Water management: Trade-offs in water quality policy and the nexus

Environmental Economics in Practice – lecture 4

May 31, 2017, Vincent Linderhof

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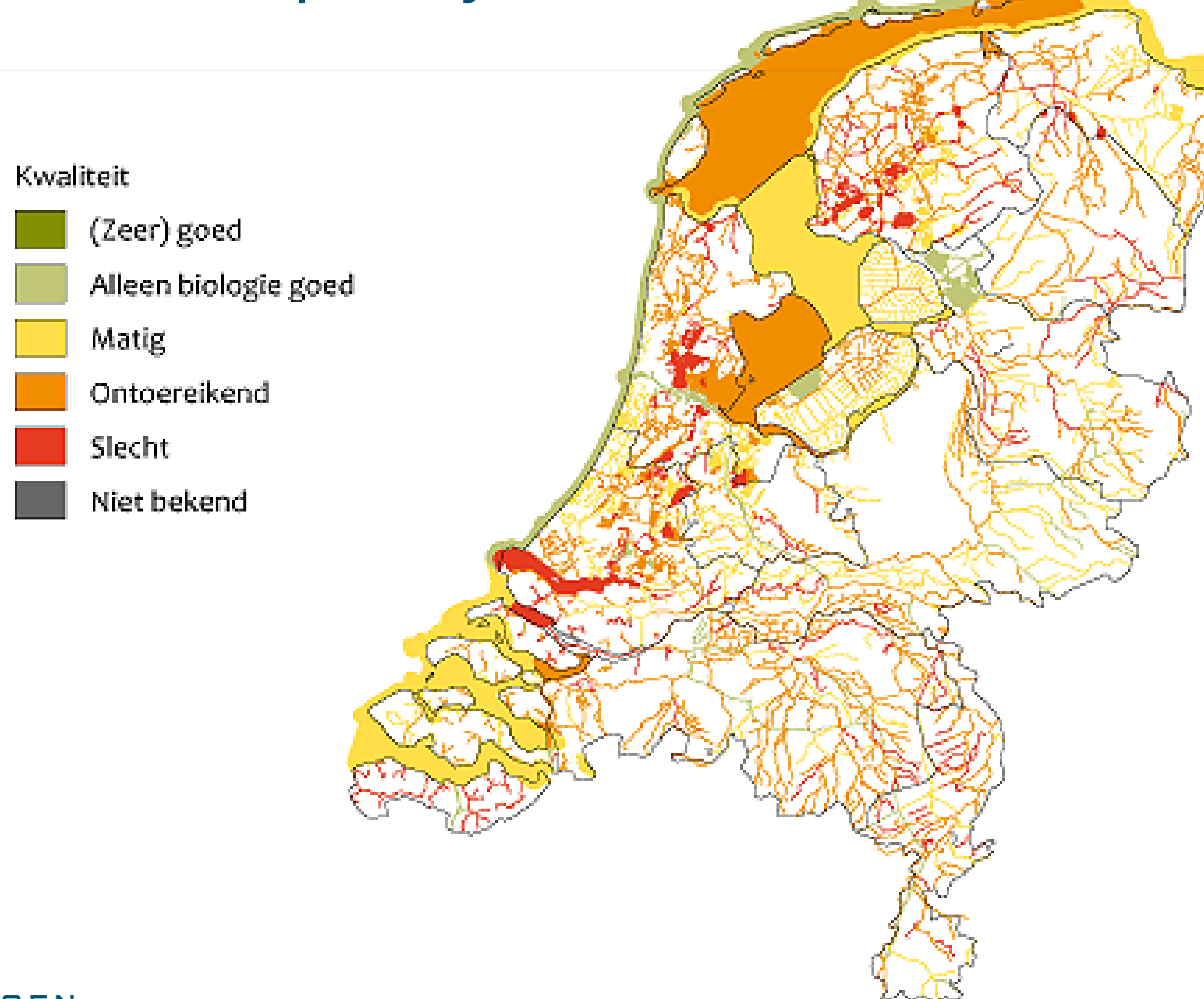
Outline

- Introduction
- Water Framework Directive (water quality)
- National economic models with hydrology
- Regional hydrological model for cost-effectiveness analysis
- Nexus: trade-offs in policy making
- Conclusions

Status of water quality



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Introduction – economy and water

Production and consumption affect water quality!

Contaminated water

Solutions =>cheapest solution?

Water Framework Directive (2000/60/EC)

- Water quality objectives: good ecological status in 2015, 2021, 2027 for ground water and surface water
- List of biological and chemical factors
- List of priority substances: revised as new problems occur such as medicine residues
- “One out”-”all out” criterion for each water body
- National vs. regional water system

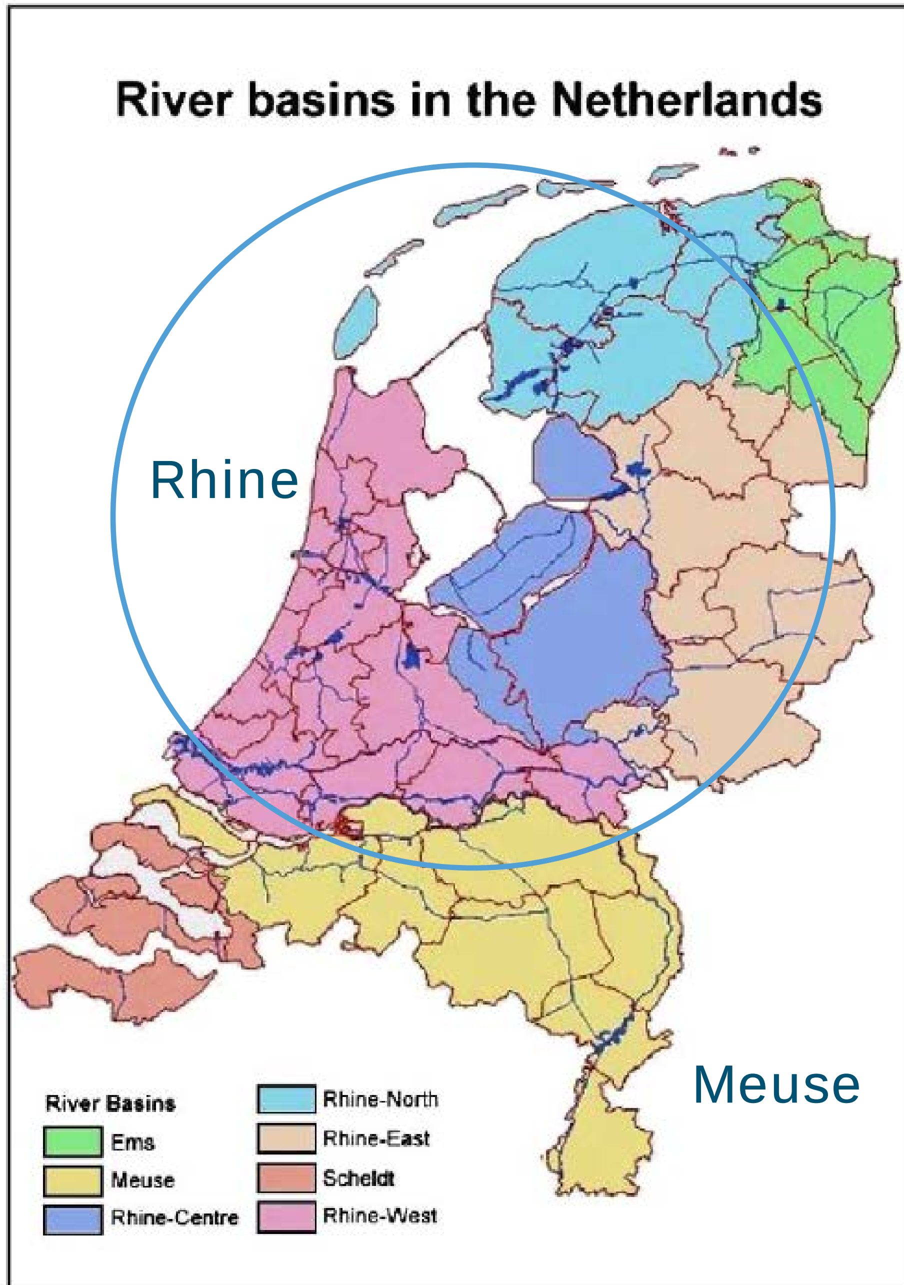
- Explicit economic analyses => impact on the economy (disproportional costs)

WFD – link with economics

- Article 5: economic analysis of water use
- Article 11&13: program of measures & RBMP
    - Article 5: cost-effectiveness analysis
- Article 9: cost recovery and pricing policies of water services
    - “polluter pays”-principle
    - production and distribution, collection and transport of waste water, waste water treatment, groundwater, water system management

River basins in NL

River basin management plans (RBMP)



Eems

Scheldt

Meuse

Fig. 5 – The Netherlands split up in the seven river basins distinguished in the WFD.

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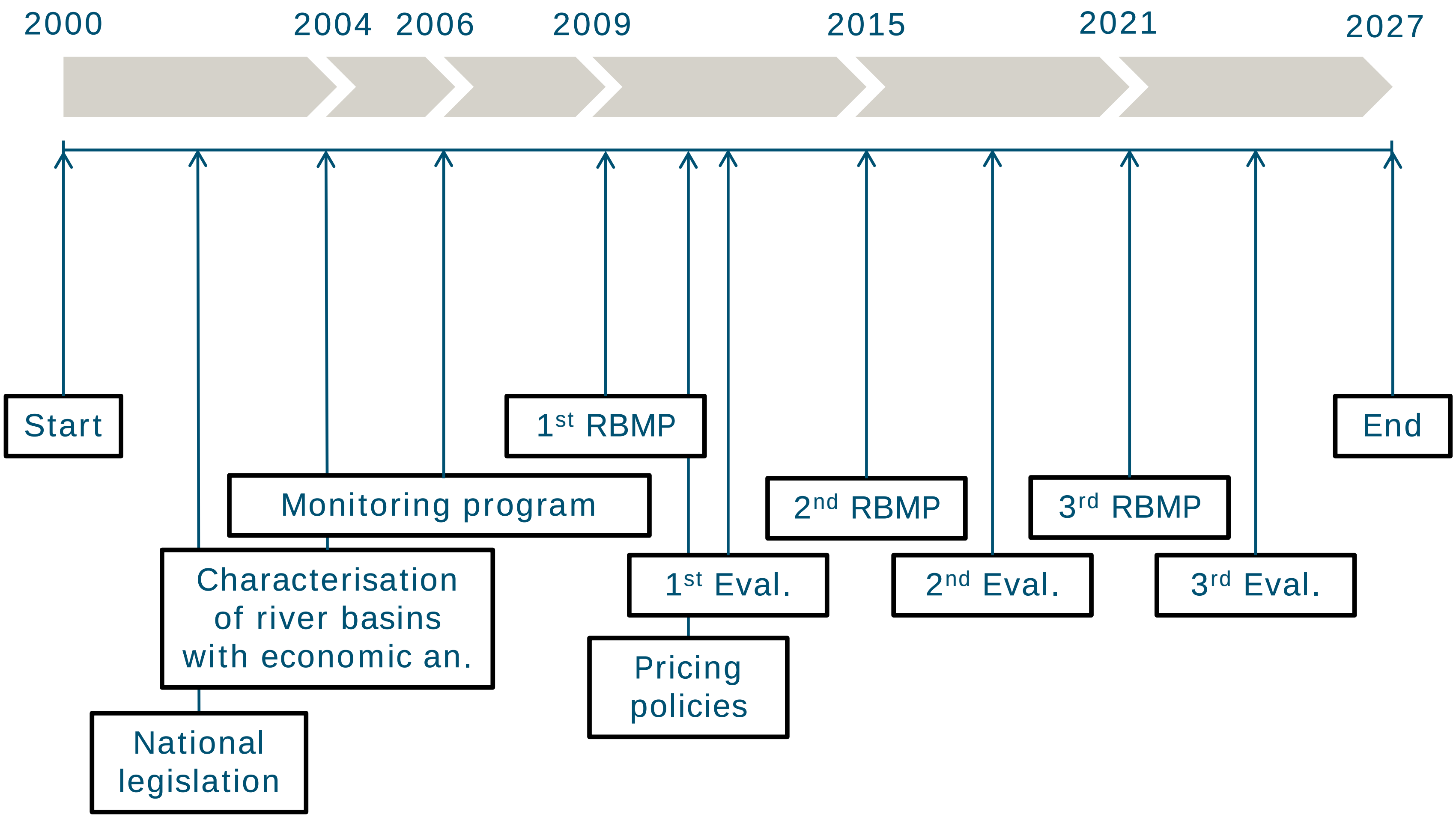
WFD – time line



Measures: fish passages

Measures: WWTP improvements

Measures: manure and natural banks

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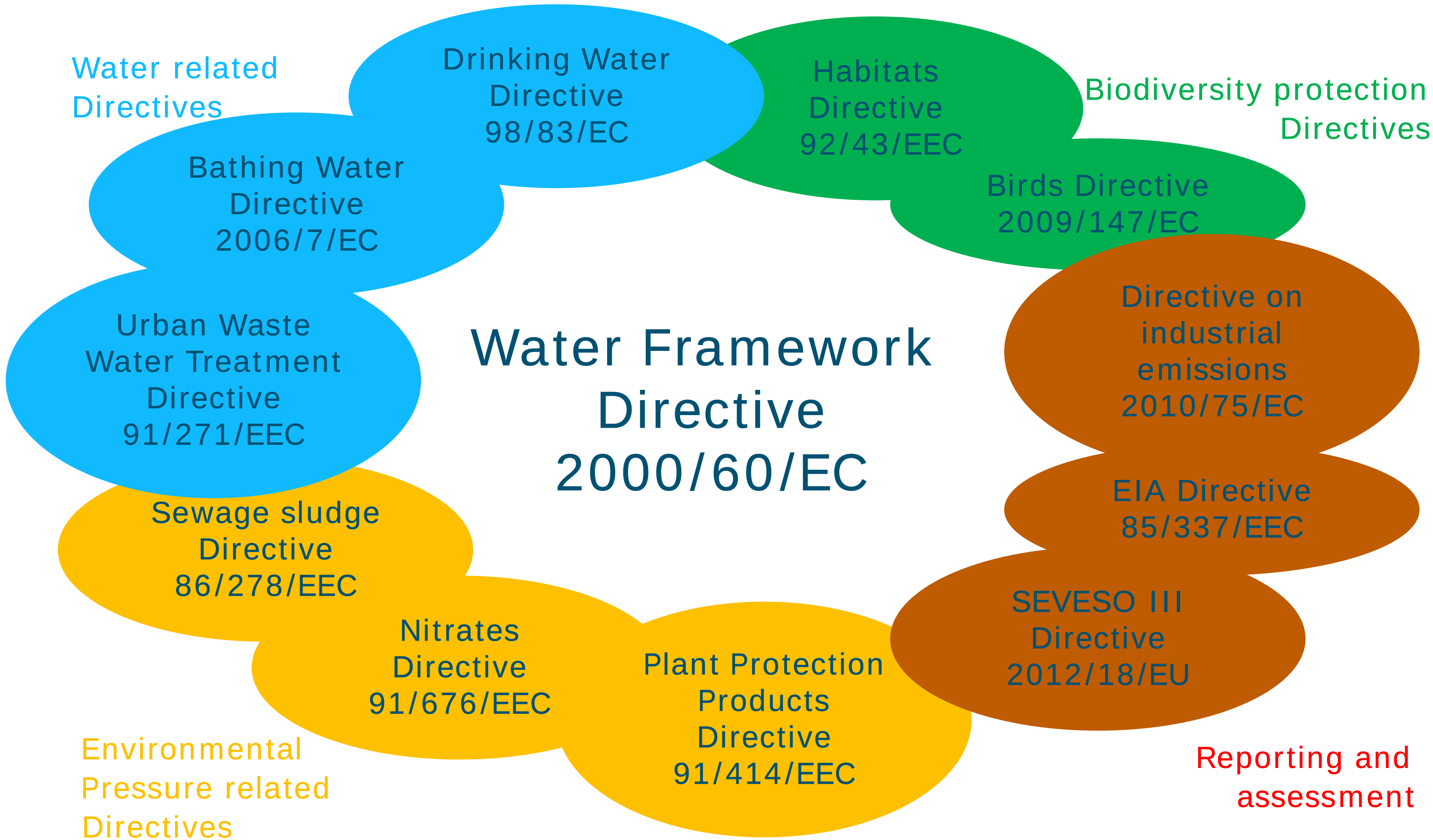
WFD – Link with other directives



WFD - Basic vs. supplementary measures

Compliance to UWWT Directive

Waste water treatment plant
municipality >2,000 inhabitants
until 2017

Basic measures in WFD

Part of baseline water use

Compliance to WFD Directive

Waste water treatment plant
municipality <2,000 inhabitants
after 2017

Supplementary measures in WFD

Part of cost-effectiveness analysis

Both are part of the River Basin Management Plan

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Water services in Dutch water system

Water "service"	Responsible organisation
Water safety	Water boards and National government
Production of tap water	Drinking water companies
Sewage system	Municipalities
WWTP	Water boards
Regional surface water system (quality & quantity)	Water boards/provinces
National water system (quality & quantity)	National government

- Cost recovery objective
- No environmental costs taken into account

Economic impact of WFD: two approaches

- How can we measure the economic impact of water quality policy?
- Hydro-economic models
  - National economic models (Brouwer et al., 2008; Dellink et al., 2011)
- Regional model with cost optimization
  - Hydrological model with costs and benefits (WFD regiOptimizer for N and P concentrations) Linderhof et al. (2010)

Hydro-economic model (Brouwer et al., 2008)

- Applied General Equilibrium model (static)
- Focus on water-related environmental themes (eutrophication and heavy metals)
- Sustainability standards to be met with
  - Abatement technologies (except for dehydration and soil contamination)
  - Emission permits
- Revenues of emission permits are recycled by either tax reduction or lump sum subsidies to households

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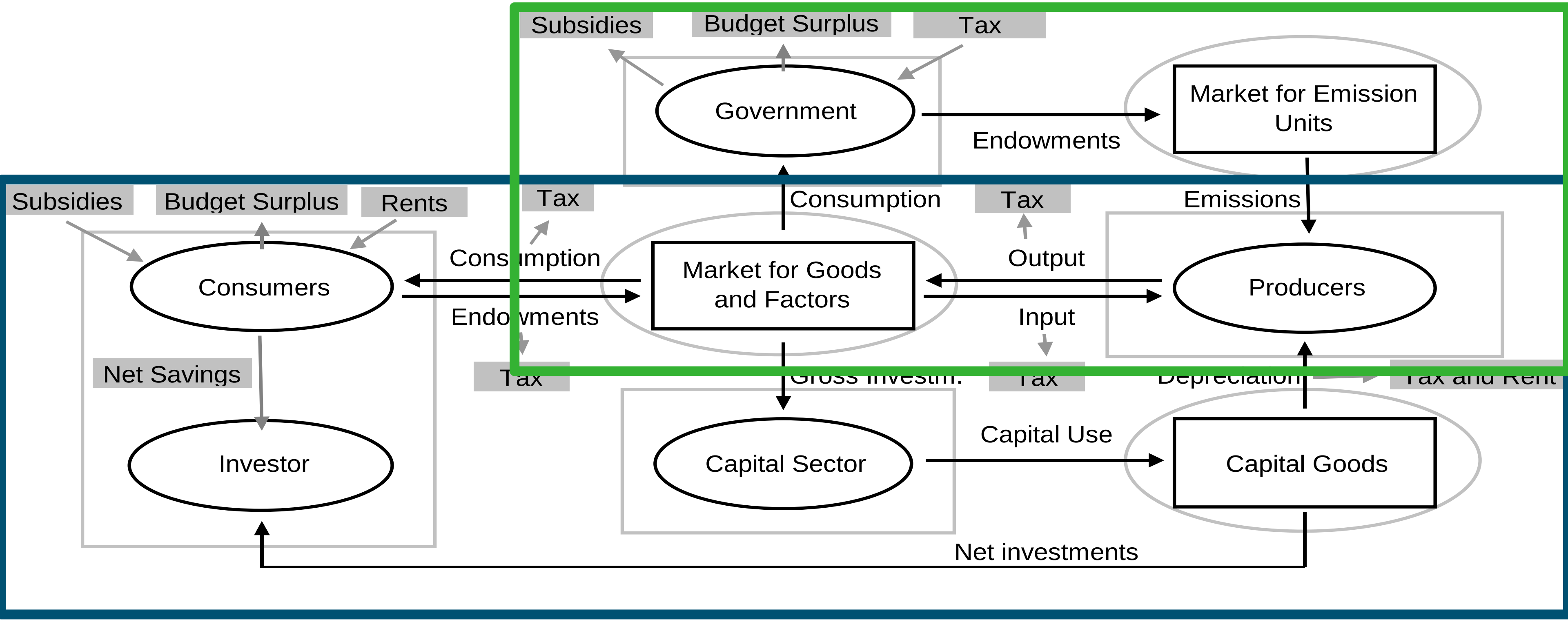
Hydro-economic model



Source: Gerlagh et al. (2002); Brouwer et al. (2008)

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Hydro-economic model: SAM

Table 1 – Social Accounting Matrix (SAM) and Net National Income in the Netherlands in 2000 (in billion euros)

	Primary sector	Secondary sector	Tertiary sector	Capital	Abatement	Trade balance	Net investments	Consumption	Endowments	Sum
Primary sector	18.4	−10.3	−0.9	−0.6	0.0	−4.5	0.0	−2.1	–	0
Secondary sector	−5.5	170.4	−52.5	−59.6	−0.1	0.9	0.0	−53.7	–	0
Tertiary sector	−2.8	−56.9	313.2	−23.1	−0.1	−10.7	0.0	−219.8	–	0
Capital	−3.1	−18.0	−40.1	91.4	0.0	0.0	−30.1	0.0	–	0
Abatement	0.0	−0.1	0.0	0.0	0.2	0.0	0.0	−0.1	–	0
Labour	−1.9	−41.6	−122.7	0.0	0.0	0.0	0.0	0.0	166.2	0
Profits	−4.6	−26.6	−59.4	0.0	0.0	0.0	0.0	0.0	90.6	0
Taxes	−0.5	−17.0	−37.7	−8.1	0.0	0.0	0.0	−20.0	83.3	0
Sum	0	0	0	0	0	−14.3	−30.1	−295.7	340.1	0

Source: Statistics Netherlands.

Table 3 – Emissions in the Netherlands in 2000

	Primary sector	Secondary sector	Tertiary sector	Consumption	Total
Eutrophication (million P-equivalents)	90.4	15.8	11.6	19.6	137.4
Dispersion of toxic substances (billion AETP-equivalents)	0.8	61.7	7.8	17.9	88.3

Source: Brouwer et al. (2008)

Hydro-economic model: abatement cost curves

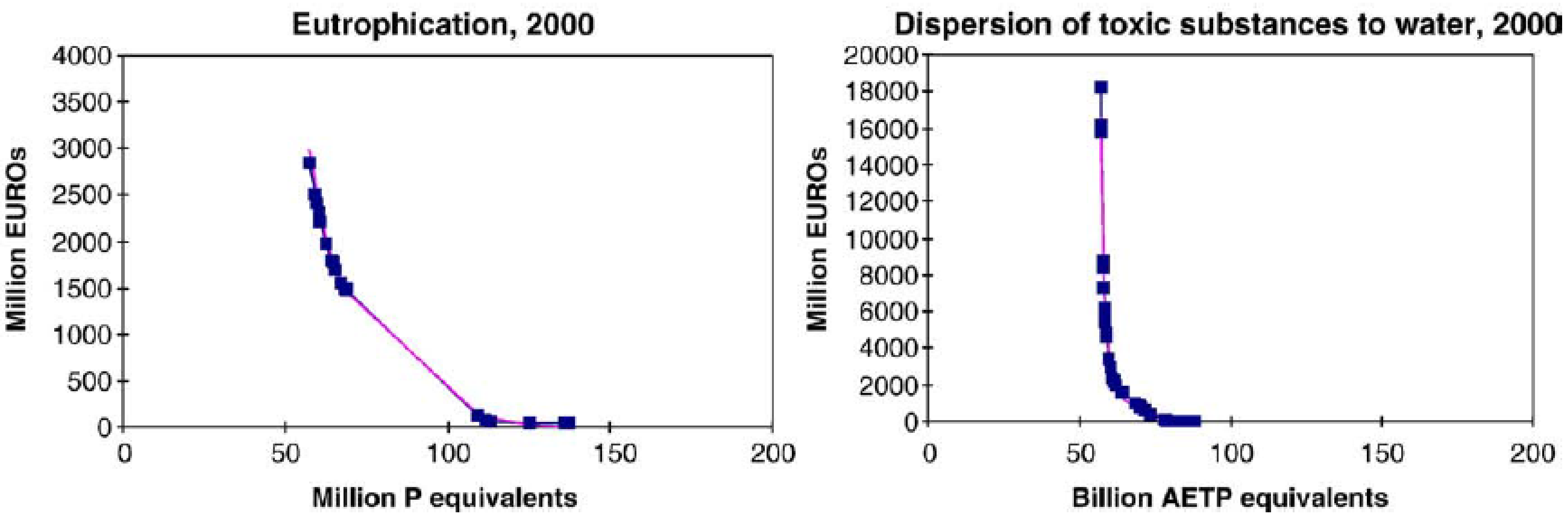

Fig. 2 – Estimated abatement cost curves for eutrophication and the dispersion of toxic substances to water.

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Hydro-economic model - results

Table 4 – The impact of the different emission reduction scenarios on Net National Income and their total economic cost (in billion euros; price level 2000)

Variant	Variant 1			Variant 2		
Emission reduction scenario	10%	20%	50%	10%	20%	50%
Net National Income	339.3	338.4	329.6	339.4	338.1	308.0
Loss in NNI compared to baseline	0.7	1.6	10.5	0.7	1.9	32.1
Relative change in NNI (%)	−0.2%	−0.5%	−3.1%	−0.2%	−0.6%	−9.4%

Unilateral

Dutch water policy:
goods with polluting
production more imported.

Multilateral

EU water policy:
polluting production
reduced.

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Static vs. dynamic hydro-economic model (Dellink et al., 2011)

- Not only two situations compared, but also the path from one to another
- The economic model is a forward-looking neo-classical growth model (based on DEAN, Dellink (2003))
- Emission reduction translated into reduction of nutrient concentrations

DEAN

Economic model → Emission to water (nutrients and toxic substances) → Hydrological model →

WFD explorer

From sector to river basin NAMWARiB Brouwer et al. (2005)

Results for phosphates in 2027

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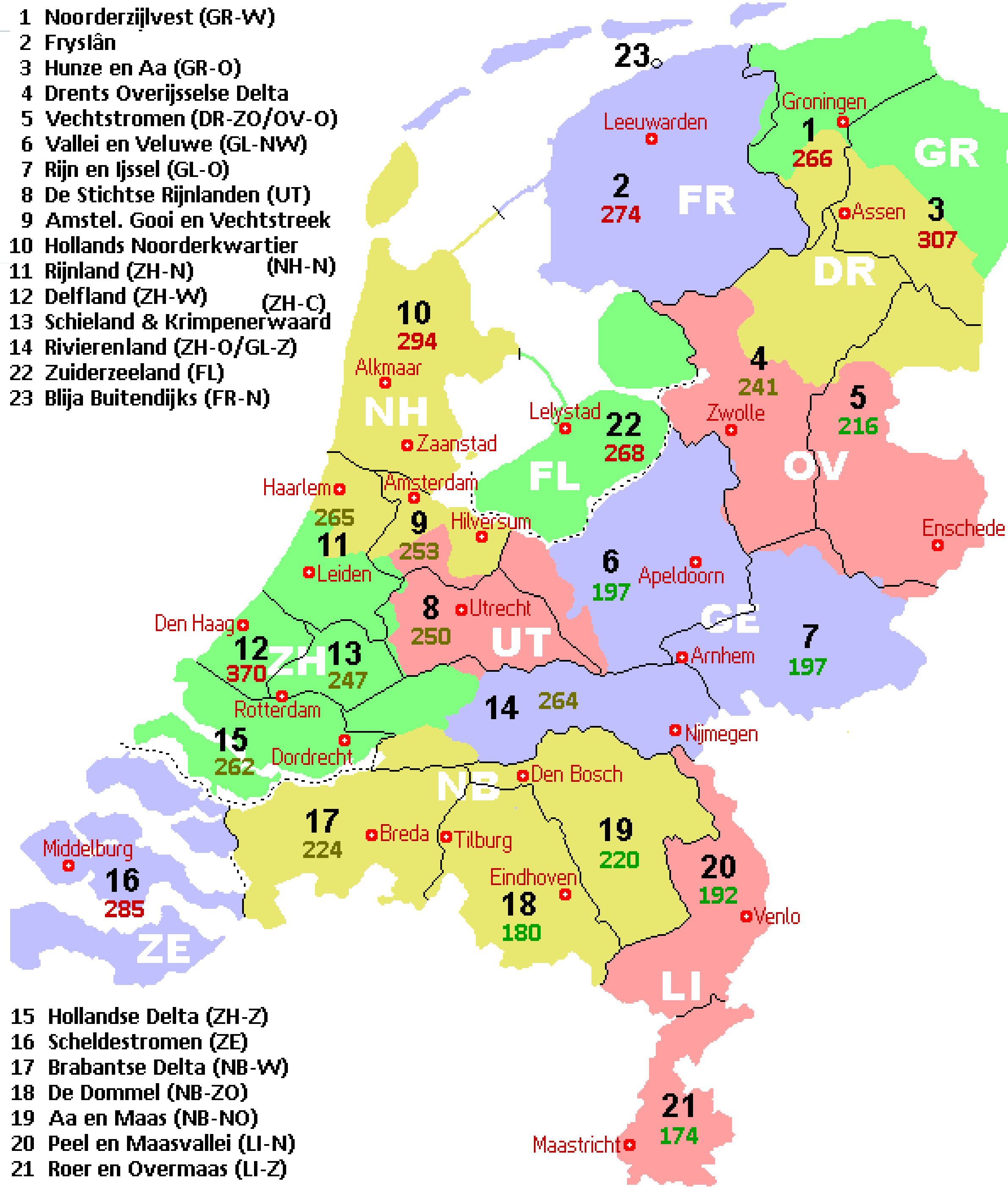
Economic assessment of WFD – National model

- Economic impact on different sectors
- Cost-effective measures including intra sectoral effects
- Based on emission reduction
- No biological or hydro-morphological measures taken into account
- Abatement cost curves rather inflexible
  - Not sector specific
  - No regional differences (or diffuse sources)

Regional model



1 Noorderzijlvest (GR-W)
2 Fryslân
3 Hunze en Aa (GR-O)
4 Drents Overijsselse Delta
5 Vechtstromen (DR-ZO/OV-O)
6 Vallei en Veluwe (GL-NW)
7 Rijn en Ijssel (GL-O)
8 De Stichtse Rijnlanden (UT)
9 Amstel. Gooi en Vechtstreek
10 Hollands Noorderkwartier (NH-N)
11 Rijnland (ZH-N)
12 Delfland (ZH-W)
13 Schieland & Krimpenerwaard (ZH-C)
14 Rivierenland (ZH-O/GL-Z)
22 Zuiderzeeland (FL)
23 Blija Buitendijks (FR-N)

15 Hollandse Delta (ZH-Z)
16 Scheldestromen (ZE)
17 Brabantse Delta (NB-W)
18 De Dommel (NB-ZO)
19 Aa en Maas (NB-NO)
20 Peel en Maasvallei (LI-N)
21 Roer en Overmaas (LI-Z)

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Hydrological model – CEA (Linderhof et al. 2010)

- Cost-effectiveness analysis: cost minimization of program of measures subject to water quality targets (concentration)
- Measures
  - Related to one or more substances (N and P)
  - Measures linked to water bodies (WWTP) or catchment areas (agriculture)
- Hydrological structure (WFD Explorer)
  - Water bodies (part of water system)
  - Catchment areas

Beerze-Reusel

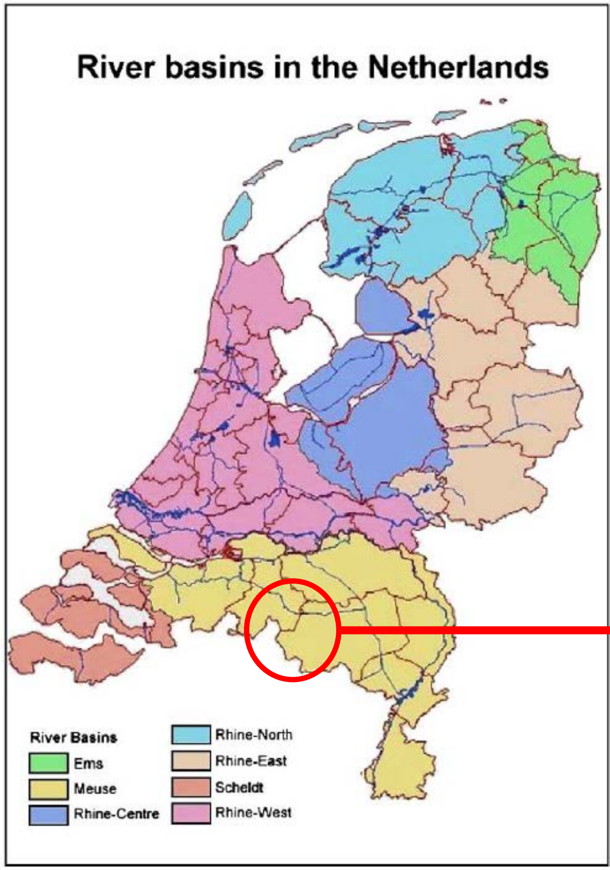
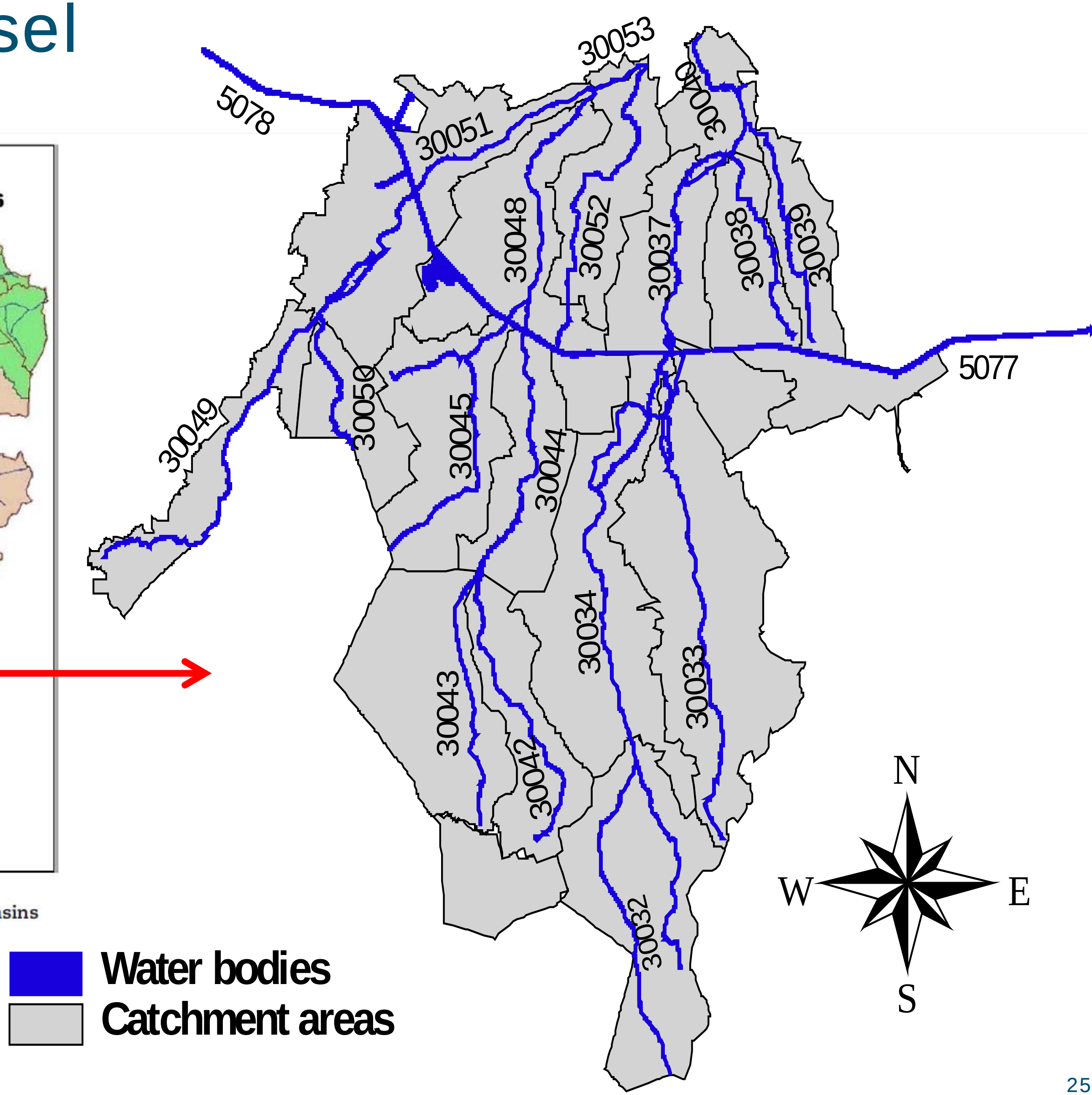
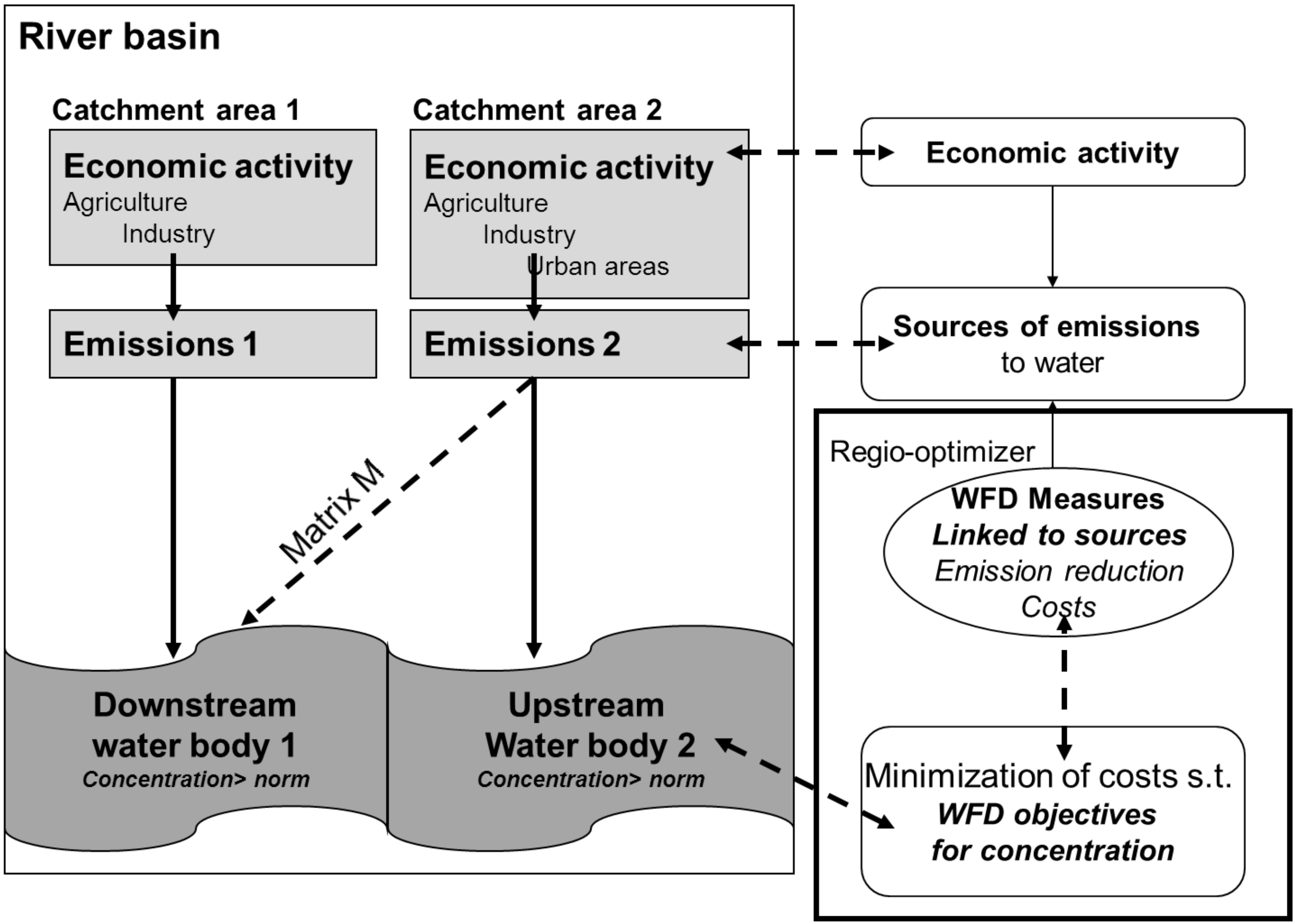


Fig. 5 – The Netherlands split up in the seven river basins distinguished in the WFD.



Structure



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Model

Minimize $\sum_{j \in J} \sum_{k \in K} X_{jk} C_{jk}$ (1)

Subject to

Emission levels: $E_{ks} = E_{ks}^{0} \left(\prod_{j \in J} 1 - \varepsilon_{jks} X_{jk} \right)$ (2)

Sum of emissions: $E_{is} = \sum_{k \in K} E_{ks} Y_{ik}$ for k and s (3)

Changes in water quality: $Q_{is} = Q_{is}^{0} \left[1 - \sum_{i' \in I} M_{ii's} \left(\frac{E_{i's}^{0} - E_{i's}}{E_{i's}^{0}} \right) \right]$ (4)

Water concentration target: $Q_{is} \leq \tau_{is}$ (5)

$0 \leq X_{jk} \leq 1$ (6)

i is water body/catchment area, *j is* measure; *k* is emission source, *s* is substance. *X* is implementation degree, *E* is Emissions, *Q* is Concentration, *C* is costs, *M* is transport matrix, and τ is target of concentration

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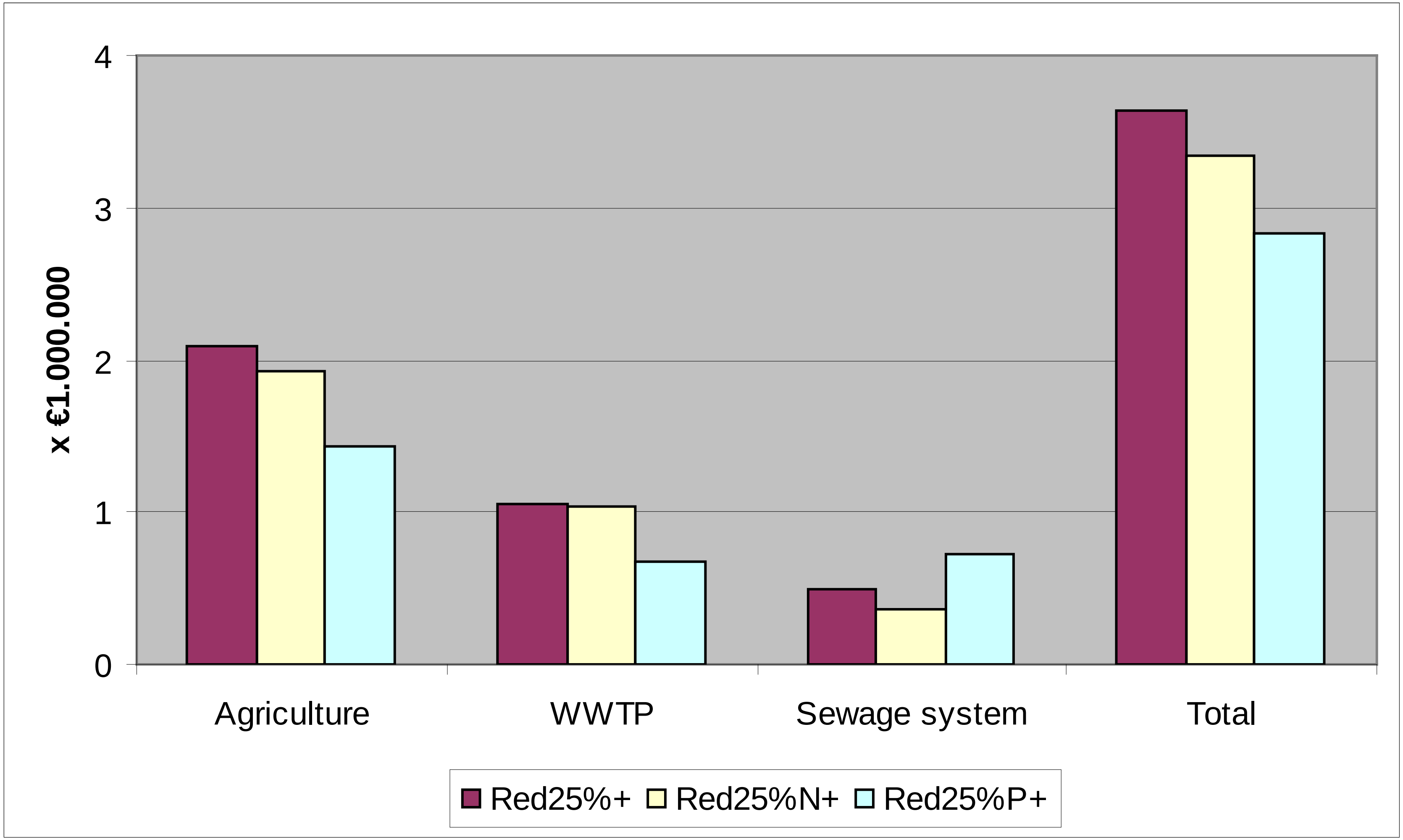
Program of measures

Type of measure	Emission reduction capacity (%)	Number of measures
Agriculture and atmospheric deposition (catchments)		
Manure free corridor	5	21
Buffer strips (crop free corridors) special crops	5	21
Crop free corridors with paths open for public	10	21
Buffer strips (crop free corridors) grassland	8	21
Buffer strip (crop free corridors) arable land	8	21
Helofytefilters with reed	5	21
Natural banks (5 meters wide)	5	21
Subtotal Agriculture		147
Upgrade of WWTP (four WWTP)		
Fourth stage of WWTP	90	4
Helofytefilters with reed (additional stage) *	5-8	4
Additional N-filters*	56-90	3
Additional chemicals to remove P emissions*	20-55	3
Additional P filters*	14-89	3
Subtotal WWTP		17
Sewer improvements (catchments)		
Separate sewage system for rain water	80	21
Sewer improvement: decoupling of stormwater overflow	50	21
Reconstruct stormwater overflow facilities	75	21
Sewer improvement: larger storage settling tanks	50	21
Sewer improvement: increasing the flowing of rain water	50	21
Subtotal Sewer		105
Total number of measures		269

Results



4
3
2
1
0
x €1.000.000
Agriculture
WWTP
Sewage system
Total
Red25%+
Red25%N+
Red25%P+

Economic assessment of WFD (regional model)

- Minimal costs for measures
- Based on nutrient concentration objectives
- Costs of measures for different sectors
- No intra-sectoral economic effects
- No biological or hydro-morphological measures taken into account
- Measures
    - Sector specific
    - Regional differences (or diffuse sources)

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Nexus: SIM4NEXUS (2016-2019)

- SIM4NEXUS aims to address knowledge and technology gaps and thereby facilitate the design of policies within the Nexus.

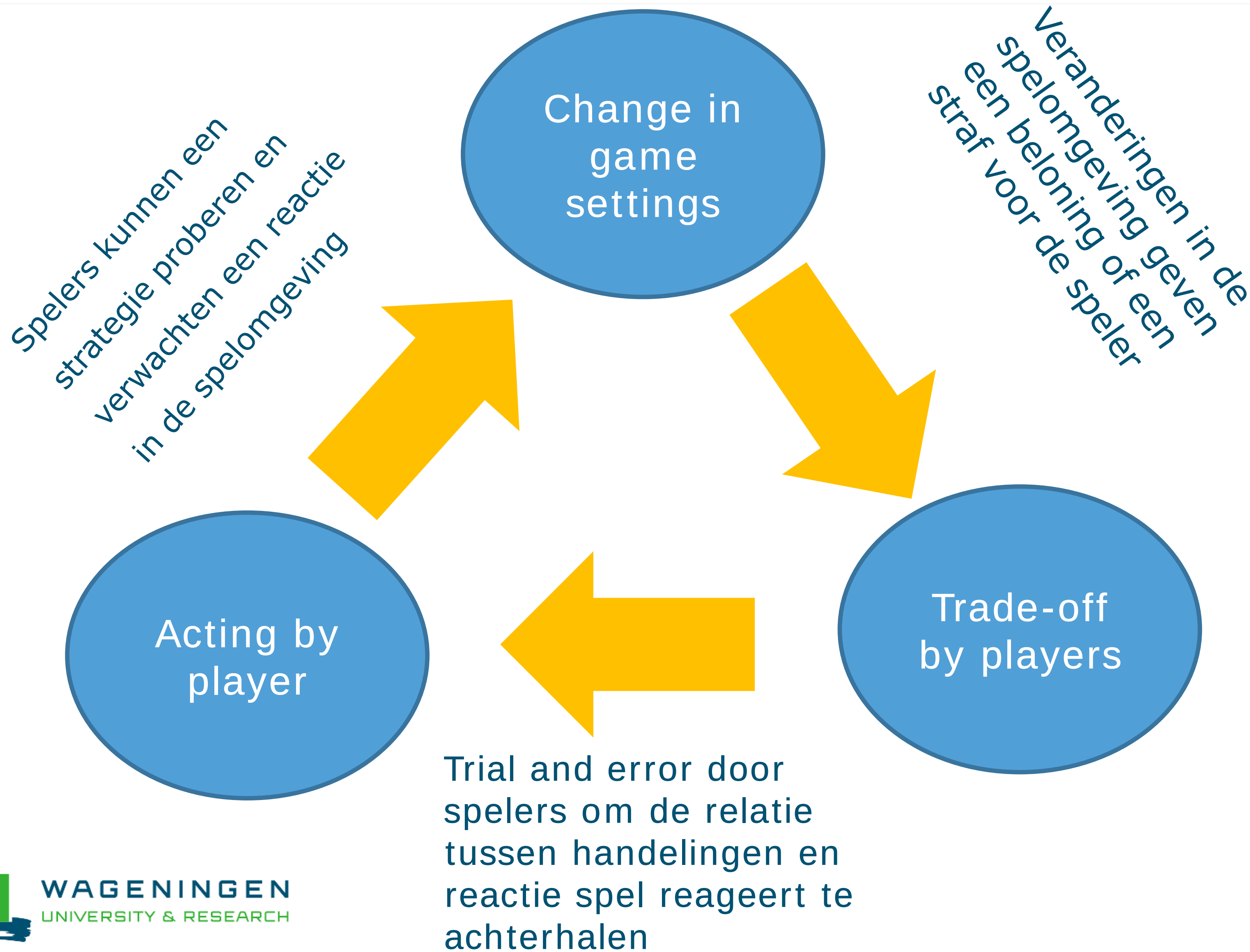
- The project will deliver a Serious Game, a cloud-based, integrated tool for testing and evaluating policy decisions.
- Why?
  - Trade-offs (multiple policy objectives)
  - Synergies

http://www.sim4nexus.eu

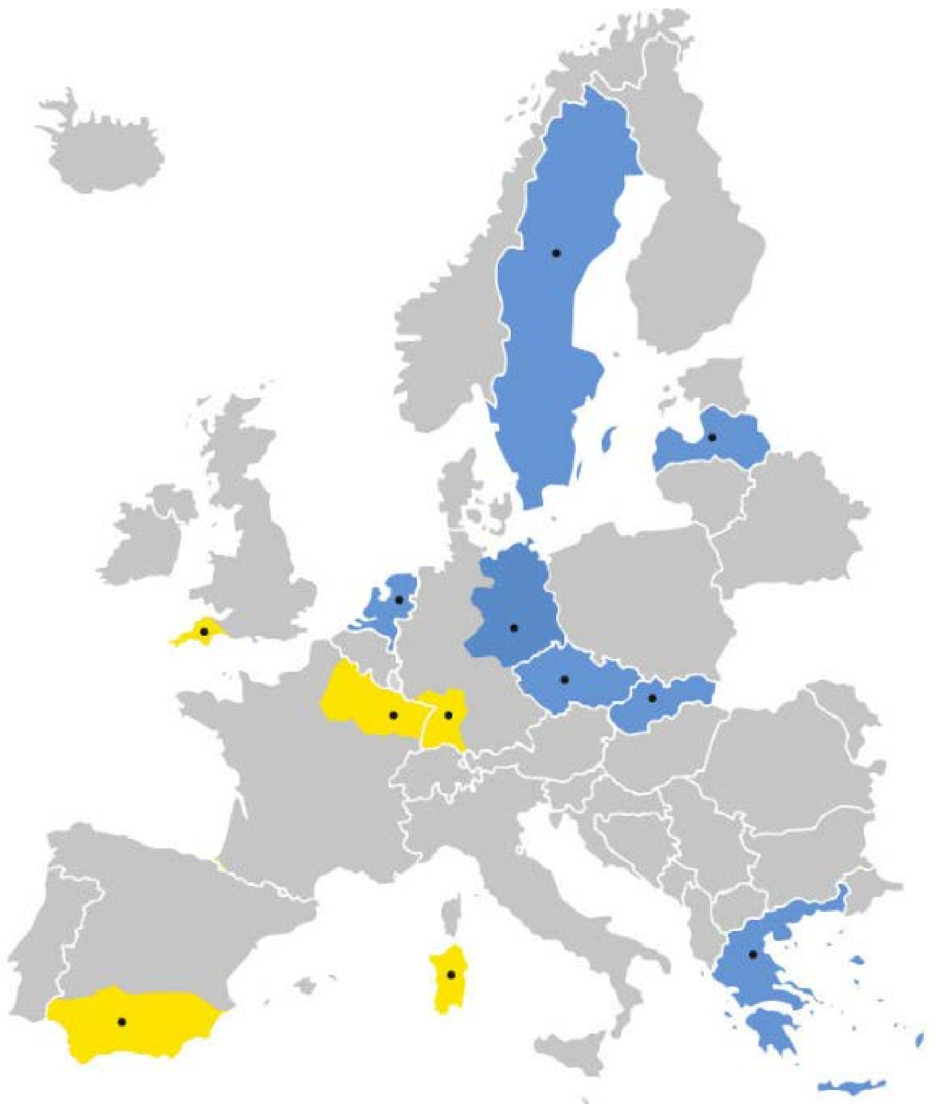
SIM4NEXUS (2016-2019)

- EU-funded project with national co-funding
- 25 partners (PBL, IHE, University of Exeter etc.)
- System dynamics approach (to model the complexity for the serious game)
- Use of results of thematic models (MAGNET, E3ME, CAPRI)
- Involvement of stakeholders

Serious game tool: learning by playing



Case-studies



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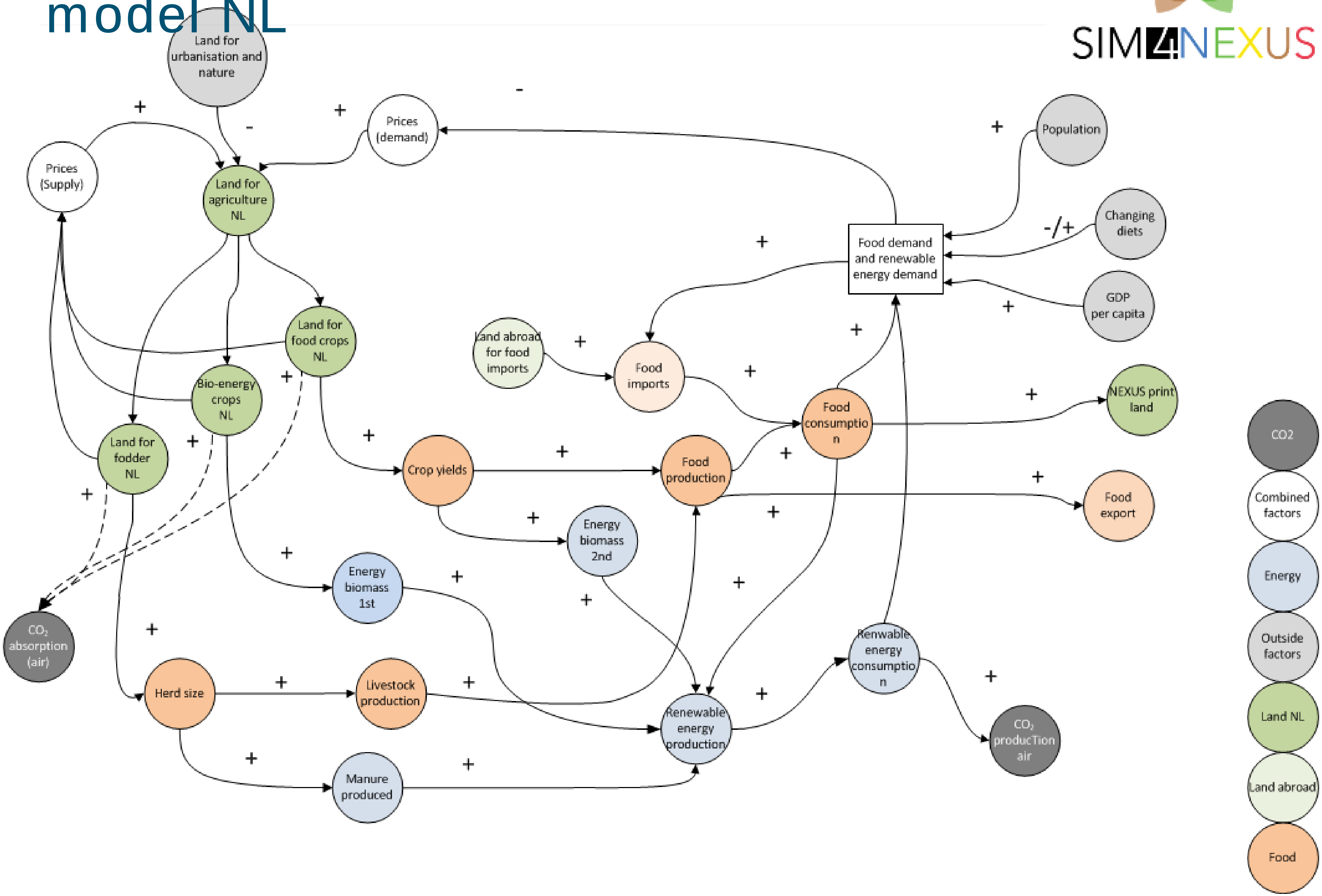
Dutch case study

How can we achieve a **low-carbon economy in 2050** for the Netherlands?

- What is the potential role of bio-energy in the achievement of a low-carbon economy in 2050 for the Netherlands?

Land is already a pressing factor in the Netherlands (high prices). Land can be used for carbon uptake (growing) biomass, which can be used to produce renewable energy (bio-energy crops, biogas from manure digestion, biomass).

Casual loop diagram: land use model NL



Low-carbon economy in NL in 2050

- Five technological options
  - Energy saving
  - Electrification of energy use
  - Use carbon neutral electricity as energy source
  - Energy from biomass
  - Carbon capture and storage (CCS)
- All options are necessary but to what extent?
  - Potential of options
  - Behaviour of actors
  - Policy instruments

Conclusions

- Water relates to many economic activities.
- Policy decisions more and more based on (economic) trade-offs!
- Hydrological models do not take into account economic changes due to interventions in the water system.
- Hydro-economic models can take into account economic aspects such as
  - Feed backs between economic sectors
  - Price changes (polluter pays principle)
  - Minimum cost for society of policies

End

Thank you for your attention!

More information:

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