29	33	36	
Decision	Ct - Carbon Tax	30	32	33	
	Fc – Fuel Cost	32	33	34	
	Min(col) Best Dec per Scen	29	32	33	

		Scenario				
		base	Ct - Carbon Tax	Fc – Fuel Cost	Min(row) Regret	
Decision	base	0	1	3	0	Minimax regret
	Ct - Carbon Tax	1	0	0	0	Minimax regret
	Fc – Fuel Cost	3	1	1	1	

Values are results *E-6

Conclusions

- A model for analyses of investments
  - with wide geographical scope
  - with long time horizon
  - with integrated handling of investment and operation costs
  - with integrated handling of electricity and heat
- Non-probabilistic decision analysis
  - with rolling horizon analyses
  - with revision of not-implemented decisions