How to achieve a low-carbon economy for the Netherlands in 2050? A System Dynamics model

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SIM4NEXUS QUALIFIES THE WATER-ENERGY-LAND-FOOD AND CLIMATE NEXUS FOR RESOURCE EFFICIENCY

Background

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.

Objective paper

To analyse effects of implementing market-based policy instruments on the implementation of mitigation options

Introduction

The Netherlands have agreed to develop towards a low-carbon economy in 2050, which implies that greenhouse gas emissions (GHG) are 80-95% lower compared to the 1990 level. In 2015, total GHG in the Netherlands were 200 $MtCO_2$-eq. per year, whereas the total GHG emissions declined as of 1990, the CO_2 emissions were more or less stable, see Figure 1. In absolute terms, the Netherlands needs to diminish their GHG emissions to a level of at least 44 Mt CO_2-eq. per year in 2050 (ECN and PBL 2015).

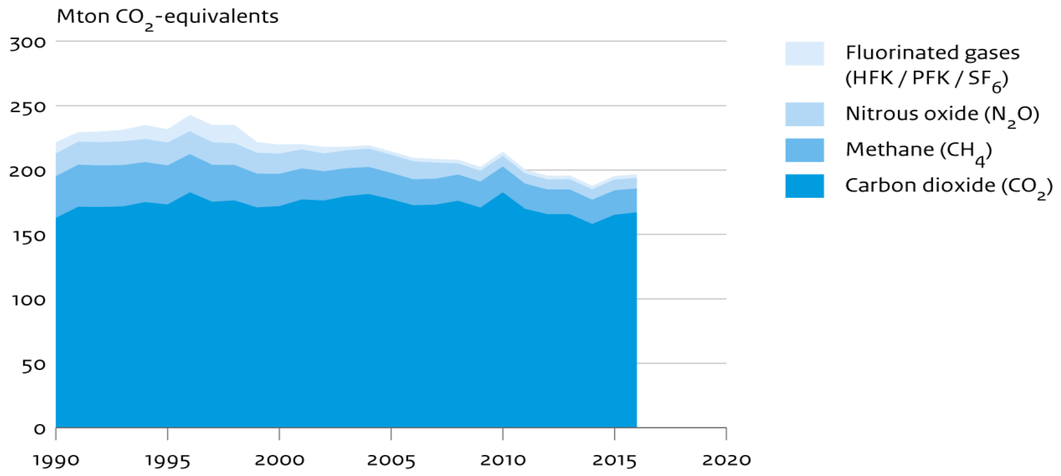

Figure 1. Greenhouse gas emissions development in the Netherlands 1990-2015 (CLO 2017)

Four main mitigation scenarios are discussed in the Netherlands, in addition to carbon levy:

- Production of CO_2-neutral electricity including bioenergy (RE scenario)
- Energy savings (ES scenario)
- Carbon Capture and Storage (CCS scenario)
- Electrification (implicitly included in CO_2-neutral electricity production)

Previous studies argued that all mitigation options will be required to achieve the low-carbon targets in 2050. However, policy instruments and behavioural changes were ignored. In all policy scenarios, we impose a carbon levy (on top of the relevant ETS price for carbon), affecting non-renewable energy only, and a subsidy on the relevant mitigation option given a neutral budget for the government.

Methods

We used a System Dynamic (SD) model which is top-down modelling approach to study complex behaviour in social sciences showing relationships between and within sub-systems. Our SD model includes the demographic economic system, the energy system and the environmental system of the Netherlands. Figure 2 shows the causal loop diagram of our SD model and its sub-models.

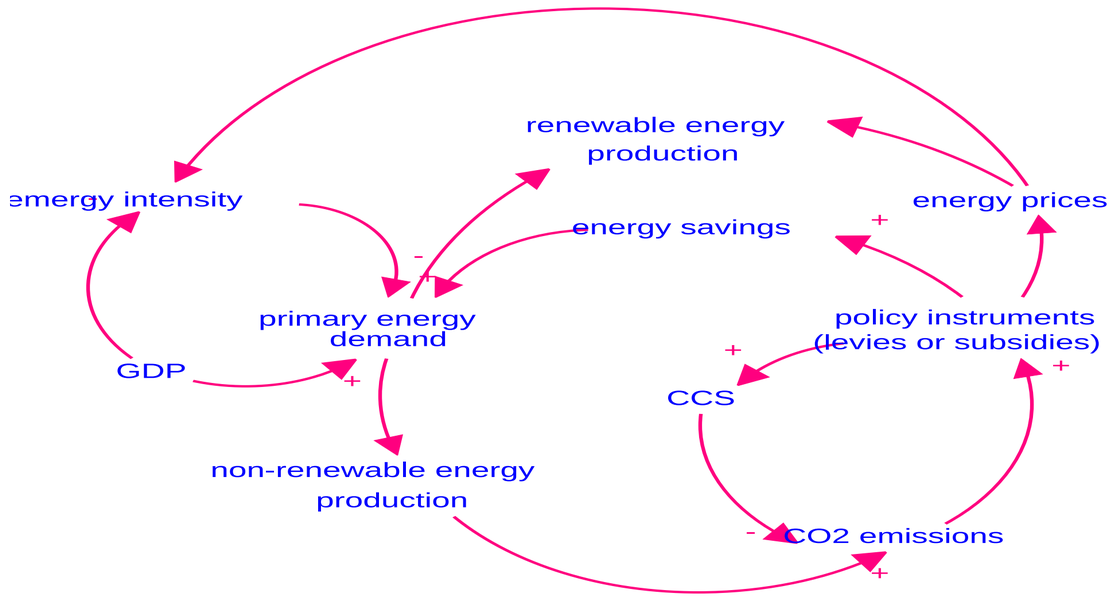

Figure 2. Causal loop diagram GHG mitigation

Data

Data of the model are derived from existing (policy) studies on carbon developments. The Business as Usual (BaU) scenario is comparable to reference scenario of the European Union for the development of GHG emissions in the Netherlands. Parameters are derived from the literature.

Results

In the BaU scenario, primary energy demand decreased from 69 Mtoe in 2015 to 59.5 Mtoe in 2050. Autonomous energy savings were included similar to the reference scenario of the EU. In all policy scenarios, the low-carbon target (34 Mt CO_2-eq.) was required, see table 1.

- The carbon levy is the major driver of the transition towards renewable energy production due to high price and cross-price elasticities of renewable energy demand.
- The carbon levy is the lowest in the RE scenario (subsidy on renewable energy production), while share of RE is the highest. Energy savings and CCS are relatively expensive and require high subsidies for implementation.

Table 1. Simulation results in 2050 for policy scenarios (* accumulated over 2021 to 2050); Integrated policies scenario is based on 80% of subsidy amount to RE, 10% to ES and 10% to CCS)

Year 2050 Scenario	Primary energy demand (ktoe)	Share RE of total PED (%)	Annual emission ($MtCO_2$)	RE production (ktoe)	Carbon levy per ton CO_2 (€)	Acc.* subsidy amount (€ bln)
BaU	59,538	26.2	114	15,594	-	-
RE	59,370	78.8	34	46,190	4.75	9.6
ES	59,117	77.8	34	45,993	11.00	22.8
CCS	59,182	72.2	34	42,751	10.20	22.1
IP	59,349	77.4	34	45,910	5.30	10.7

Conclusions

- Market based policy instruments are potentially helpful with the implementation of mitigation options for GHG emission reduction.
- The scenario for subsidizing renewable energy showed the lowest carbon levy on top of the ETS price.
- For future research, land use and water boundaries for the transition towards a low-carbon economy will be taken into account.

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