Netherlands Environmental Assessment Agency
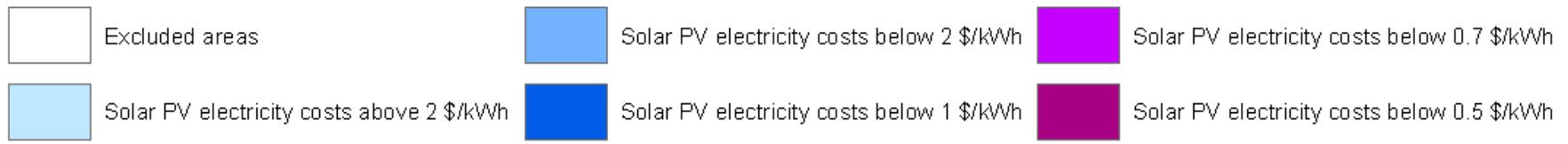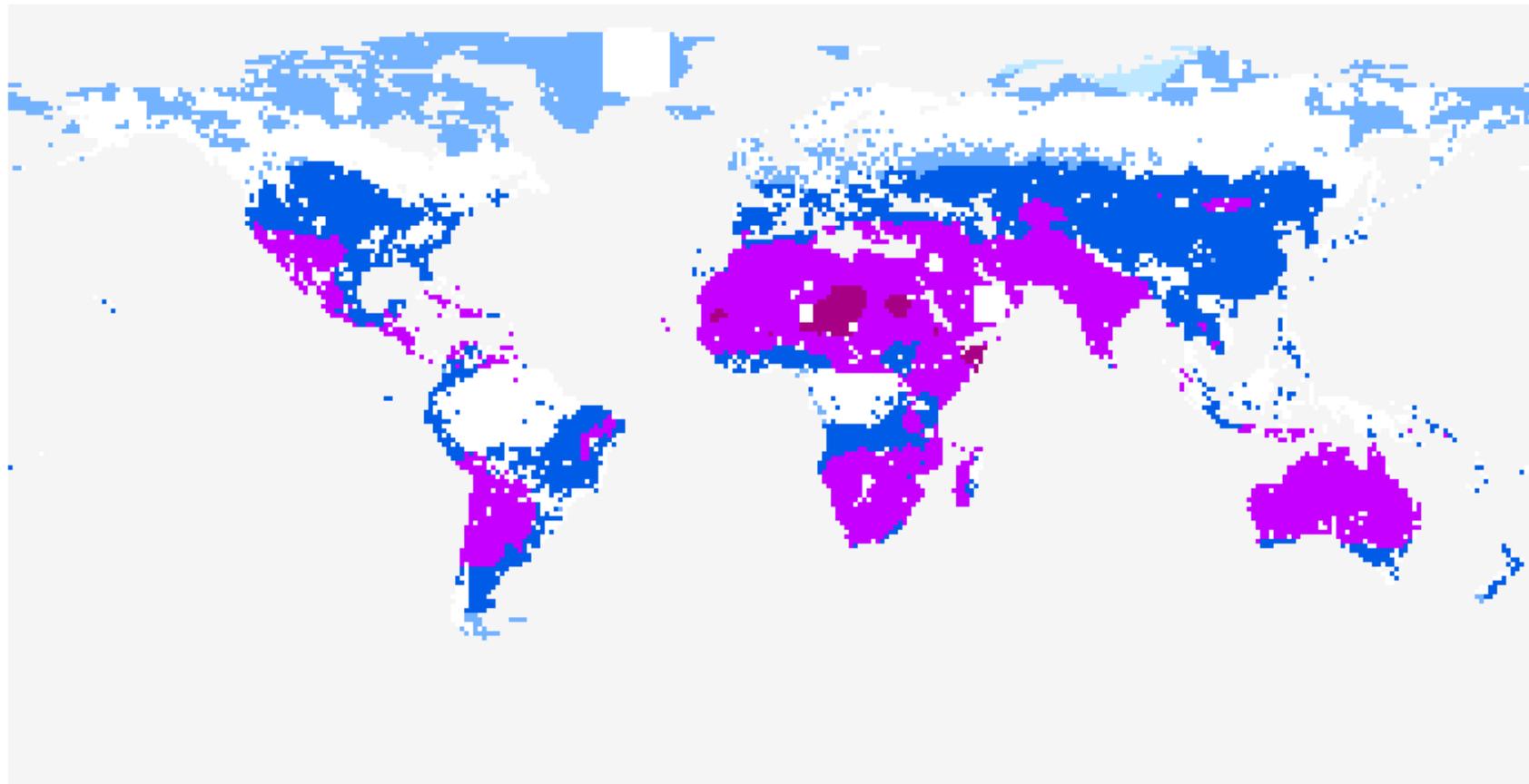
Renewables in IMAGE

Detlef van Vuuren

Solar PV cost distribution

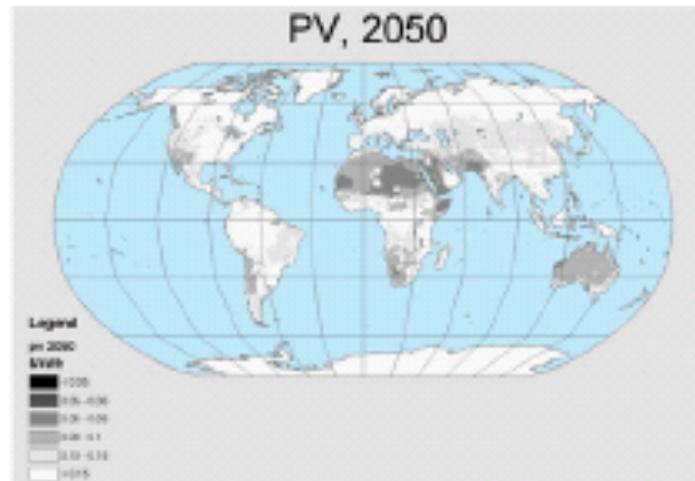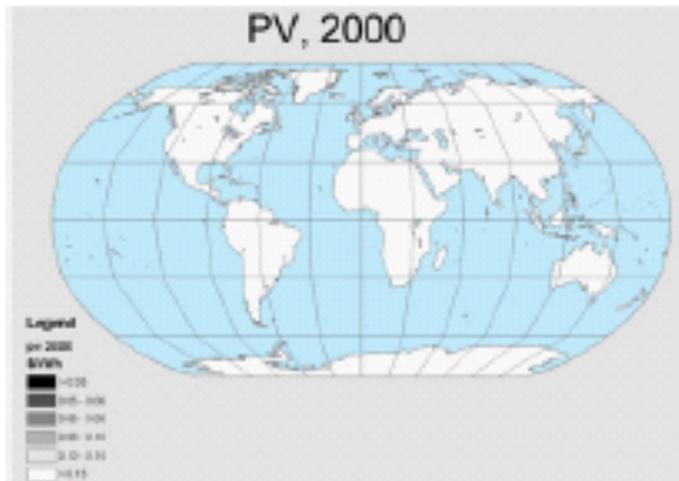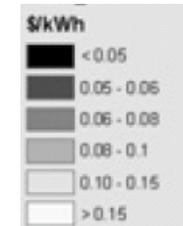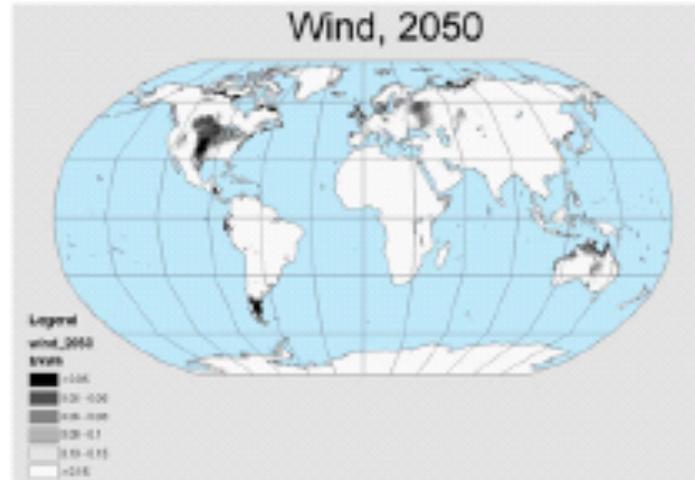|		
Excluded areas	Solar PV electricity costs below 2 $/kWh	Solar PV electricity costs below 0.7 $/kWh
Solar PV electricity costs above 2 $/kWh	Solar PV electricity costs below 1 $/kWh	Solar PV electricity costs below 0.5 $/kWh

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Wind, 2000

Wind, 2050

PV, 2000

PV, 2050

$/kWh
< 0.05
0.05 - 0.06
0.06 - 0.08
0.08 - 0.1
0.10 - 0.15
> 0.15
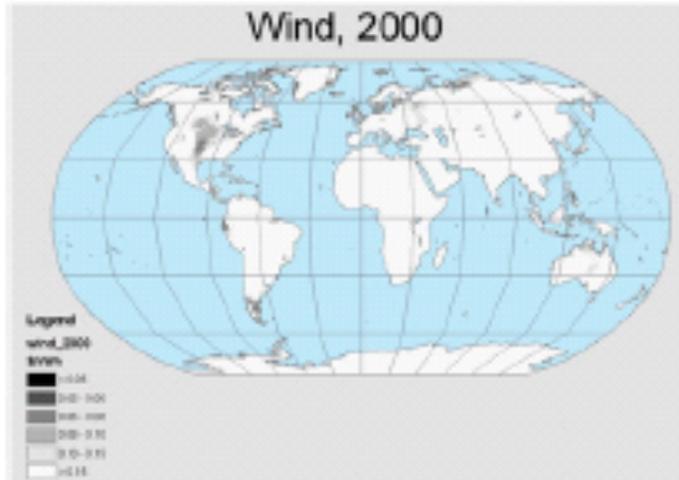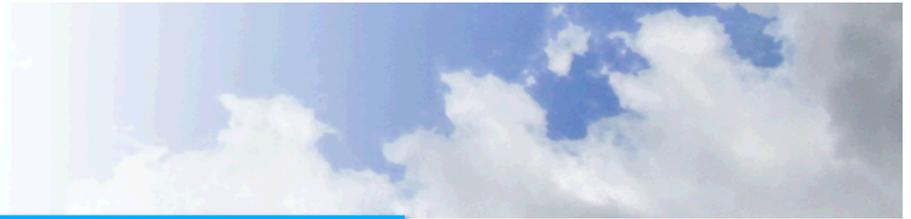
Implementation in the model

- In principle, implementation based on costs (for new capital model uses multi-logit equation to allocate investments by market).

    - Learning by doing increases penetration
    - Depletion decreases penetration

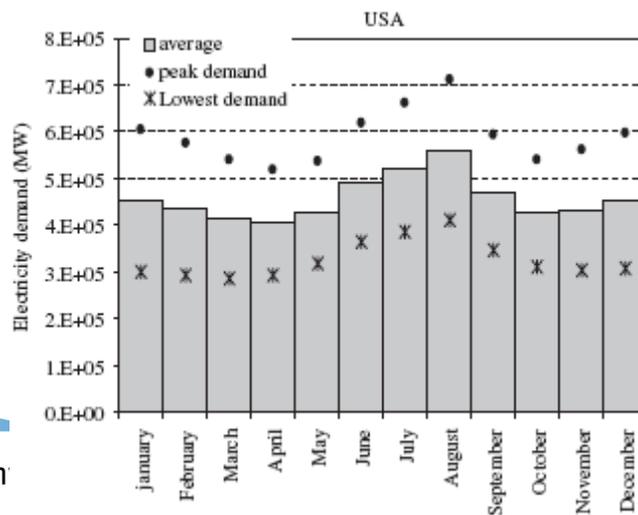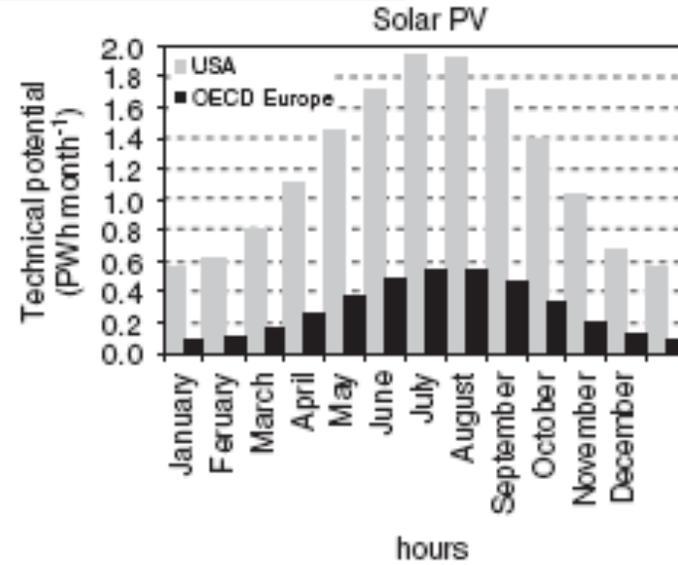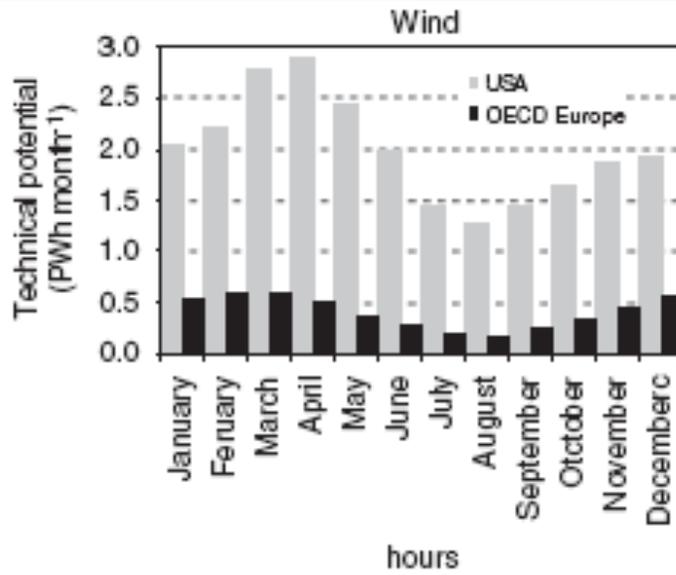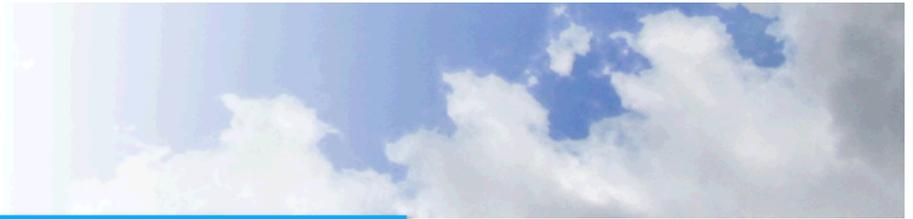- But also different equations to deal with system aspects → not easy to represent system requirements in aggregated model.

- Implementation calculations done on a monthly basis (rest of the model works on annual basis)

Hoogwijk, M., van Vuuren, D., de Vries, B., and Turkenburg, W. (2007). "Exploring the impact on cost and electricity production of high penetration levels of intermittent electricity in OECD Europe and the USA". Energy, 32, (8): 1381-1402

Why monthly?

Overall decision scheme in model

Investment strategy   Operational strategy
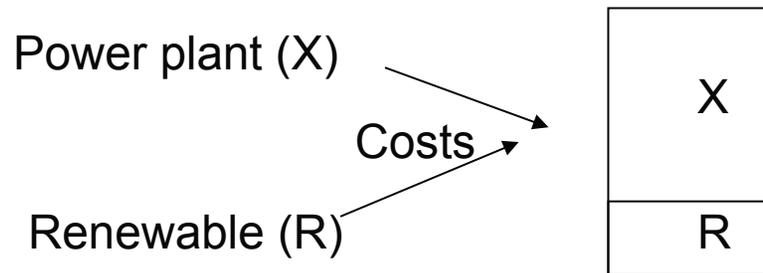

- Wind/pv first Resort LDF
- Hydropower Resort LDF
- Peak/base using rest (weighing)

Multinomial logit equations

Wind and solar in the electricity system

Power plant (X)

Costs

Renewable (R)

X
R

Hoogwijk, M., Van Vuuren, D. P., de Vries, B., and Turkenburg, W. (2007). "Exploring the impact on cost and electricity production of high penetration levels of intermittent electricity in OECD Europe and the USA, results for wind energy. " Energy Journal, 32, (8): 1381-1402.
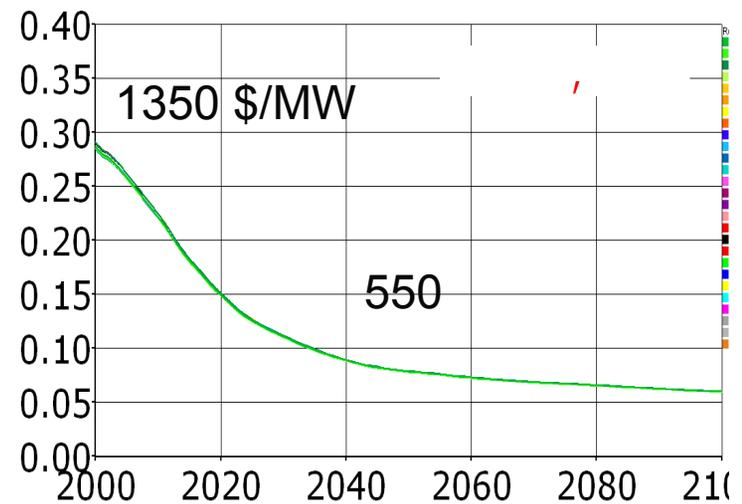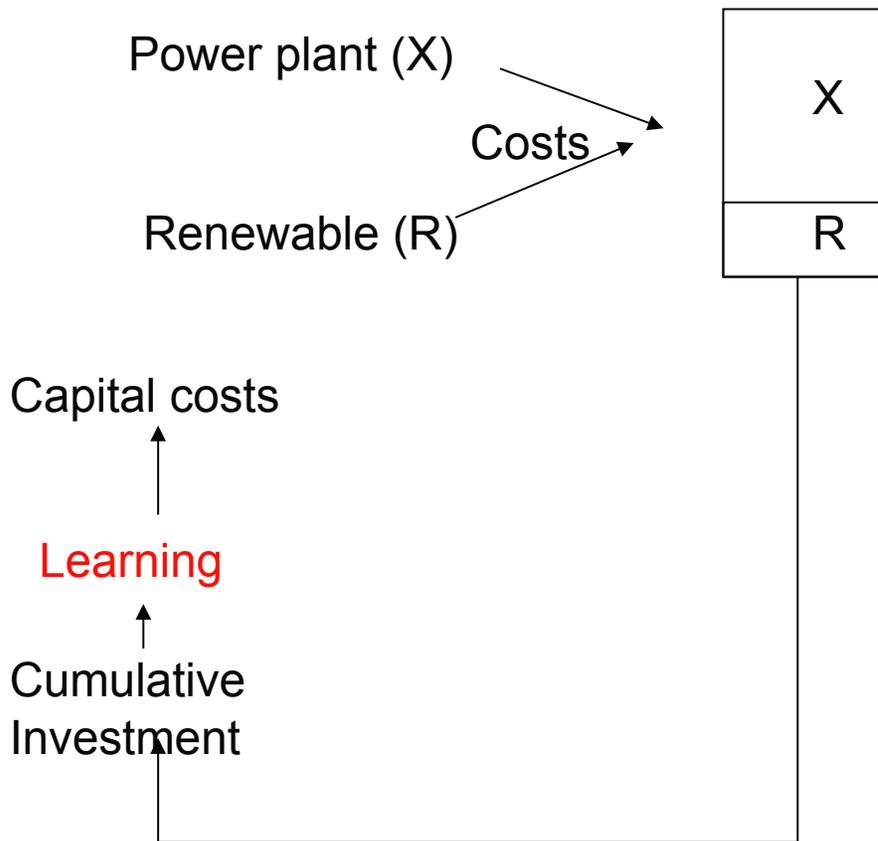
Wind and solar in the electricity system

Power plant (X)

Costs

Renewable (R)

X

R

Capital costs

Learning

Cumulative
Investment

1350 $/MW

550

0.40
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0.00

2000   2020   2040   2060   2080   210

Hoogwijk, M., Van Vuuren, D. P., de Vries, B., and Turkenburg, W. (2007). "Exploring the impact on cost and electricity production of high penetration levels of intermittent electricity in OECD Europe and the USA, results for wind energy. " Energy Journal, 32, (8): 1381-1402.
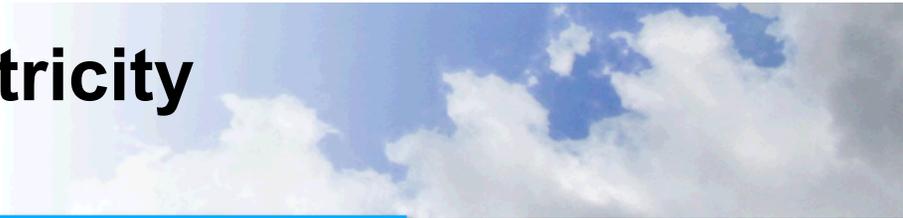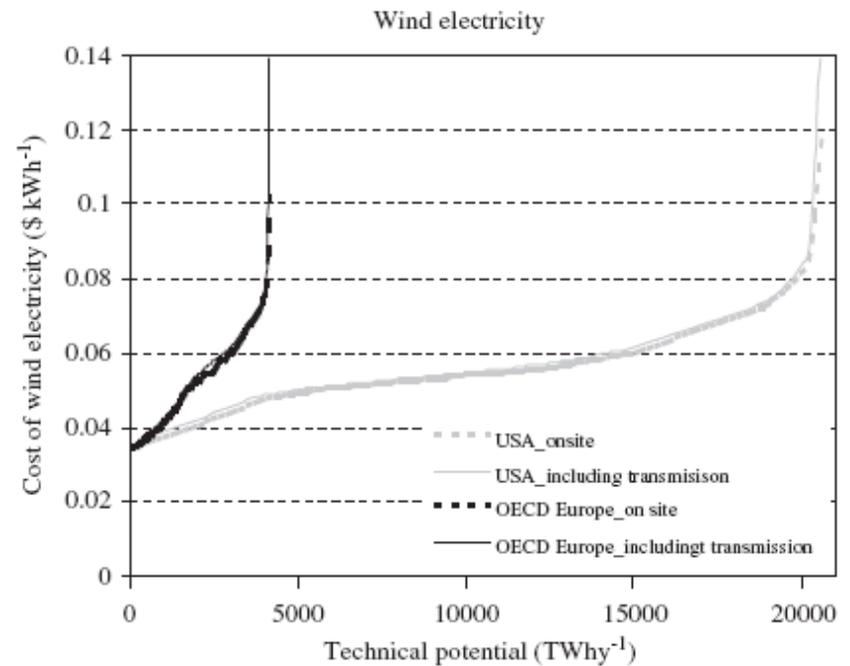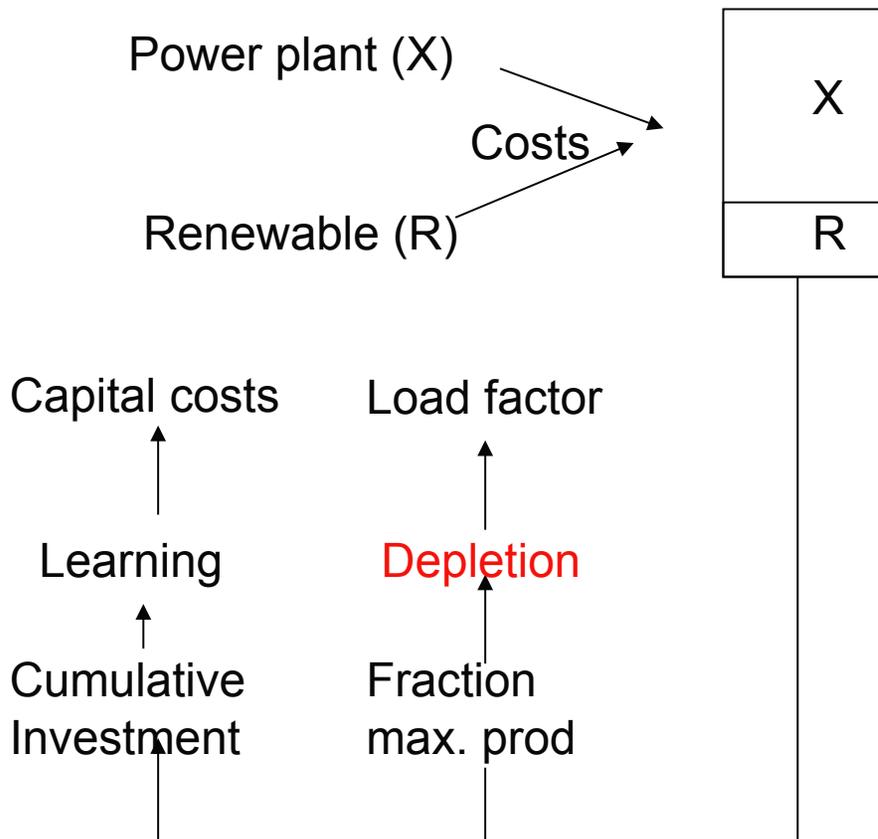
Wind and solar in the electricity system

Power plant (X)

Costs

Renewable (R)

X

R

Capital costs

Load factor

Learning

Depletion

Cumulative Investment

Fraction max. prod

Wind electricity

Cost of wind electricity ($ kWh^{-1})

- USA_onsite
- USA_including transmision
- OECD Europe_on site
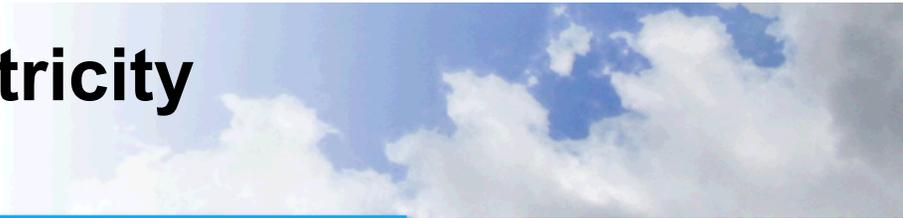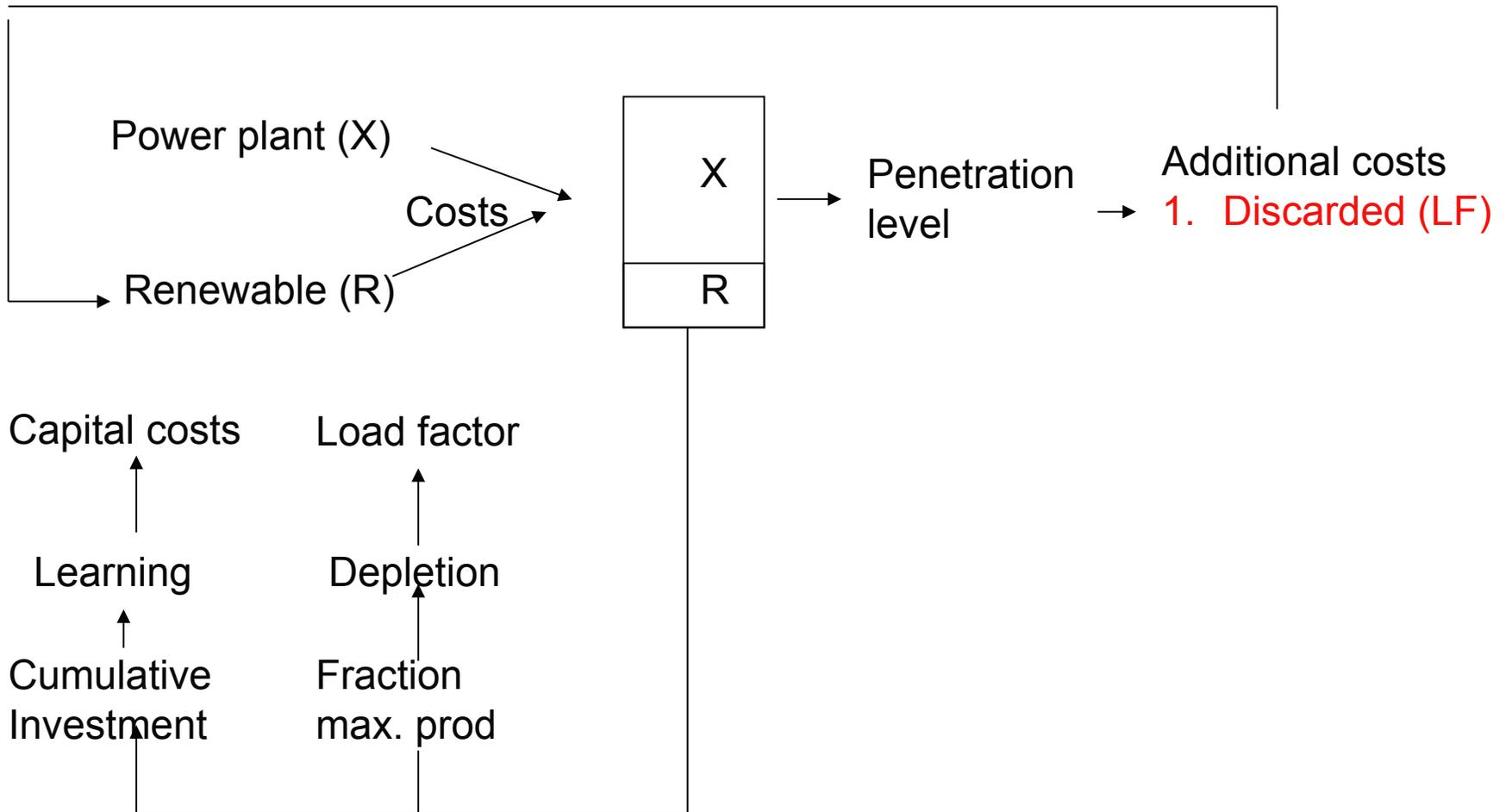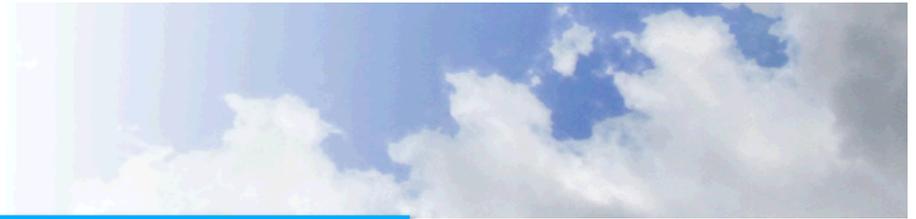- OECD Europe_includingt transmission

Technical potential (TWhy^{-1})

Hoogwijk, M., Van Vuuren, D. P., de Vries, B., and Turkenburg, W. (2007). "Exploring the impact on cost and electricity production of high penetration levels of intermittent electricity in OECD Europe and the USA, results for wind energy. " Energy Journal, 32, (8): 1381-1402.

Wind and solar in the electricity system

Power plant (X)

Costs

Renewable (R)

X

R

Penetration level

Additional costs
1. Discarded (LF)

Capital costs

Load factor

Learning

Depletion

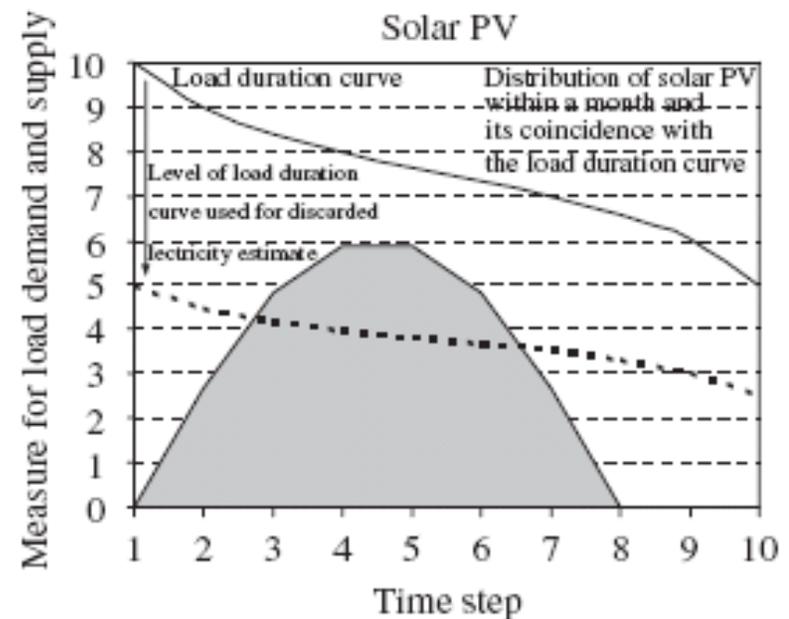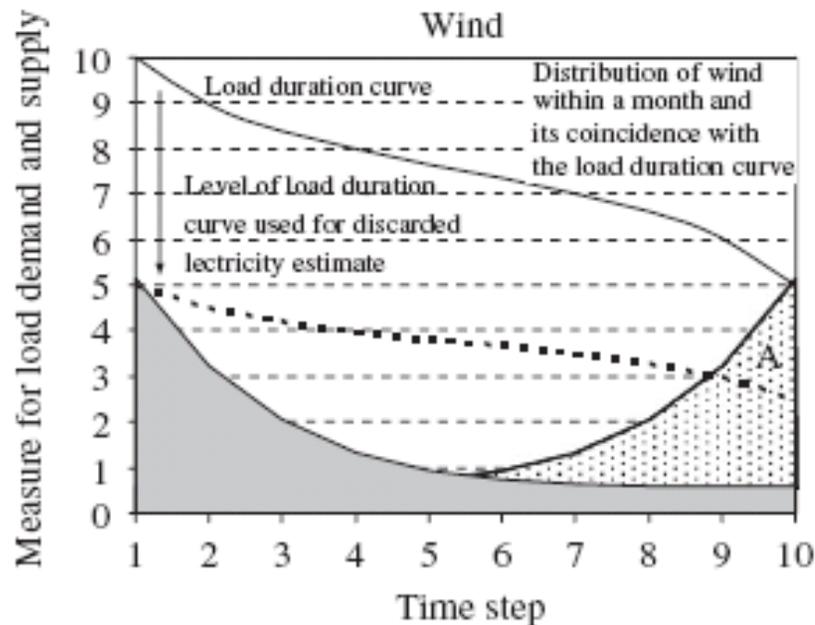Cumulative Investment

Fraction max. prod

Hoogwijk, M., Van Vuuren, D. P., de Vries, B., and Turkenburg, W. (2007). "Exploring the impact on cost and electricity production of high penetration levels of intermittent electricity in OECD Europe and the USA, results for wind energy. " Energy Journal, 32, (8): 1381-1402.
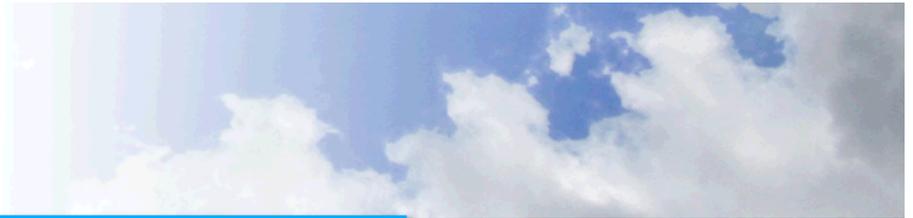
Discarded electricity
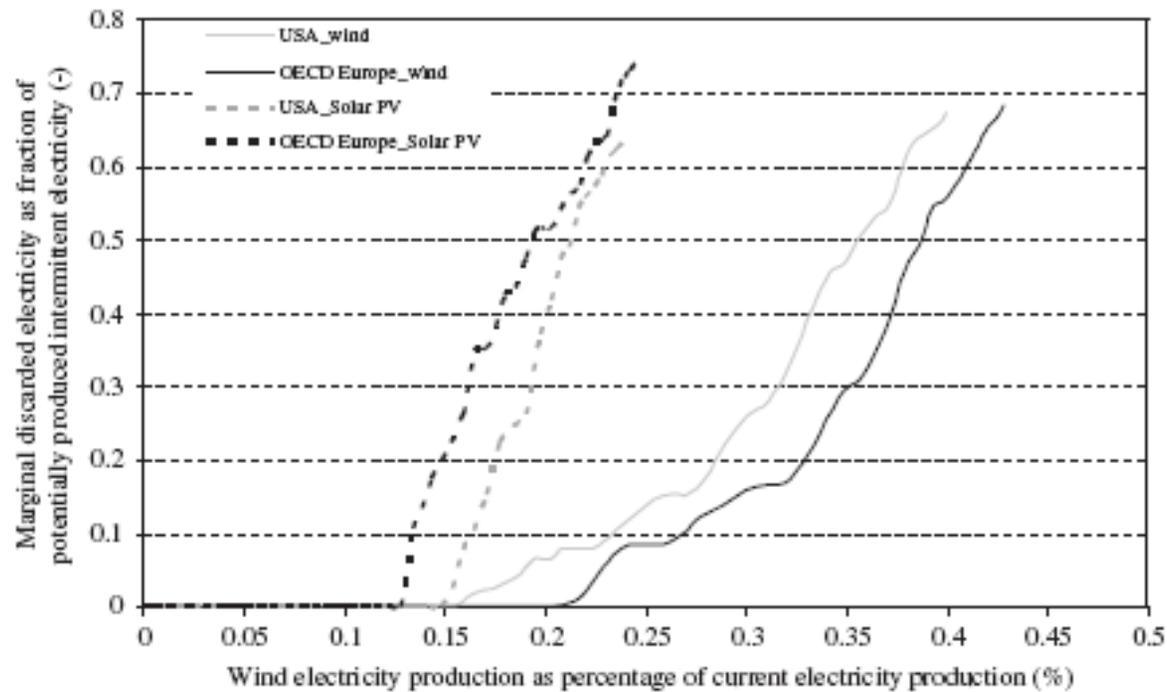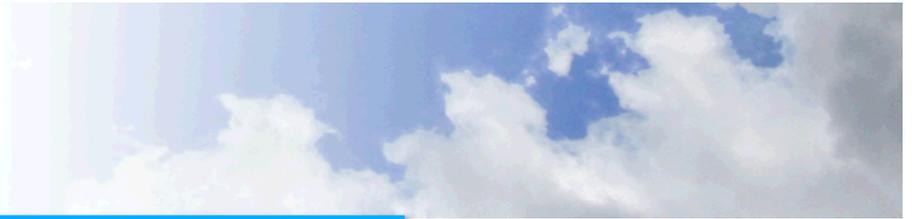
- We use a monthly LDF – with 10 steps.

Hoogwijk, M., Van Vuuren, D. P., de Vries, B., and Turkenburg, W. (2007). "Exploring the impact on cost and electricity production of high penetration levels of intermittent electricity in OECD Europe and the USA, results for wind energy. " Energy Journal, 32, (8): 1381-1402.

Discarded power

M. Hoogwijk et al. / Energy ∎ (∎∎∎) ∎∎∎–∎∎

Figure legend:
- USA_wind
- OECD Europe_wind
- USA_Solar PV
- OECD Europe_Solar PV

Y-axis: Marginal discarded electricity as fraction of potentially produced intermittent electricity (-)

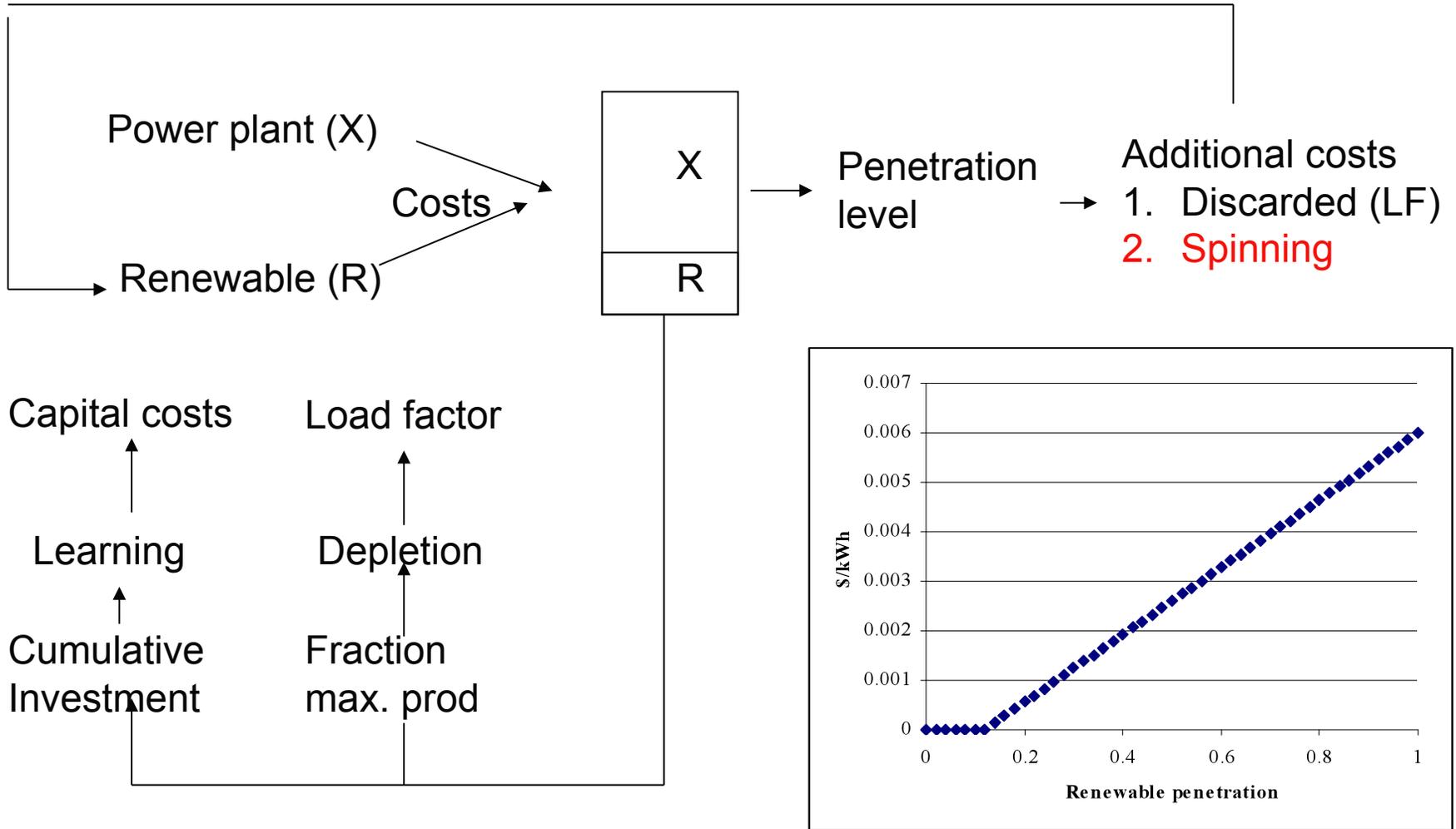X-axis: Wind electricity production as percentage of current electricity production (%)

- Next, first we resort the LDF – and implement hydropower, with slight preference for high demand period.

- We sort the LDF again…. and define peak and baseload. Both are filled with remaining power stations, with some stations prefered in peak and others in base.

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Wind and solar in the electricity system

Hoogwijk, M., Van Vuuren, D. P., de Vries, B., and Turkenburg, W. (2007). "Exploring the impact on cost and electricity production of high penetration levels of intermittent electricity in OECD Europe and the USA, results for wind energy. " Energy Journal, 32, (8): 1381-1402.
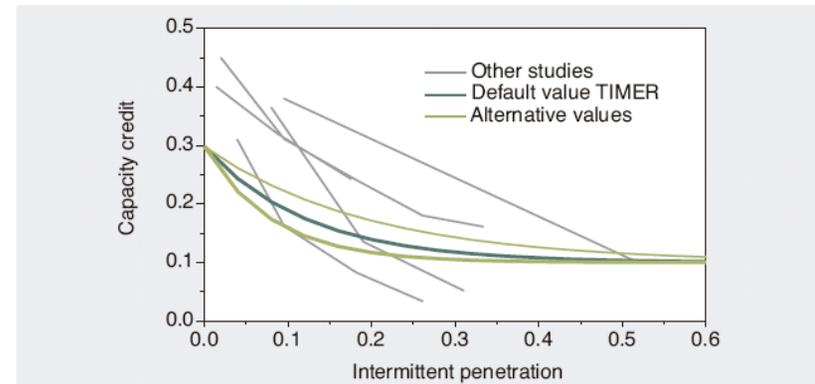
Wind and solar in the electricity system

Power plant (X)

Renewable (R)

Costs

X

R

Penetration level

Additional costs
1. Discarded (LF)
2. Spinning
3. Capacity credit

Capital costs

Load factor

Learning

Depletion

Cumulative Investment
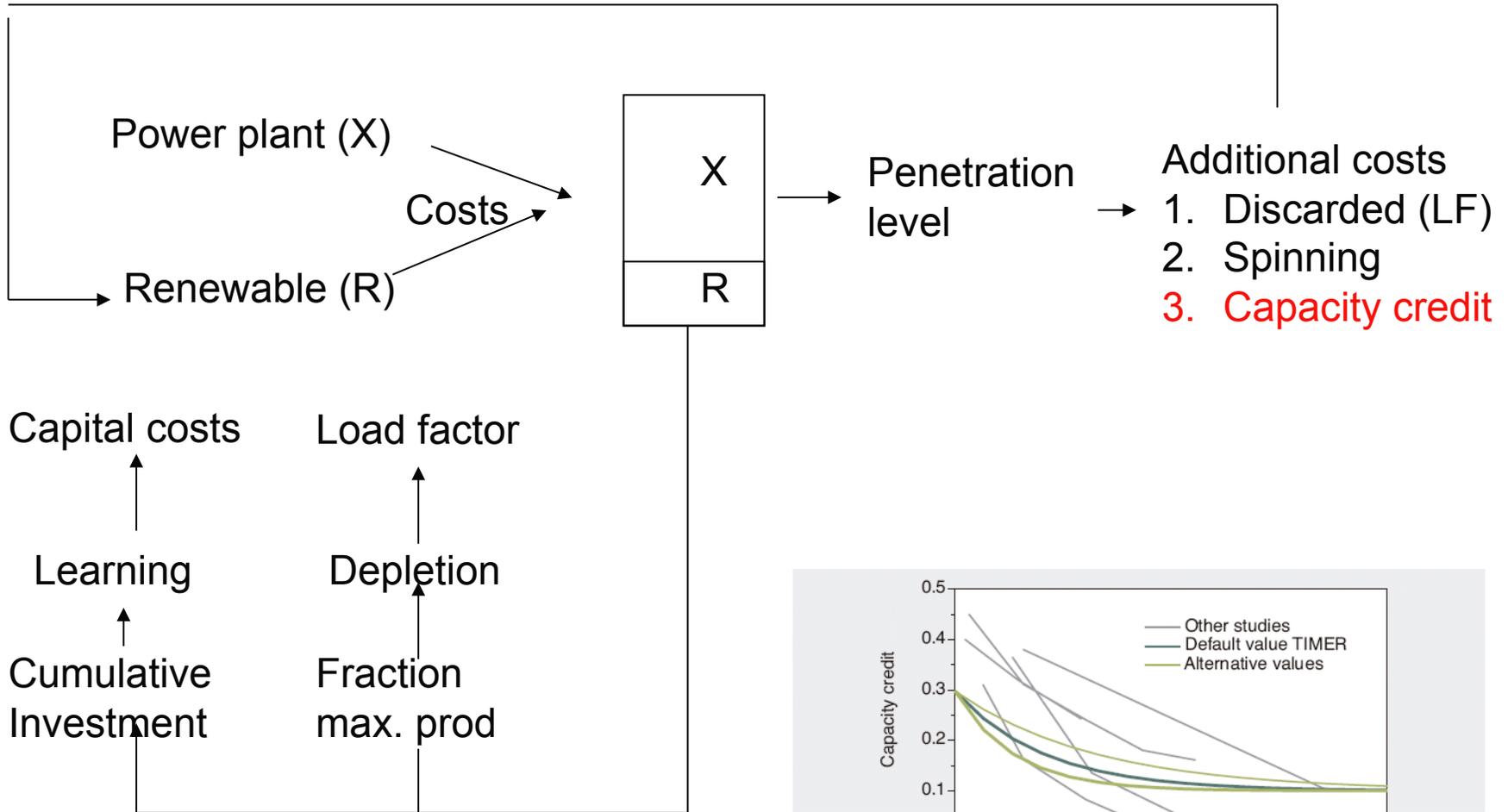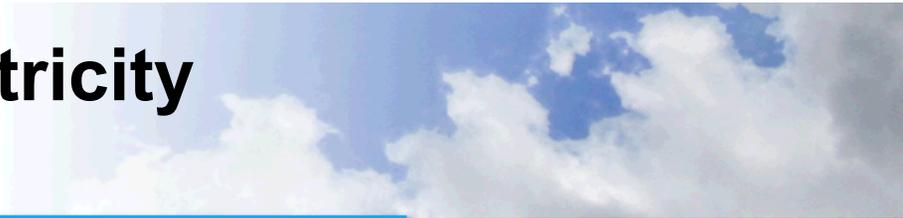
Fraction max. prod

Figure 2.7 Capacity credit assumed in TIMER compared to other studies. It should be noted that actual value at zero penetration depends on the load factor which is time / region dependent. Grey curves indicate relationships found in literature (Namovicz, 2003; Giebel, 2005)
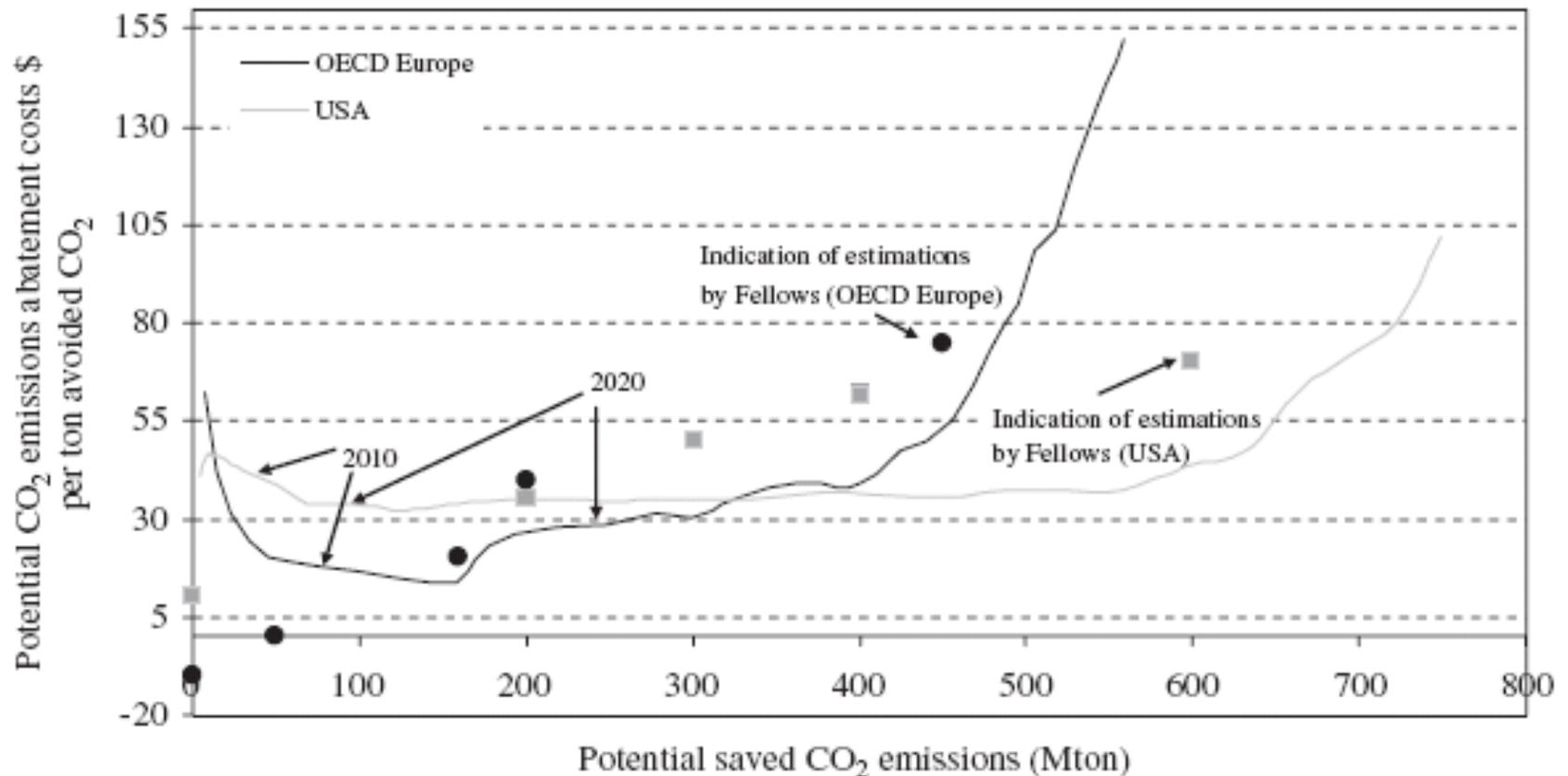
Cost increase for wind electricity

OECD Europe

Implementation may get expensive
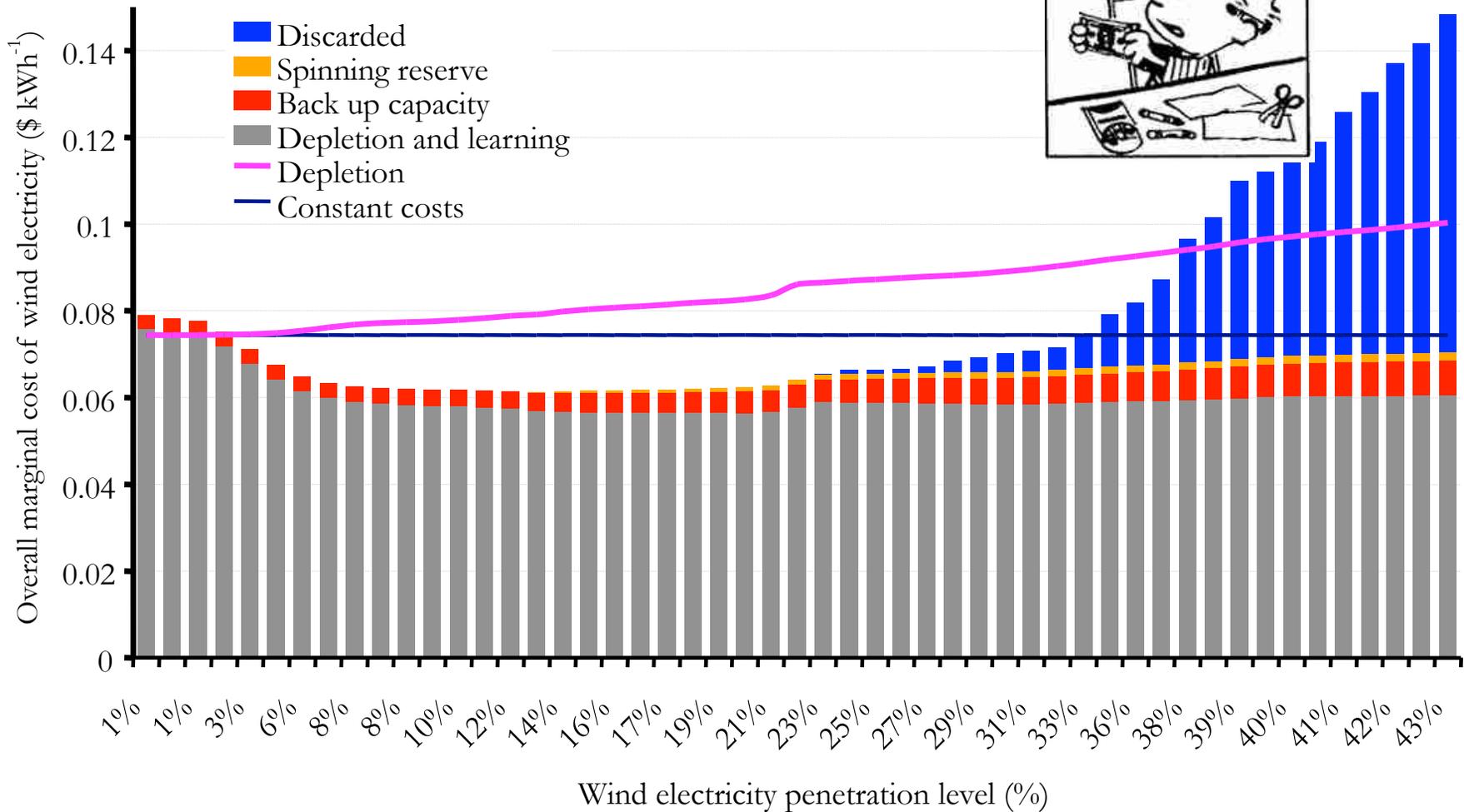
Hoogwijk, M., Van Vuuren, D. P., de Vries, B., and Turkenburg, W. (2007). "Exploring the impact on cost and electricity production of high penetration levels of intermittent electricity in OECD Europe and the USA, results for wind energy. " Energy Journal, 32, (8): 1381-1402.

Cost increase for wind electricity

→ Representation consistent with a more detailed study.

Hoogwijk, M., Van Vuuren, D. P., de Vries, B., and Turkenburg, W. (2007). "Exploring the impact on cost and electricity production of high penetration levels of intermittent electricity in OECD Europe and the USA, results for wind energy." Energy Journal, 32, (8): 1381-1402.
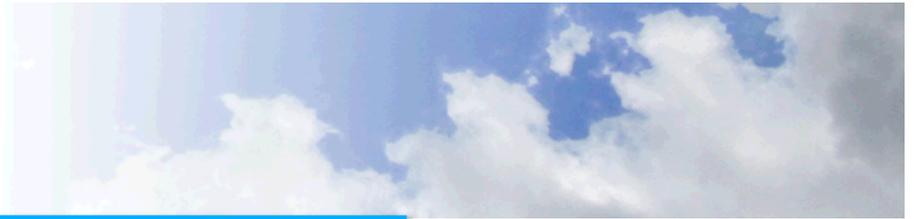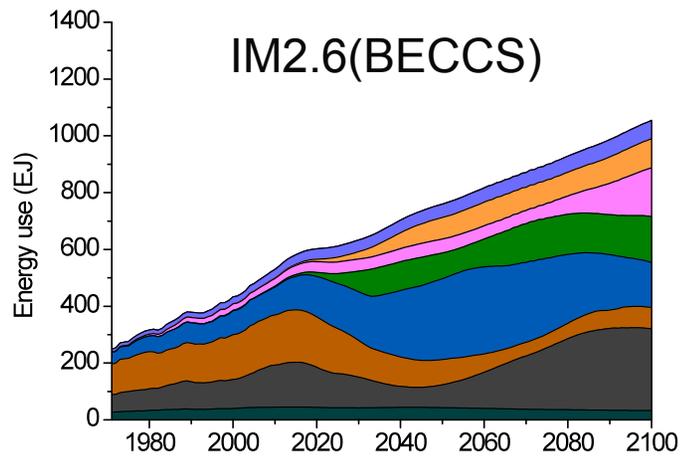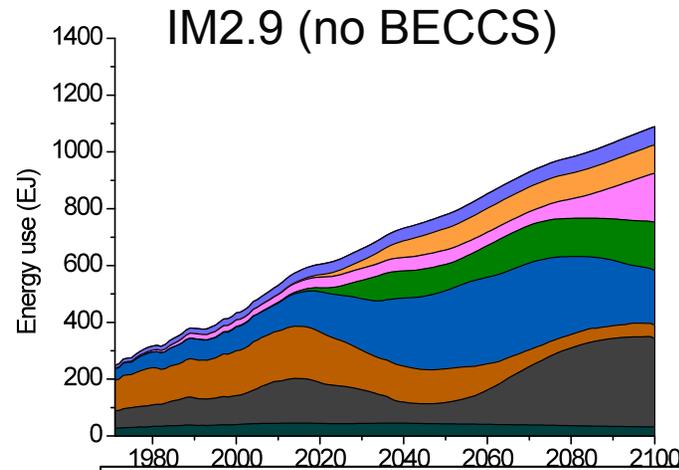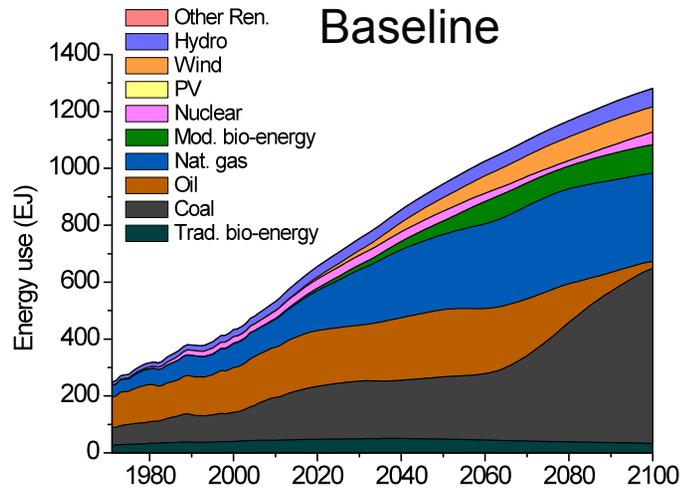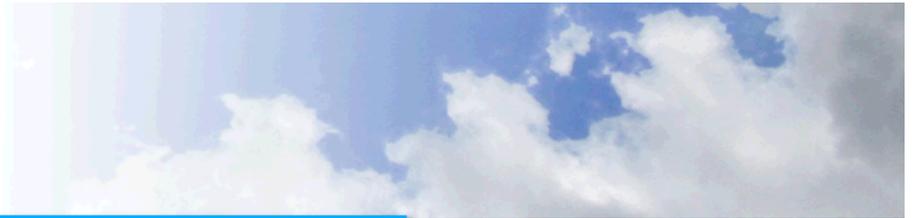
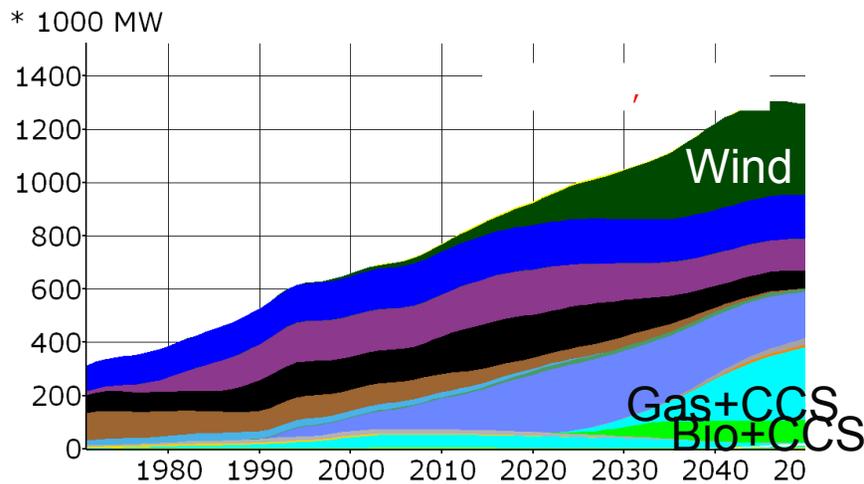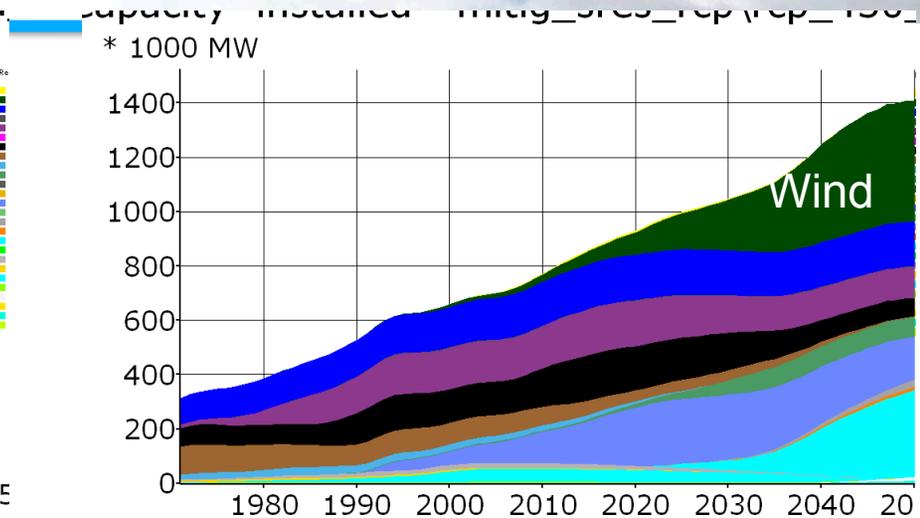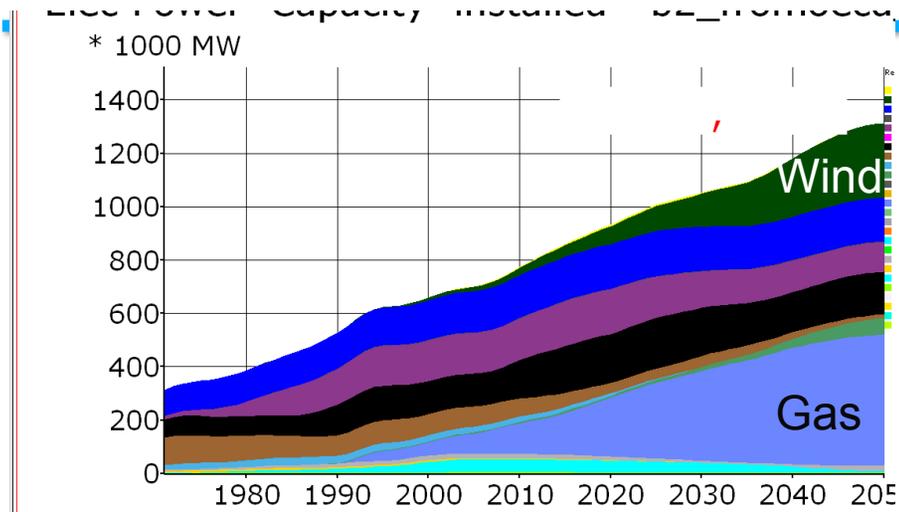There are clearly some questions open:

- Include SCP

- Better deal with storage?
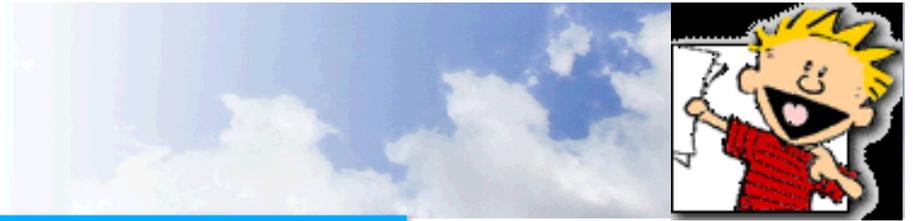
- Maybe better formulation of capacity credit

Renewables in RCP-3PD
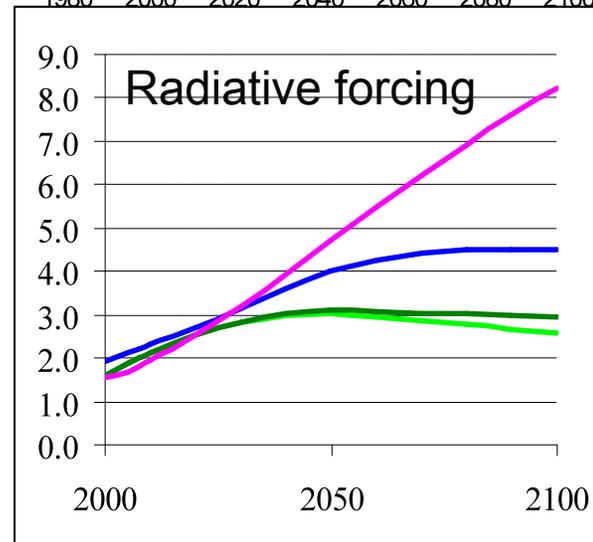
Zooming in on electricity sector (WEurope)

Thus…

➢ Detailed renewable representation in IMAGE in terms potentials / costs

➢ Penetration of renewables (somewhat depending on scenario) limited by "intermittancy" (interested in learning possible beter representation of overcoming obstracles

➢ CSS / Nuclear represent tough competition (depending on acceptability)

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