Quantification and modeling for successful energy policy

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Abu Dhabi
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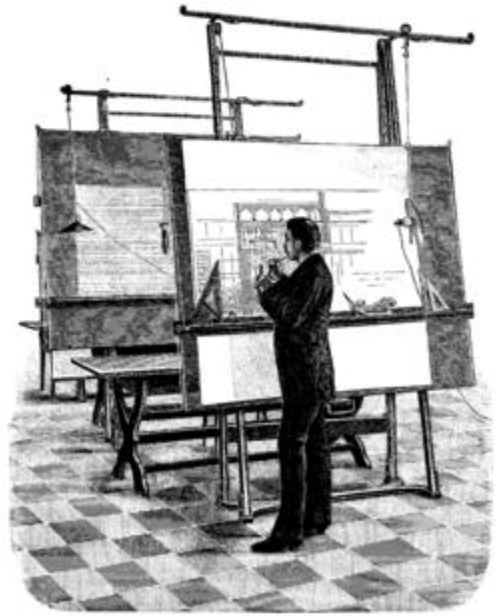
Modeling as part of a succesful energy strategy

ECN

- Introduction – how can modeling help energy policy?
- Some theory on modeling and model types used for policy support
- Examples of how energy models are used in Dutch policy practice
  - Including data requirements , uncertainties & handling
- Building an integrated energy modeling toolbox



How can modeling support policy?

- Energy transition is a complex process that relates to virtually all aspects of society
- Many options that *could* be part of succesful transition strategy
  - Each with specific pros and cons
- Potentials, developments & costs are uncertain and situational
- Many interactions and interdependencies
- Interventions already needed

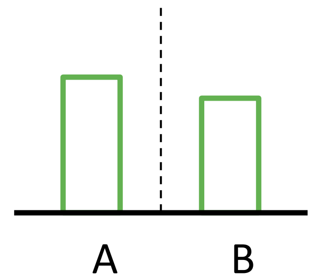
Decisions with potentially big impact under big uncertainty

→ How to achieve a transition towards a sustainable energy system without causing major disruptions in society or the economy?

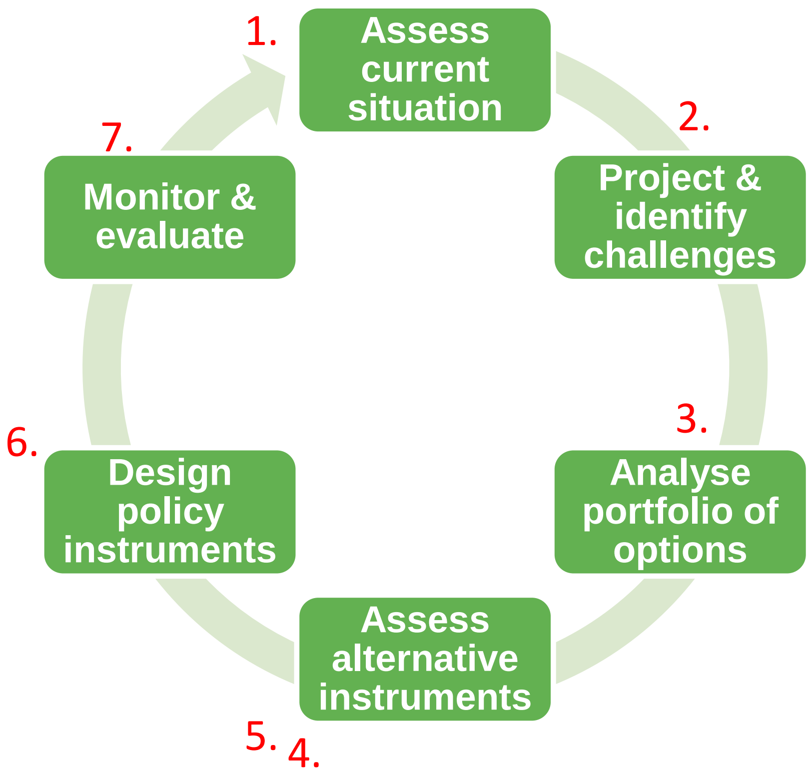
How can modeling support policy?

- Models allow quantification of policy dilemmas: numbers
- Models allow comparison of alternative options
- Models help to improve understanding consequences of interventions
- Informed decisions lead to higher chance of 'good' outcome

20.2 MEGATONS



General steps in policy 'cycle'



1. Where are we now? / Where are we headed?
2. Where do we want to get?
3. What roads could we travel to get where we want?
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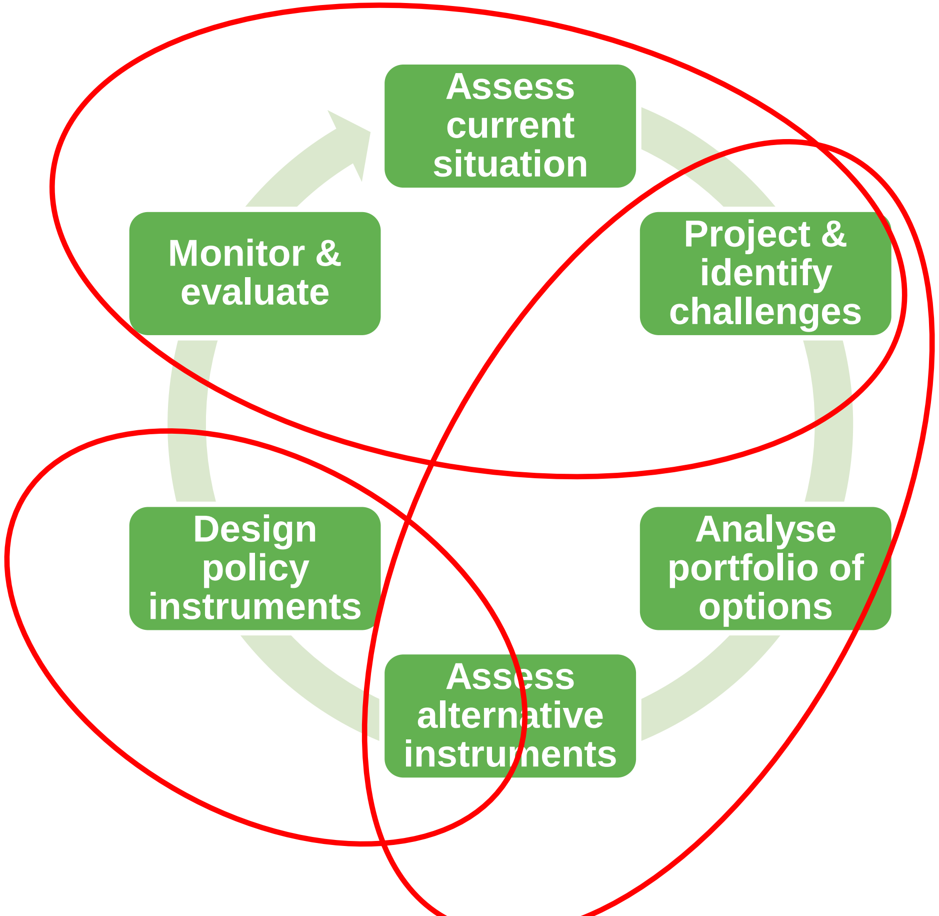
5. What policy instruments can be used?
6. How can we make the instrument most effective / efficient?
7. Does it do what we intended?

Examples from Dutch policy practice



- Models for policy assessment, monitoring and evaluation
  - National energy outlook modeling system
- Models for developing long term climate strategies (INDCs)
  - OPERA
- Specific tools for policy implementation
  - Renewable energy feed in policy

Questions that models can answer

Models supporting policy assessment, monitoring and evaluation

- What impact will policy X have in sector Y?
- Where is energy system headed given expected developments in markets and policy?
- How much is being earned, paid and invested, how many jobs?

Models supporting energy strategy

- What are appropriate targets for greenhouse gas reduction given national circumstances?
- What technology portfolio can achieve deep decarbonization in 2050 against lowest societal costs?

Specific tools for policy implementation

- What subsidy levels should we set to stimulate investment in renewable energy, or energy efficiency technologies , but avoid ‘overstimulation’?

Some modeling theory

Scenario models

- Image of one of multiple possible trajectories towards a future state of the energy system

→ There are multiple possible approaches and a wide range of possible outputs

- Scenarios should
  - Capture the most important mechanisms and interactions correctly
  - Elucidate the most important uncertainties

Scenario typologies

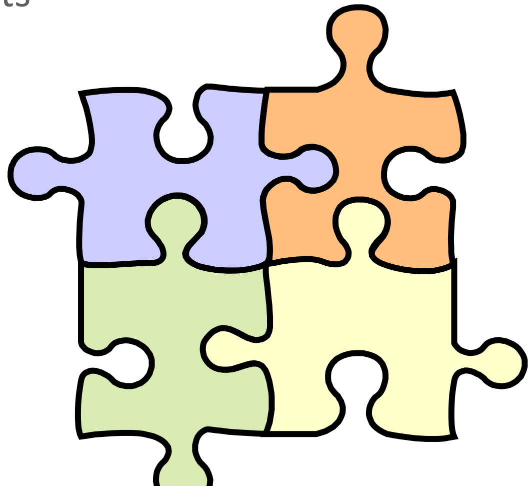
- Scenarios may take the present (projections) or the target year (backcasting) as starting point for design
  - How will things look like in the the future given certain set of assumptions?
  - What would be needed to achieve a future with specific characteristics (eg -80% GHG)?

- Scenarios may be constructed following known trends (Business as usual), or may explore possible deviations (normative or explorative scenarios)
  - What if everything develops as it always has done?
  - What if things develop like we have agreed to / want to?
  - What if things develop in a specific way?

- Scenarios are not accurate descriptions of future events – and don't need to! —they are guides for a territory that no one has yet seen

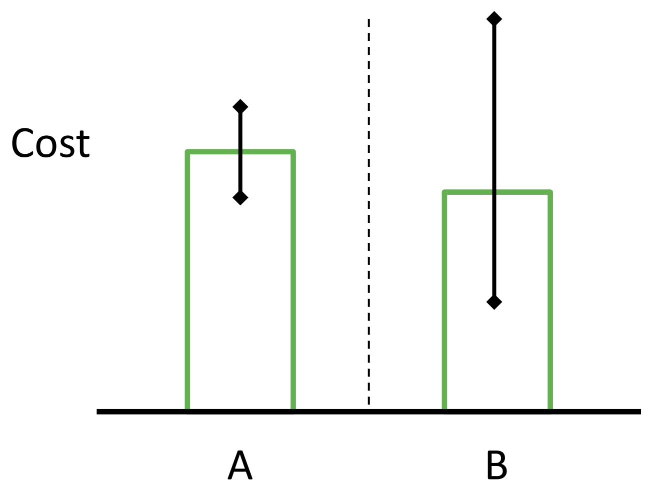
Integrated vs partial models

- Integrated energy models simulate the complex interactions within energy system
  - Most useful for overall national energy strategies, e.g. RE, EE or GHG targets
- Partial models simulate e.g. one sector only
  - Usually allow for more specific peculiarities of the particular sector
  - Useful for assessment of specific policy instruments



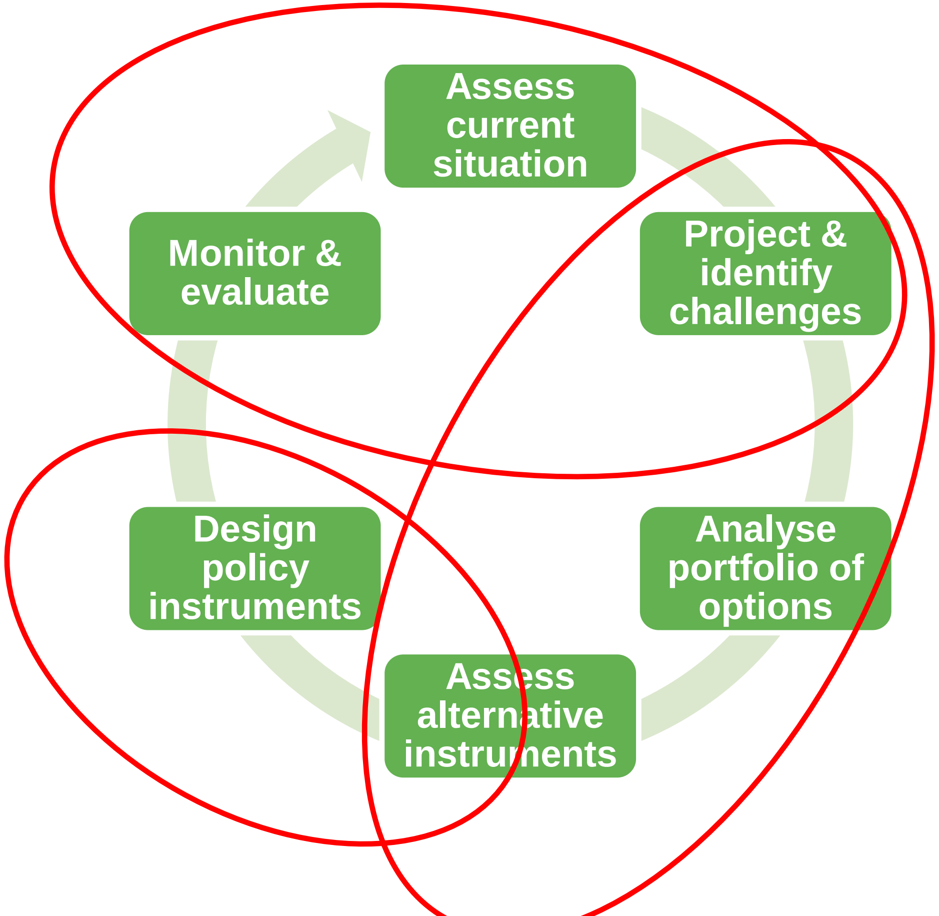
Data and uncertainties

- Garbage in is garbage out
- All models have uncertainties – be aware of them!



Examples of how energy models are used in Dutch policy practice

Examples from Dutch policy practice



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Models for Monitoring, assessment and evaluation

Supporting the energy agreement negotiations

- 40 parties → many different stakes
- Negotiating process over several months,
- More and less ambitieus propositions on the table for a wide range of topics
- Models helped to quantify various of these stakes
  - Energy & climate impacts, costs / benefits involved, jobs created
- Models help to limit ambiguity in definitions

National Energy Outlook (NEO)

- Goal
  - Providing a factual, complete, integrally consistent, quantitative overview of the current state of affairs of and future expectations for the Dutch energy system, embedded in the developments in the surrounding world

- Use
  - Data for reporting obligations
  - Observed distances to targets mark areas for increased policy attention
  - Reference baseline for policy assessments

  - Set of up-to-date energy models available for additional analyses

Methodology

PAST developments

- National energy balance (detailed sector level energy statistics)

↔

FUTURE developments

- National energy outlook modeling system (detailed sector level projections)

- Other statistics, other developments, analyses,
- interpretation, description

Data and cooperation

- Statistics Netherlands (CBS)
  - Detailed energy statistics, economic statistics
- Netherlands Enterprise agency (RVO.nl)
  - Interface of private sector activities and policy
- Netherlands environmental assessment agency (PBL)
  - Strategic policy analysis, interpretation, modeling
- Energy research Centre of the Netherlands (ECN)
  - Strategic policy analysis, interpretation, modeling, NEOMS

ECN

NEO modeling system

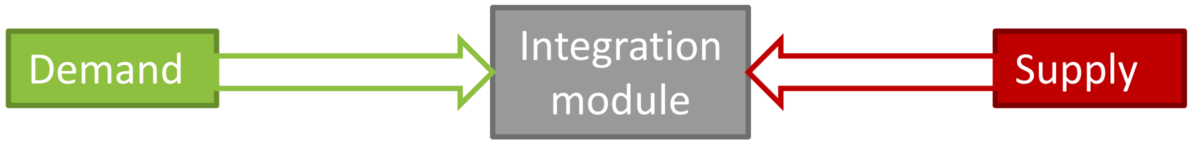
- Integrated modeling system with balanced supply and demand throughout the economy

- Long standing history, first component since 1982
  - In integrated form since mid 1990's
  - 'Living' model – continuously evolving

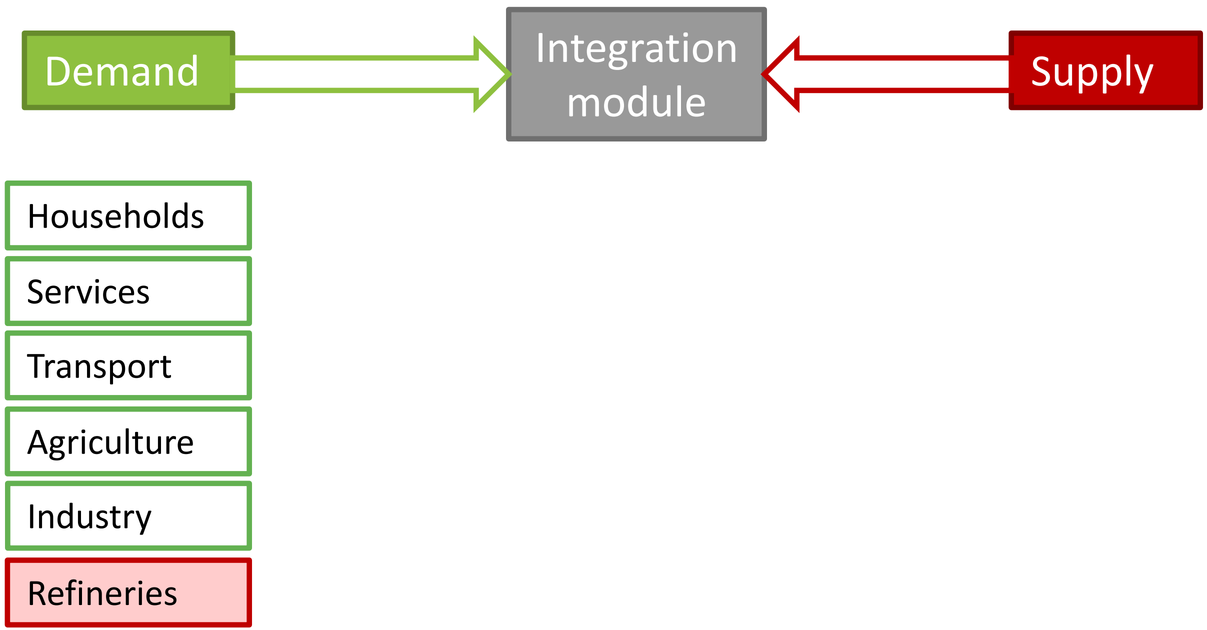
- Set of ~15 interconnected models for sectoral developments
  - Each model simulates developments in part of the energy system
  - Interconnections lead to internally consistent energy balance

- Consistent set of economic driving forces
  - (demography, economic growth, resource prices)

NEO modeling system



NEO modeling system



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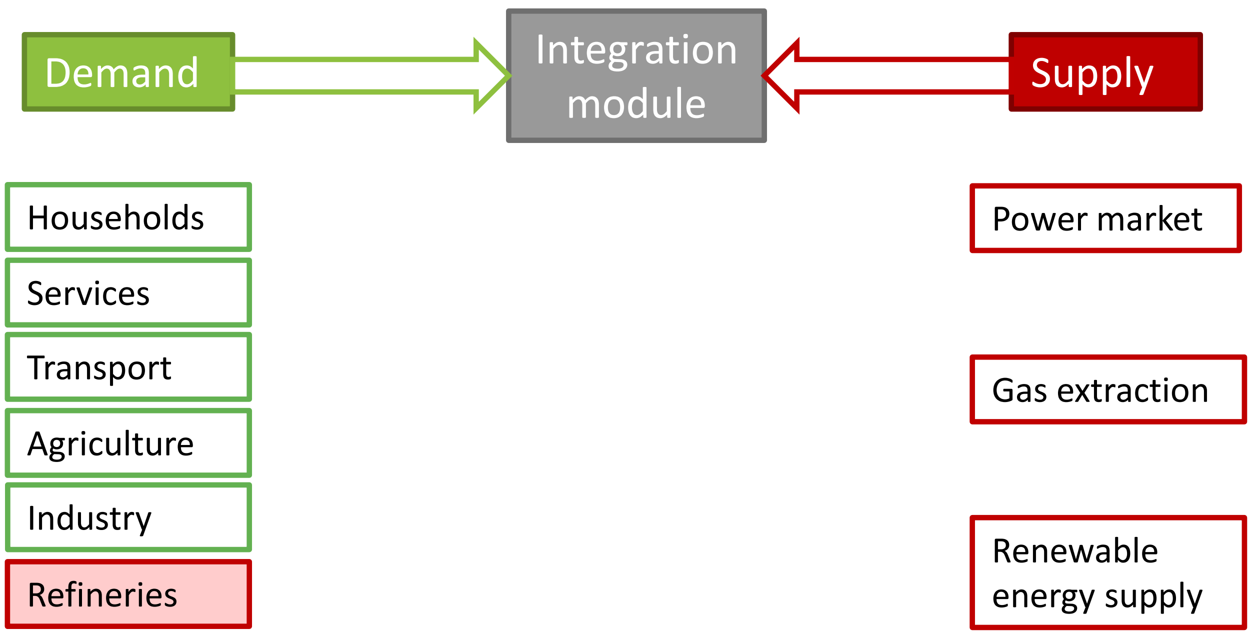

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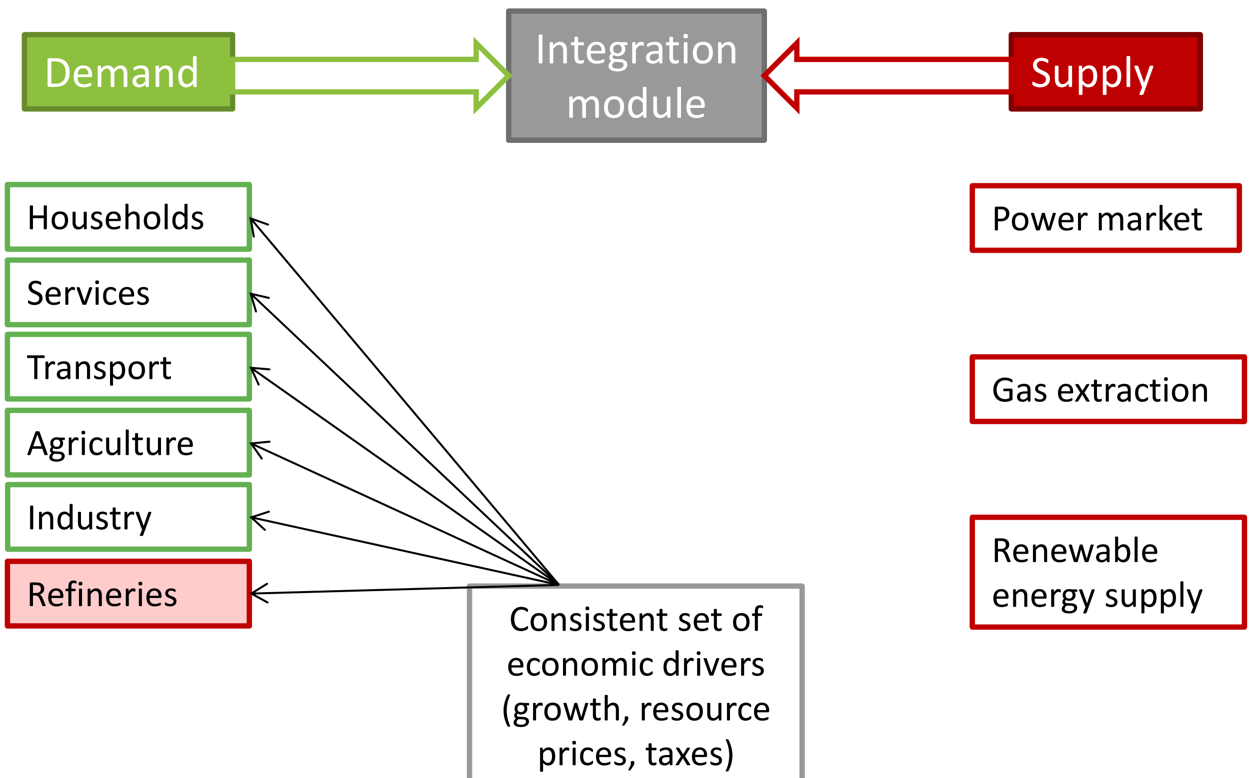

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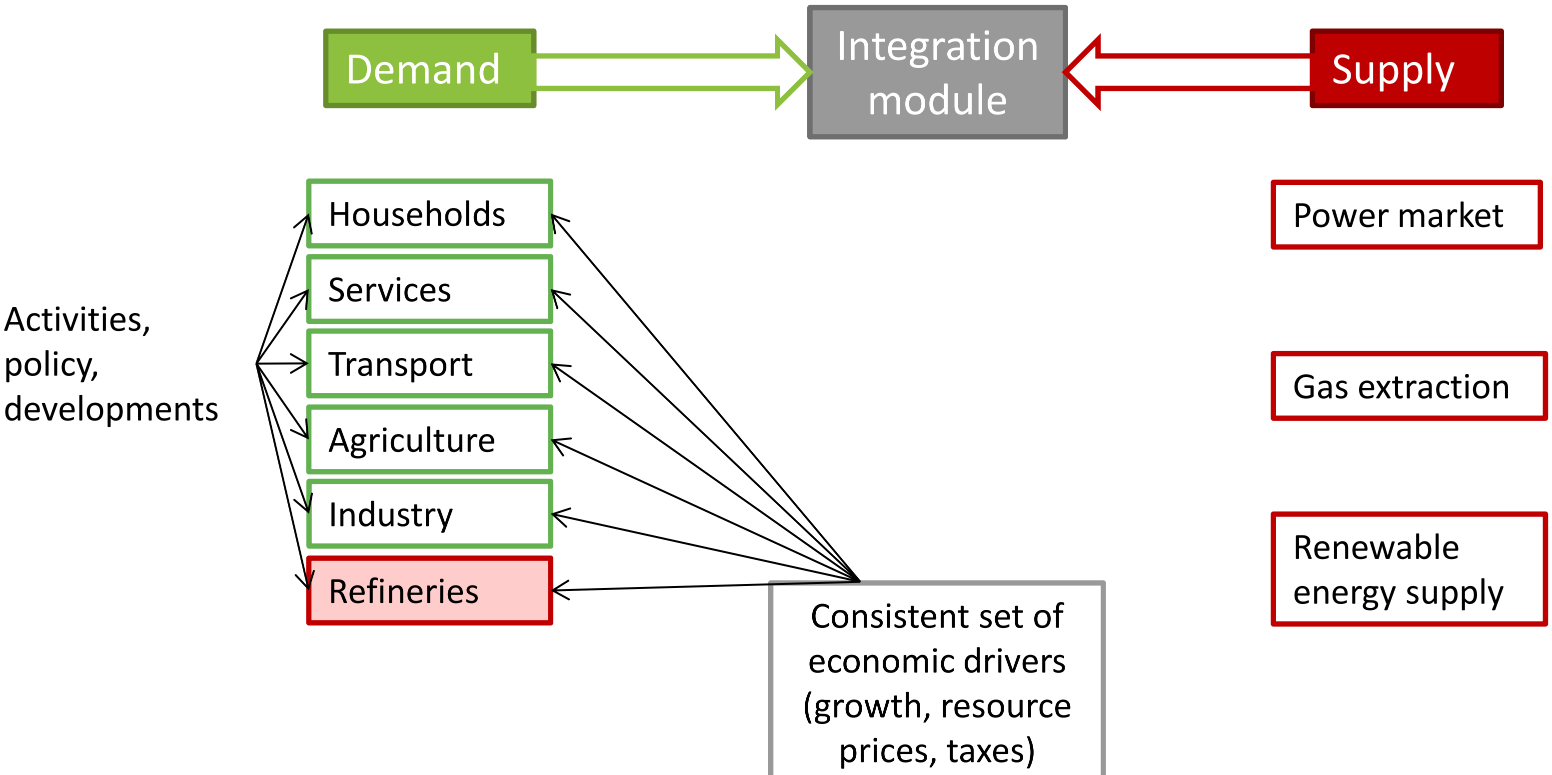

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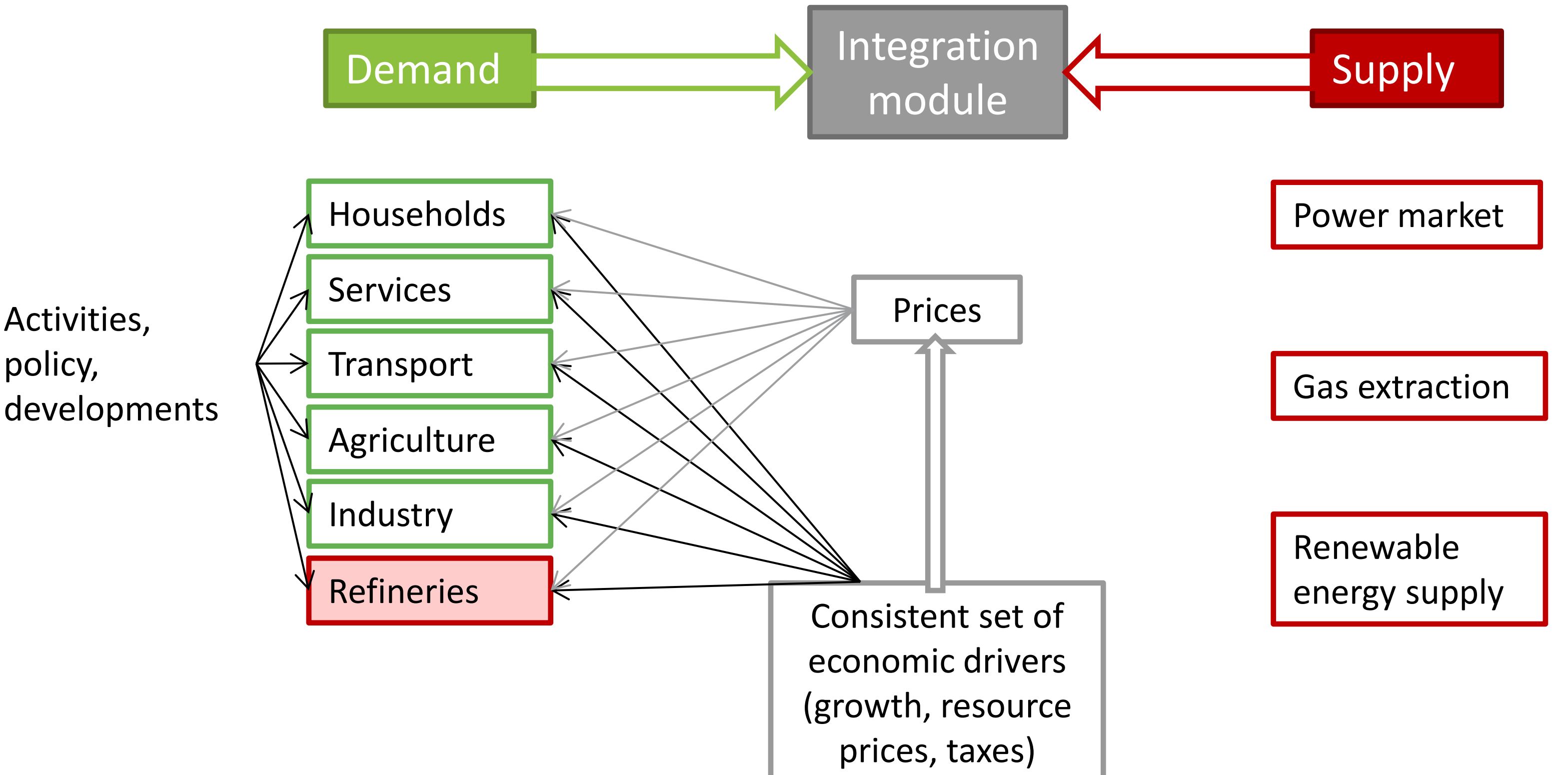

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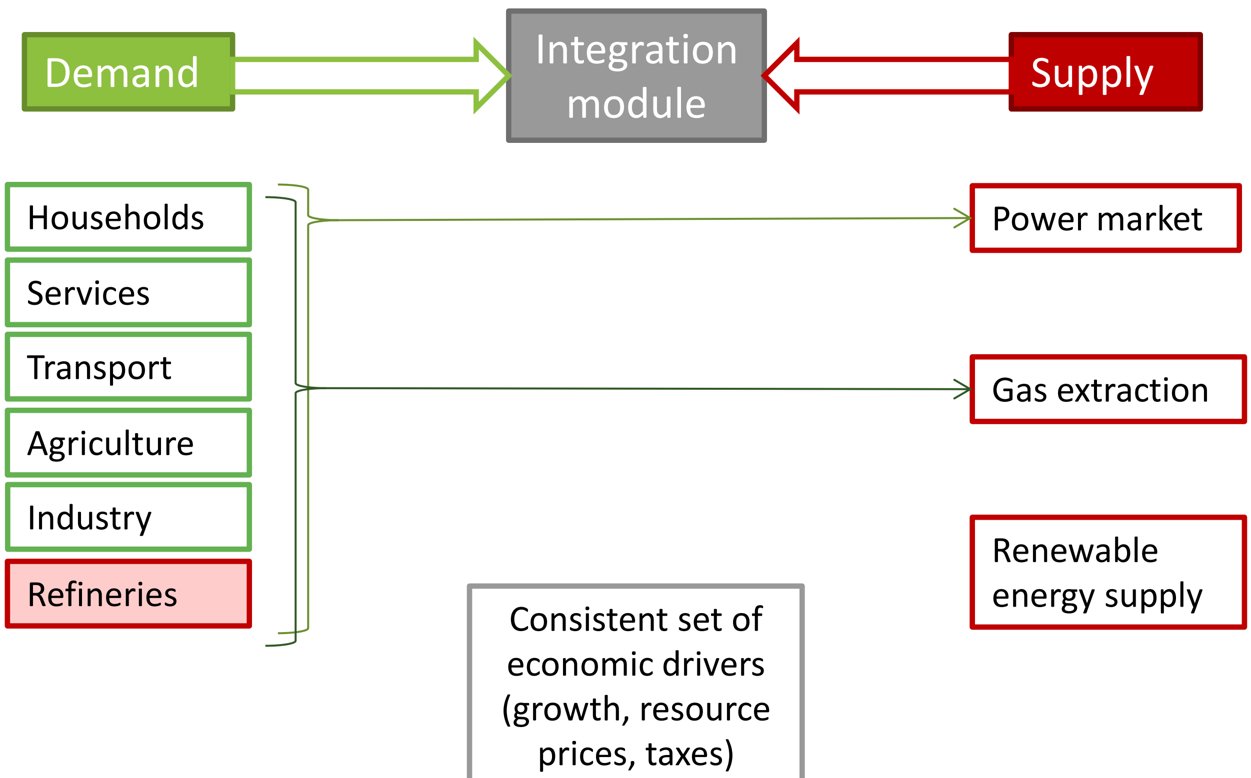

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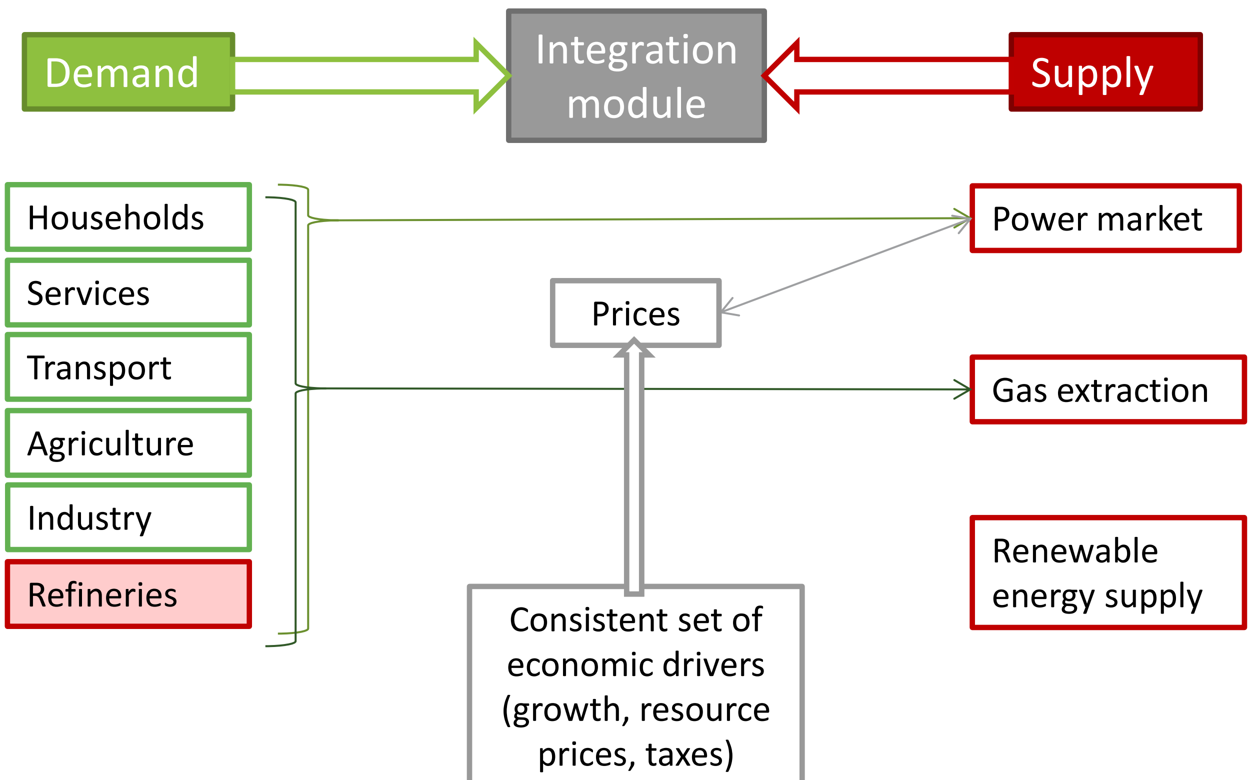

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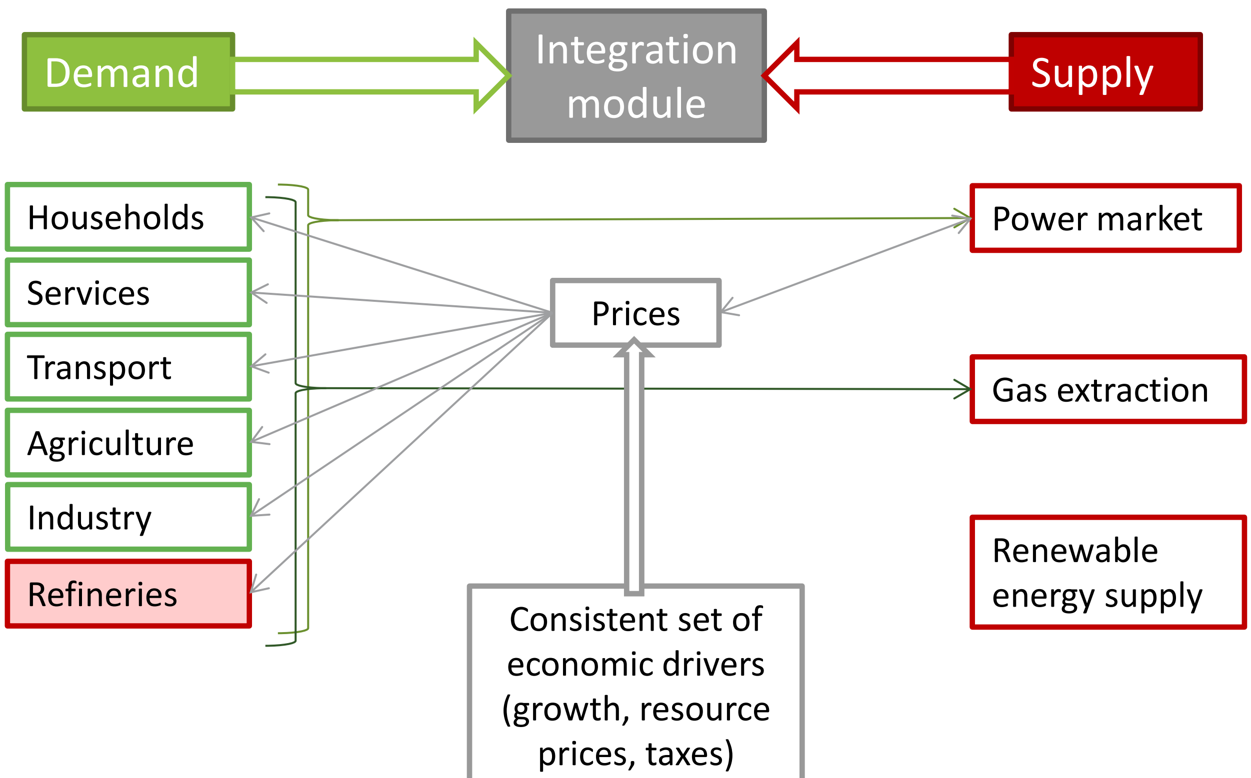

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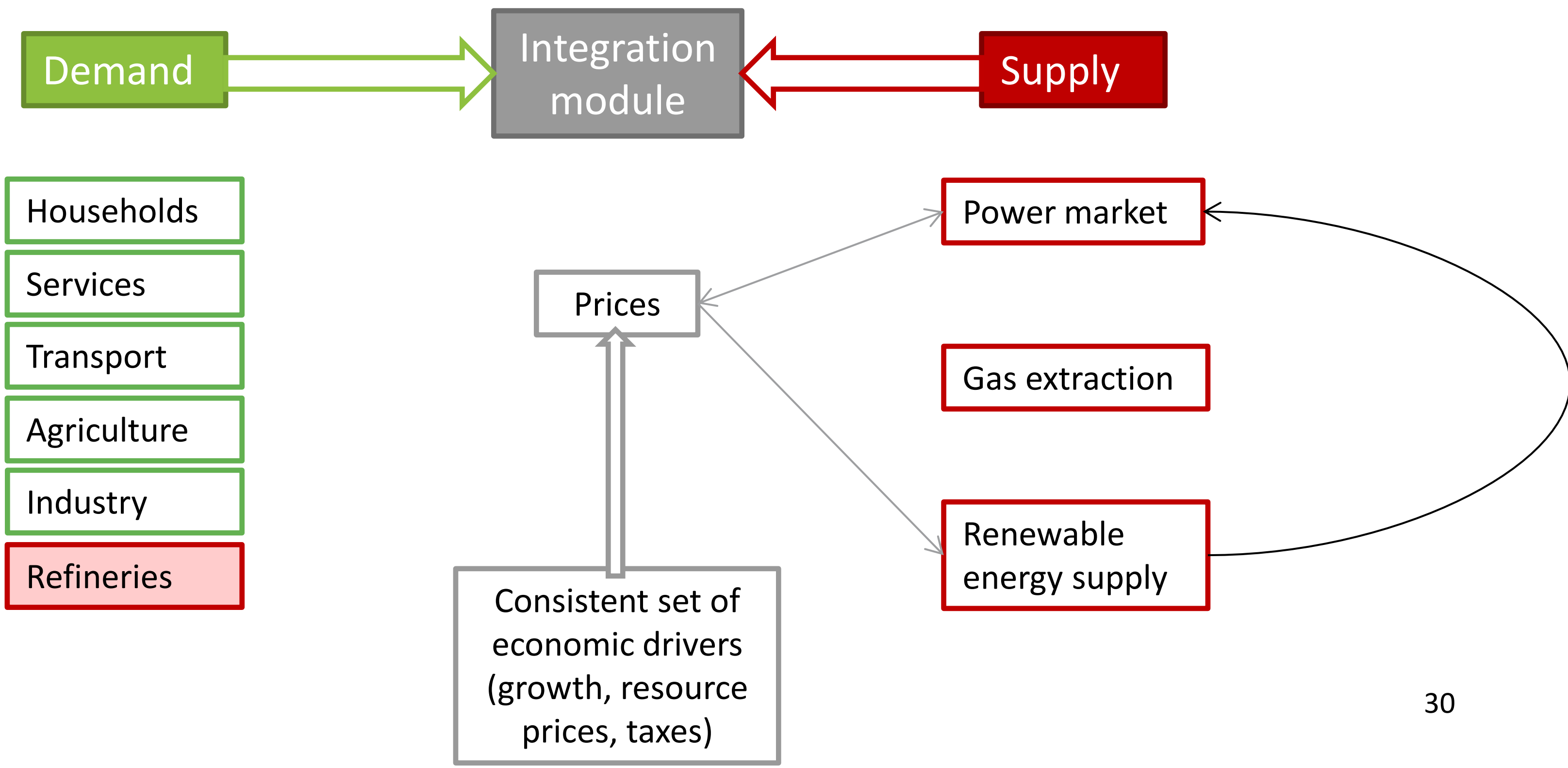

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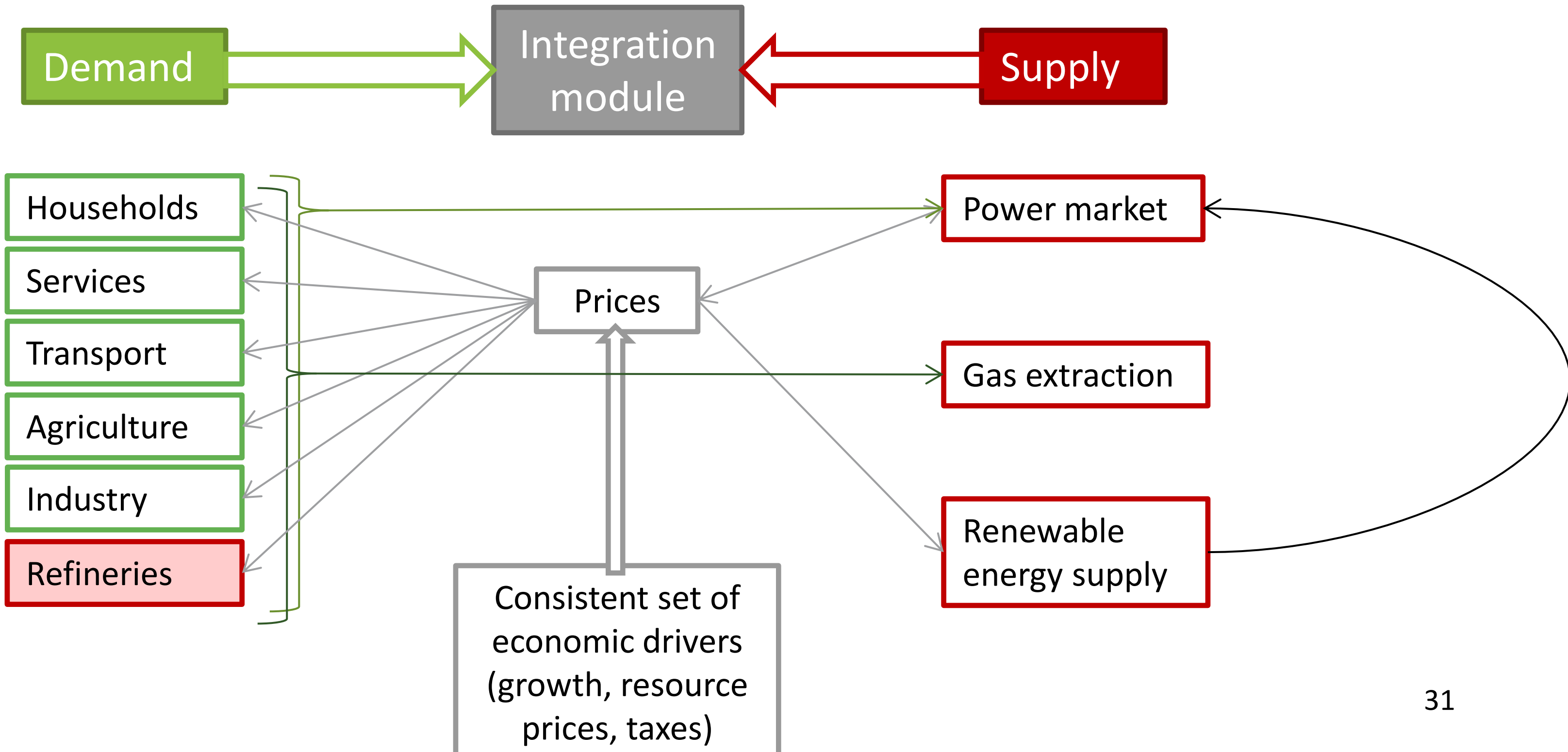

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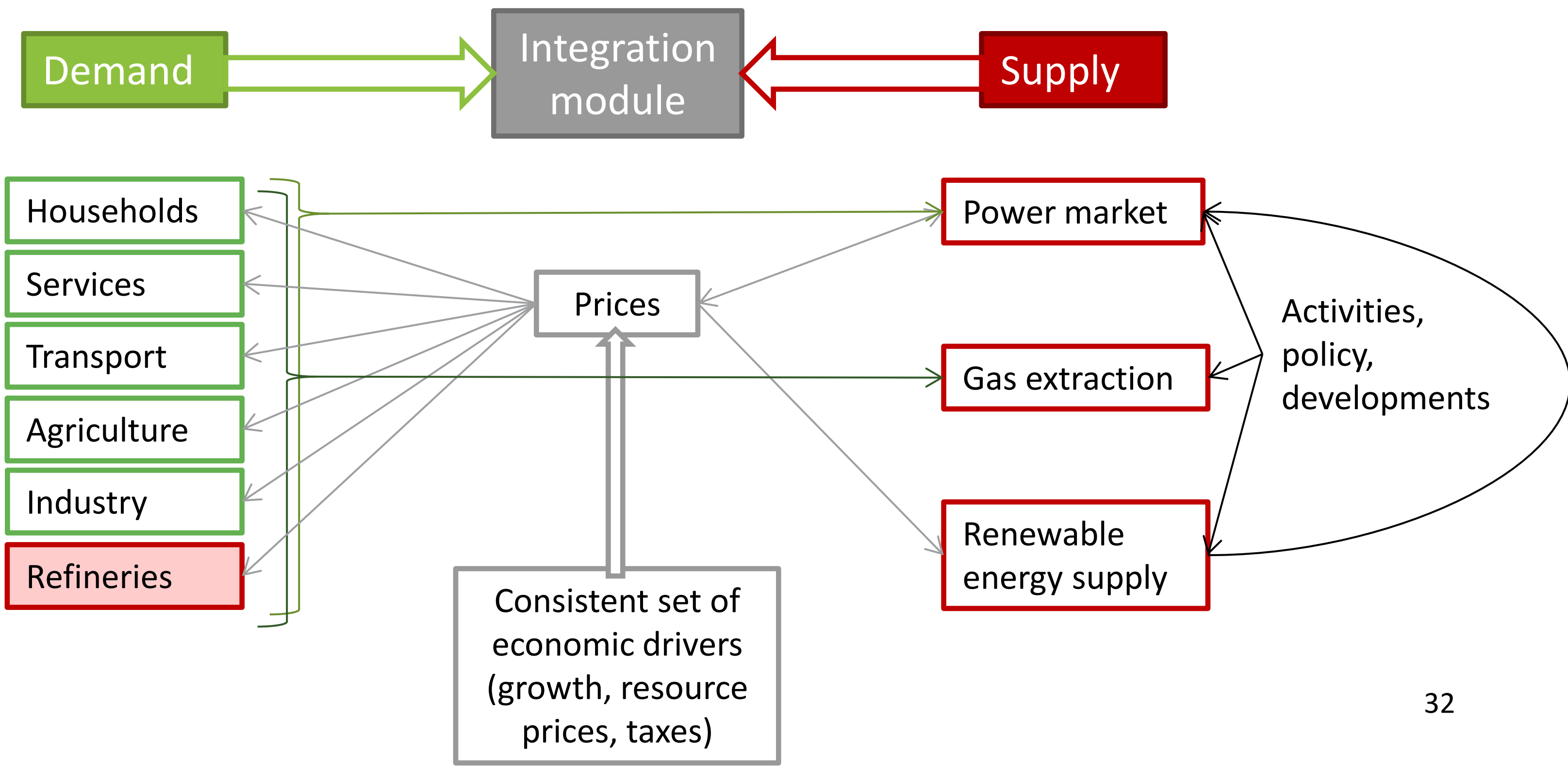

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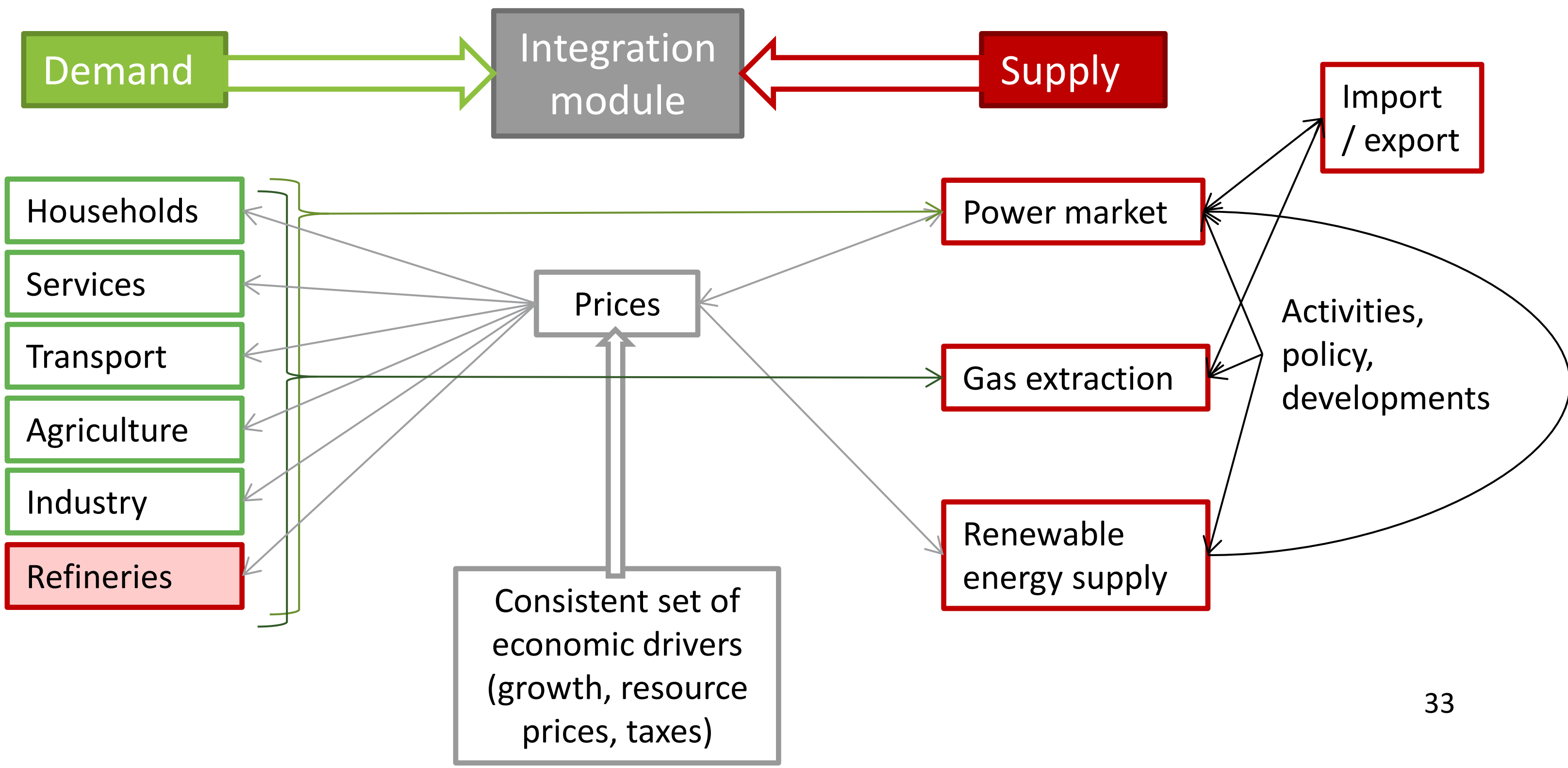

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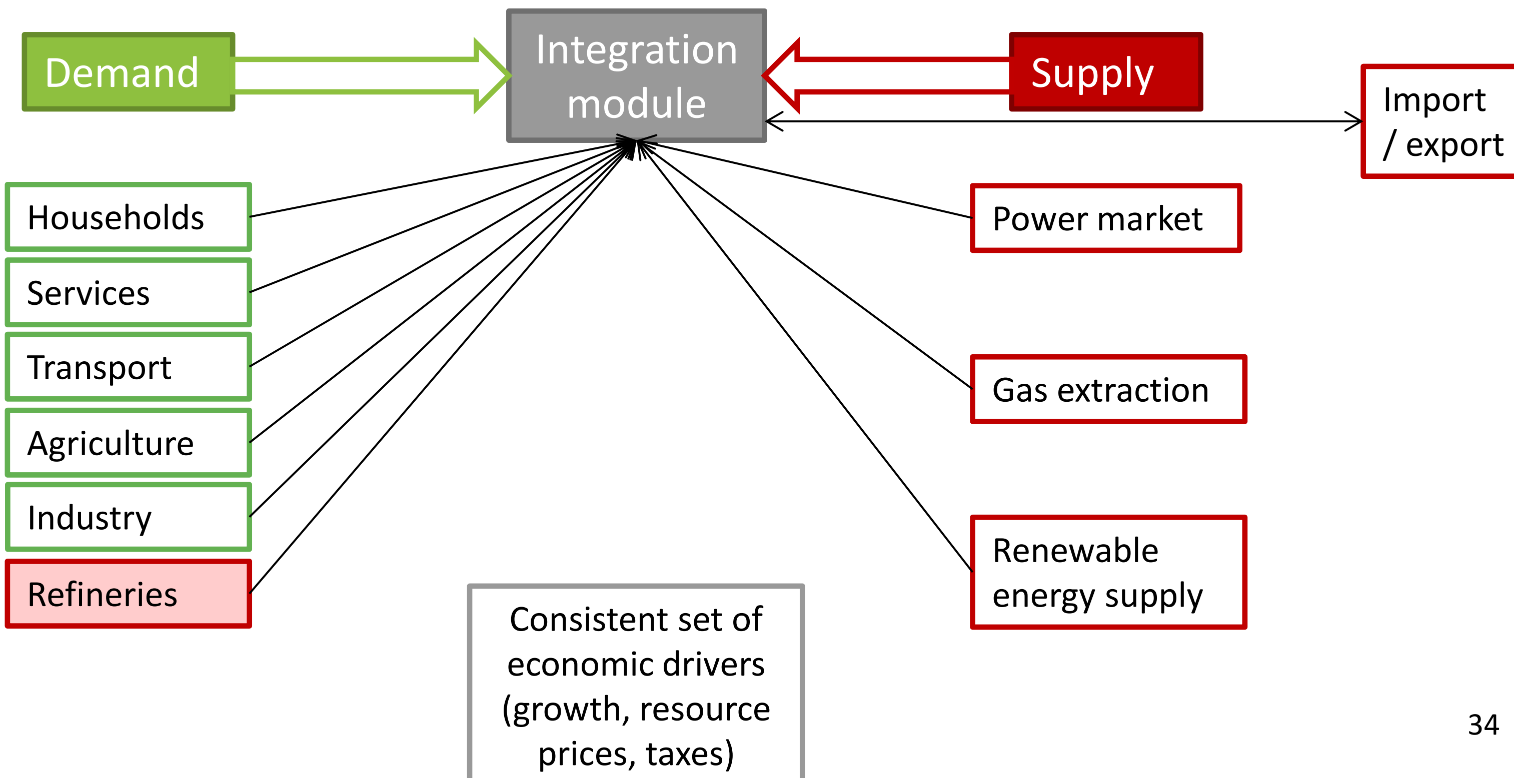

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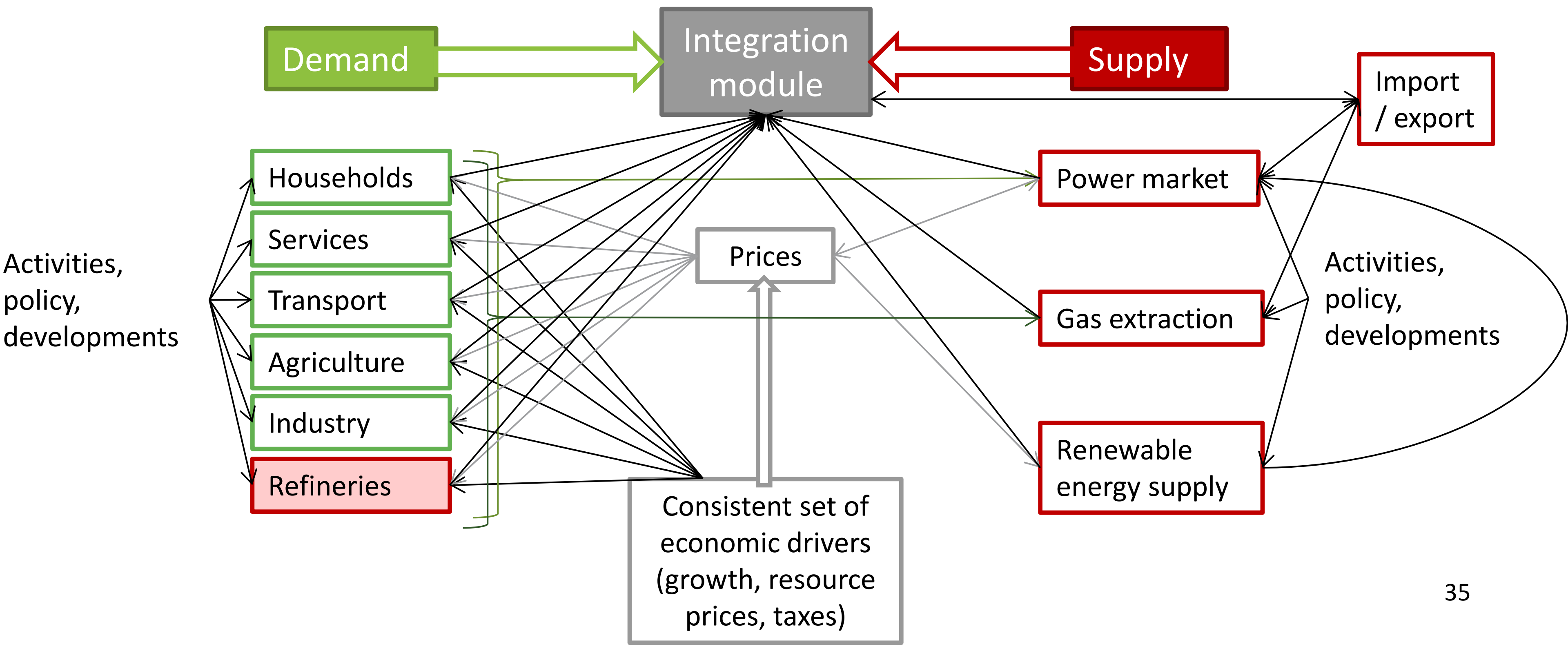

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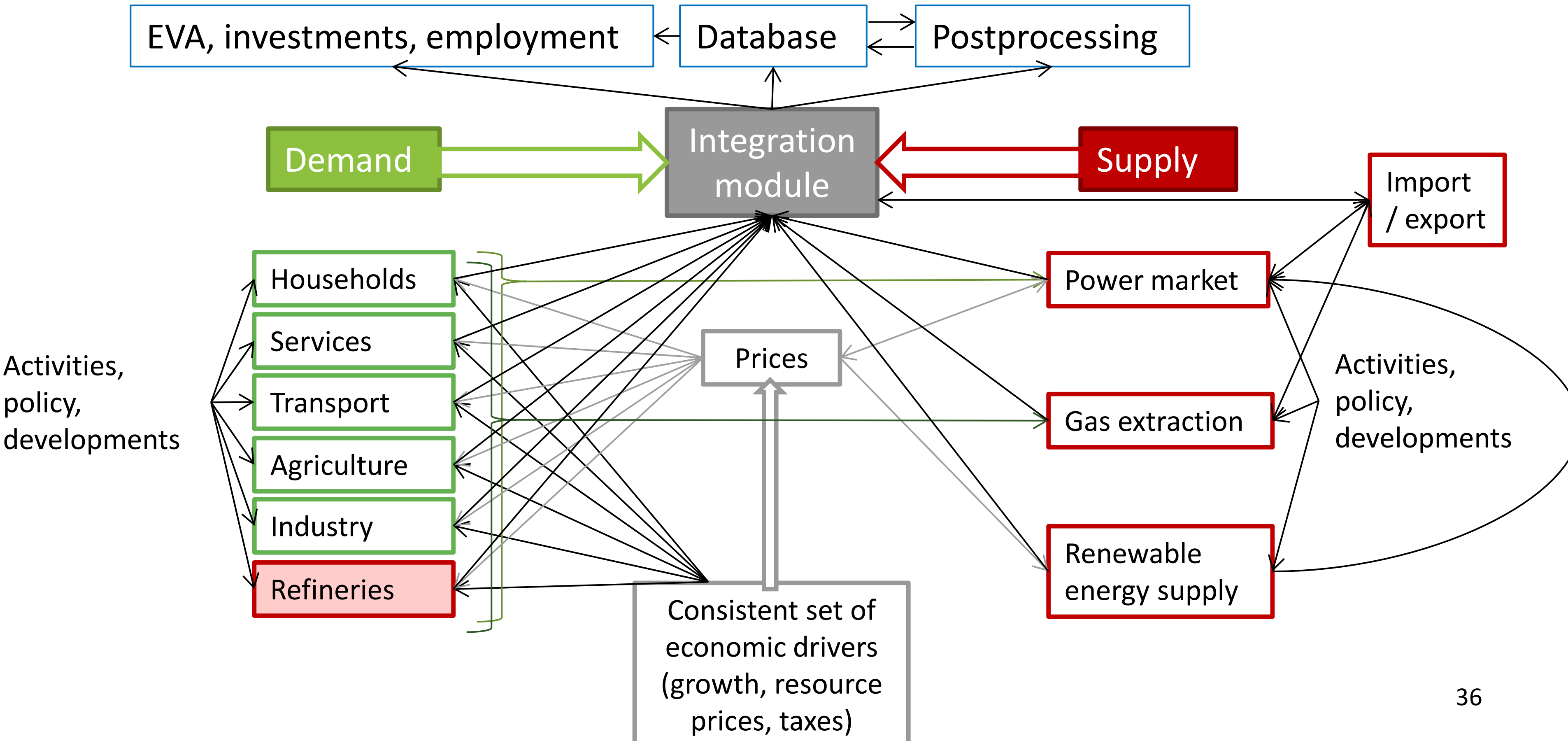


Submodels: simulating investment decisions

- Submodels are also used stand alone for sectoral policy assessments

E.g. Energy use in Households

- 'Micro data' on dwelling types, energy bills, household types and historic investments
- Allows modeling investment decisions for future investments
  - Existing dwellings: replacement decisions for boilers, windows, etc. following costs and observed investment behaviour
  - New dwellings: building code mandates energy efficiency measures – package dependent on investment costs

- Similar detail for other sectors

Submodels: simulating power market

E.g. Power market model

- Covers entire NW-European power market
- Data on technical and economic performance of individual plants
- CHP in industry and agriculture
- Renewable energy production from various sources

- Hourly match of demand and supply

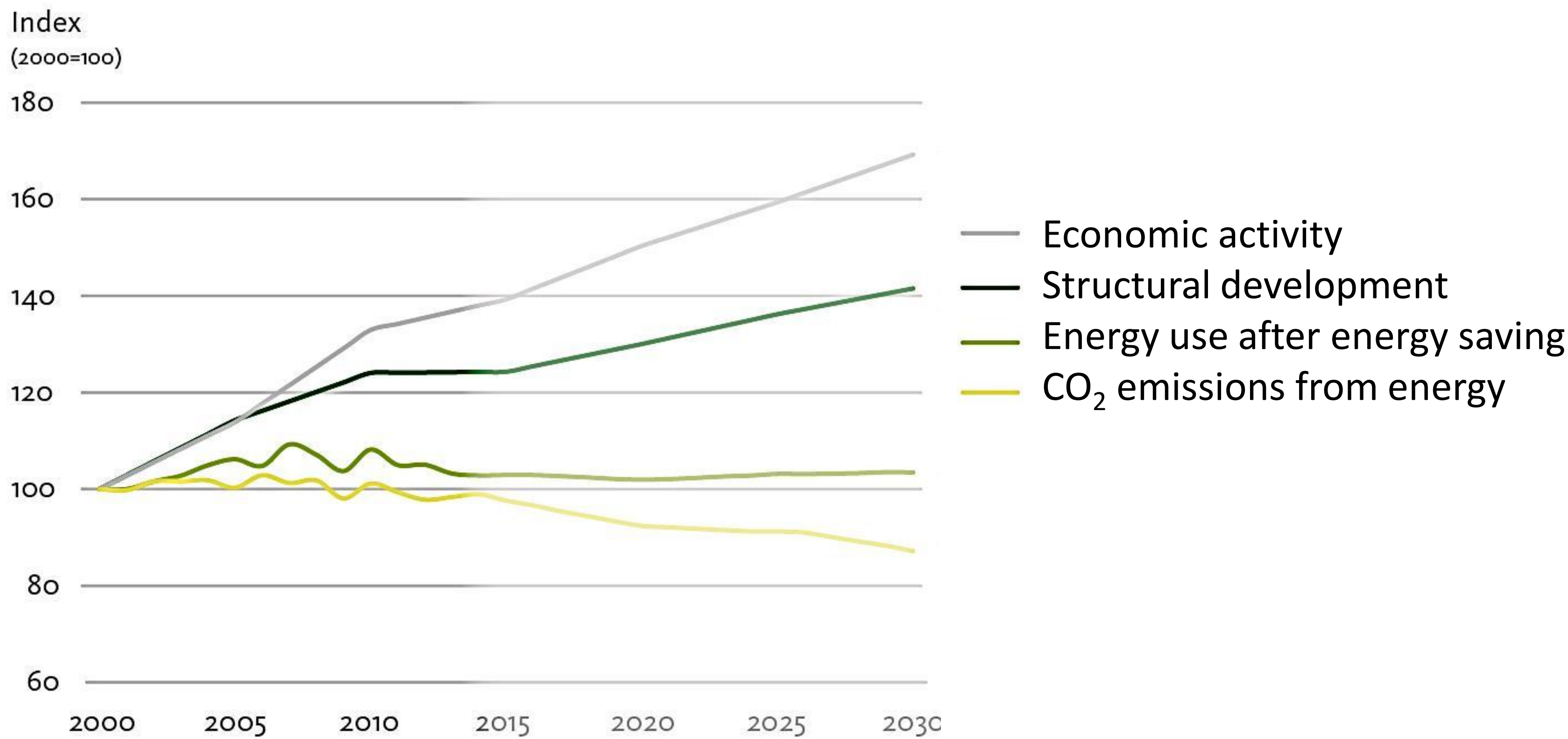
- Resulting power mix and hourly commodity trading price

National Energy Outlook 2014

www.ecn.nl/docs/library/
report/2015/e15005.pdf

ECN
Planbureau voor de Leefomgeving
Centraal Bureau voor de Statistiek
Rijksdienst voor Ondernemend Nederland

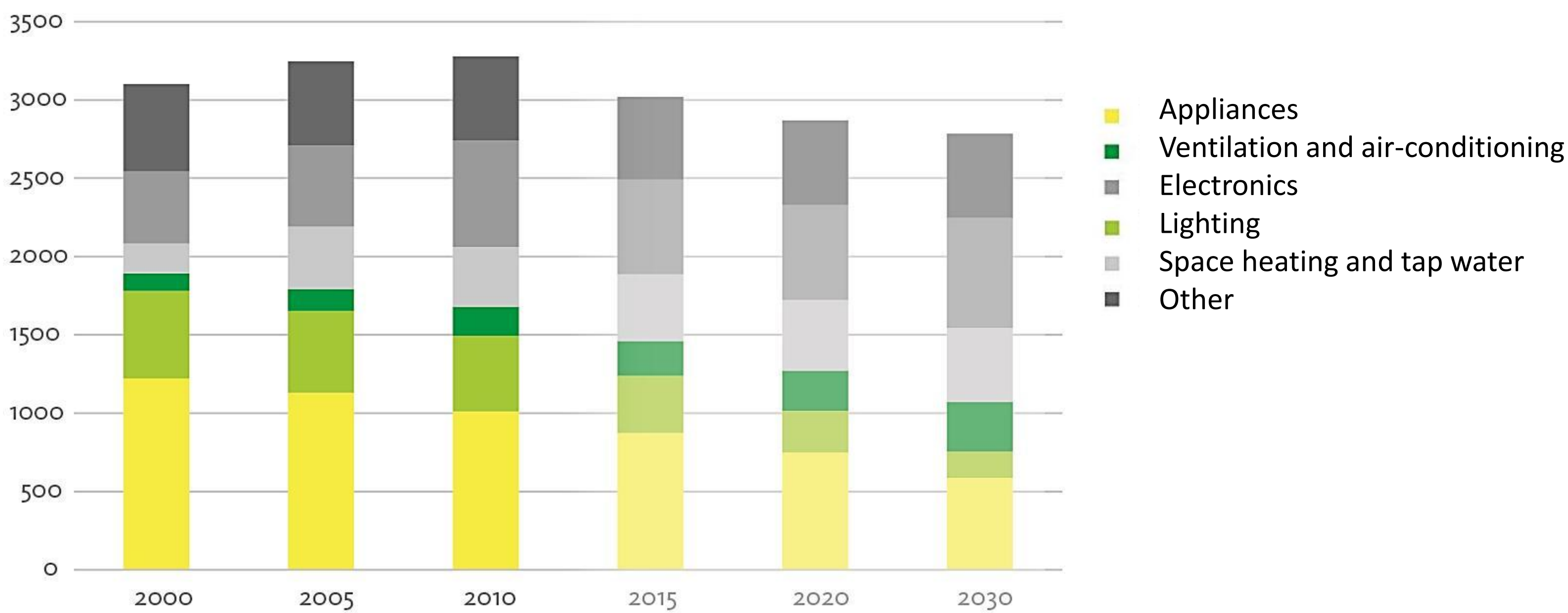
Energy use, CO_2-emissions and economy show ´decoupling´



Regulations work!

Average electricity use of households declines

Electricity use (kWh)

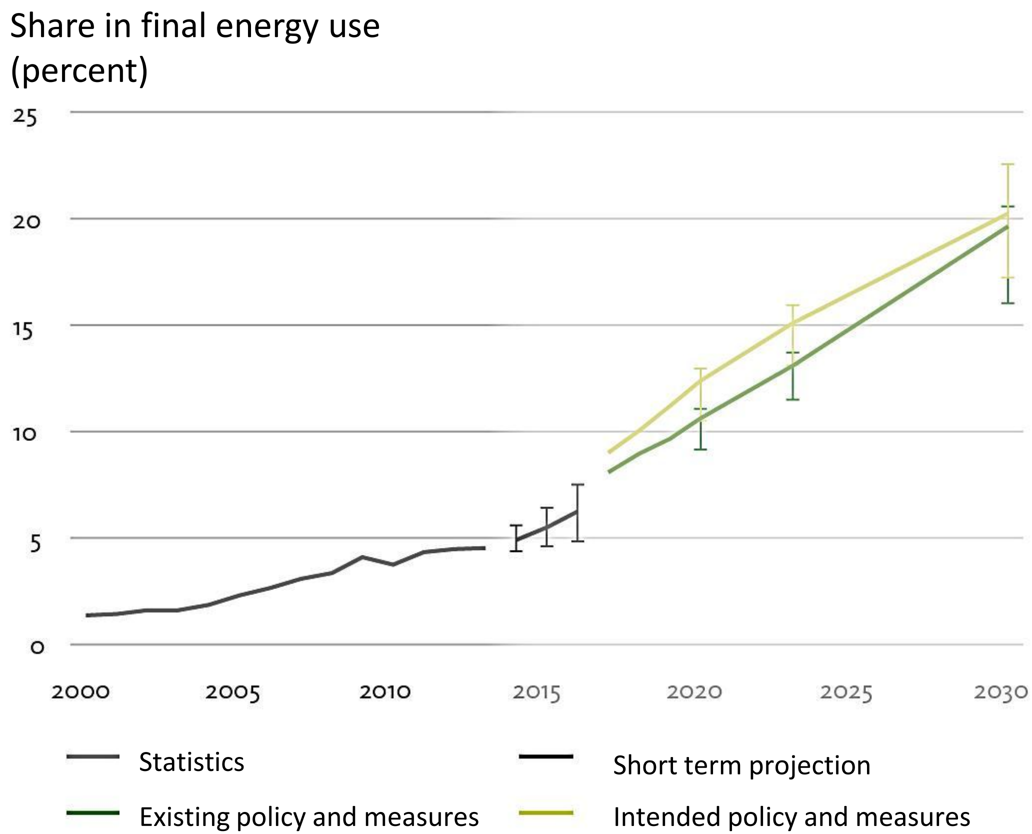


Energy efficiency: Not all goals within reach (yet)

- Energy savings pace 2010-2020
  - Existing policy 1,0% p.a (0,7 – 1,2%)
  - Intented policiy 1.2% p.a. (1,0 – 1,4%)
  - After 2020 drop to 0,7% p.a.
- EU Energy efficiency directive
  - Existing policy: probably uncompliant
  - Intented policy: probably compliant
- Energy agreement 100 PJ
  - Out of reach yet

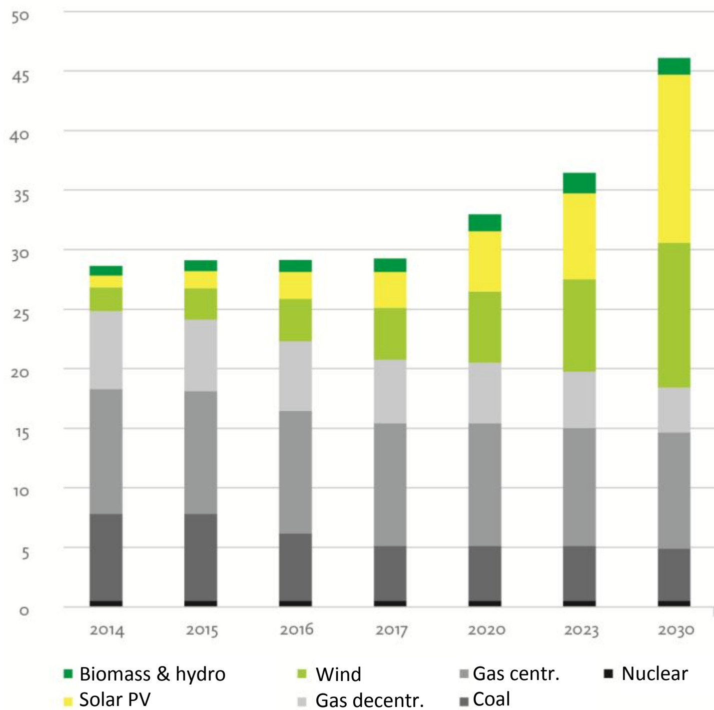
Sector	Savings EA (PJ)	Goal
Industry	7 – 14	
Agriculture	3- 9	
Built environment	10 – 39	
Transport	-	
Total	19 - 61	100

Substantial growth of renewable energy, big uncertainties

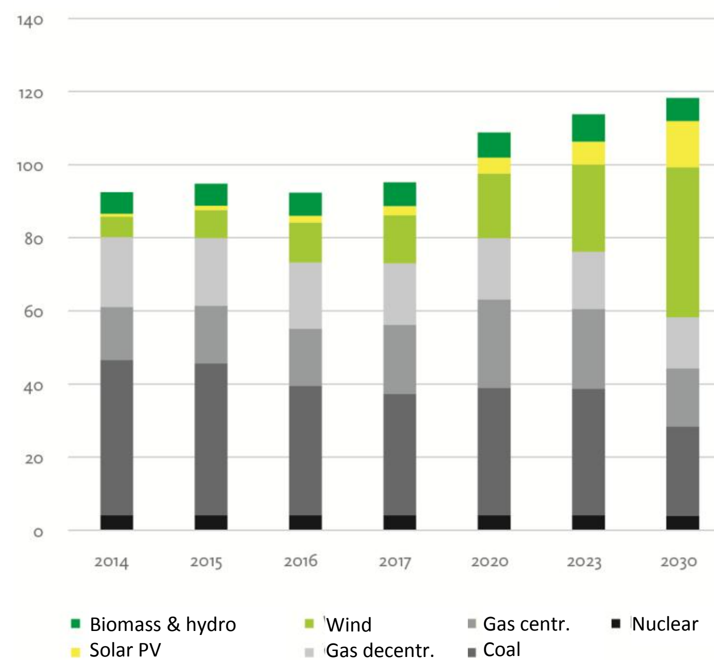


Electricity production

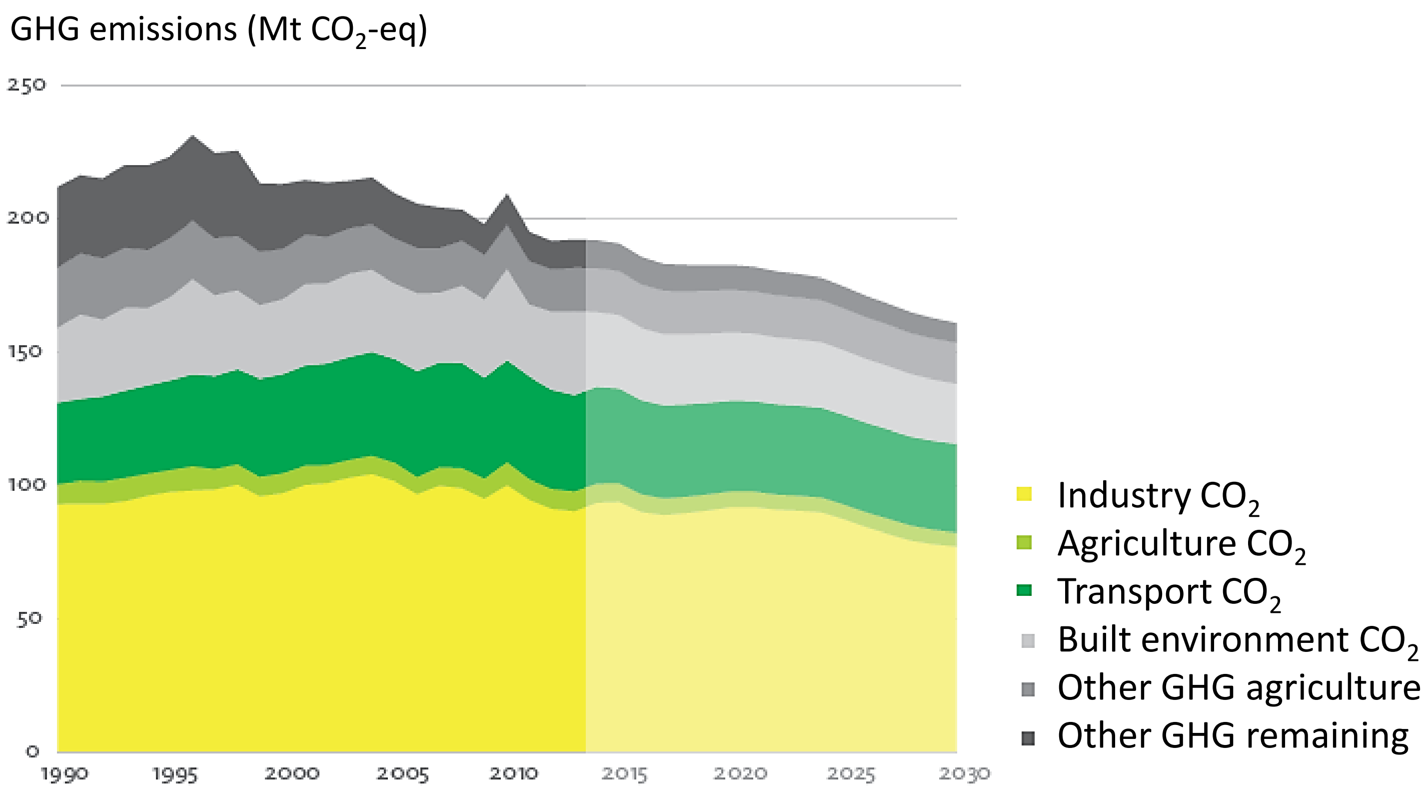
Capacity (GW)



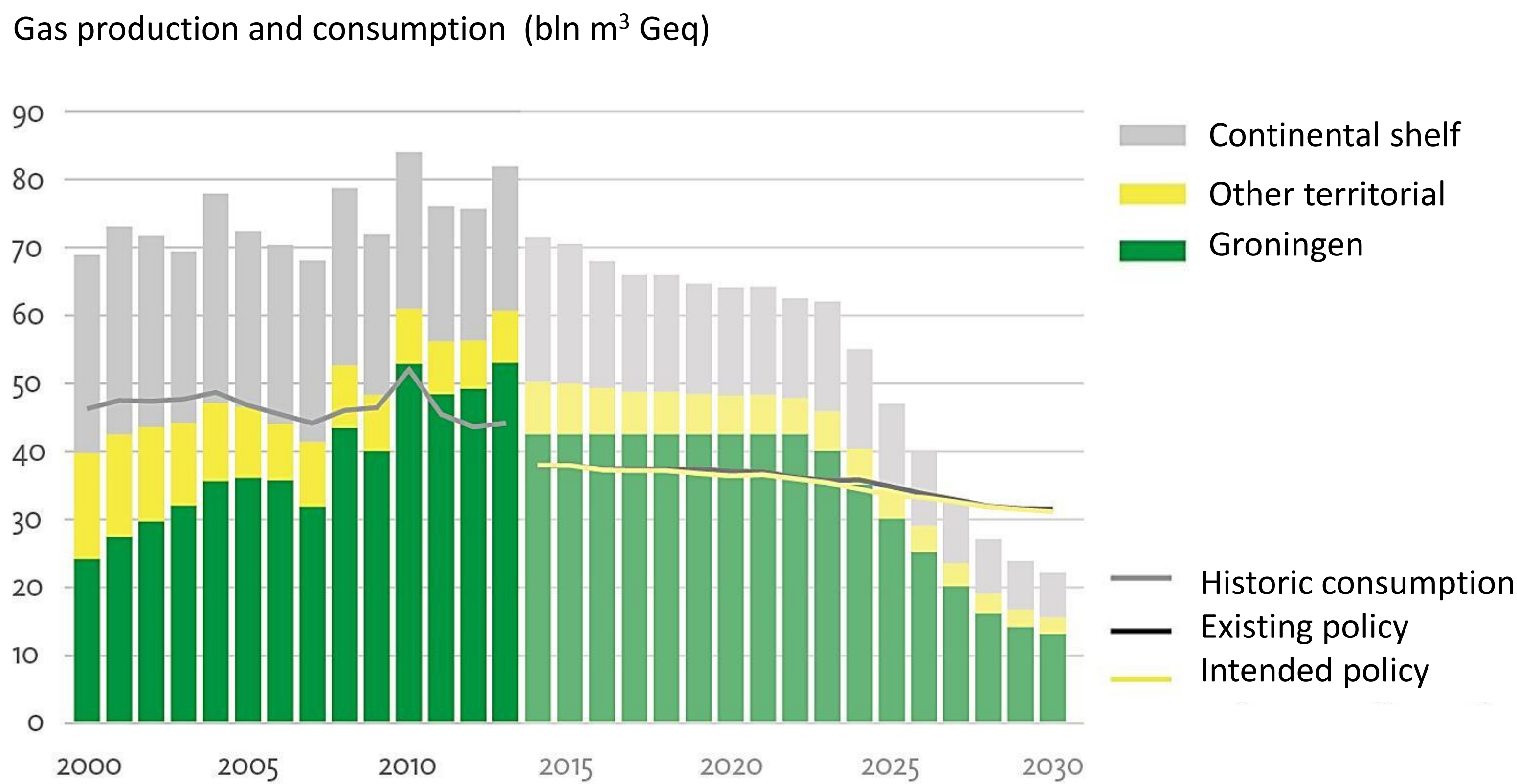
Production (TWh)



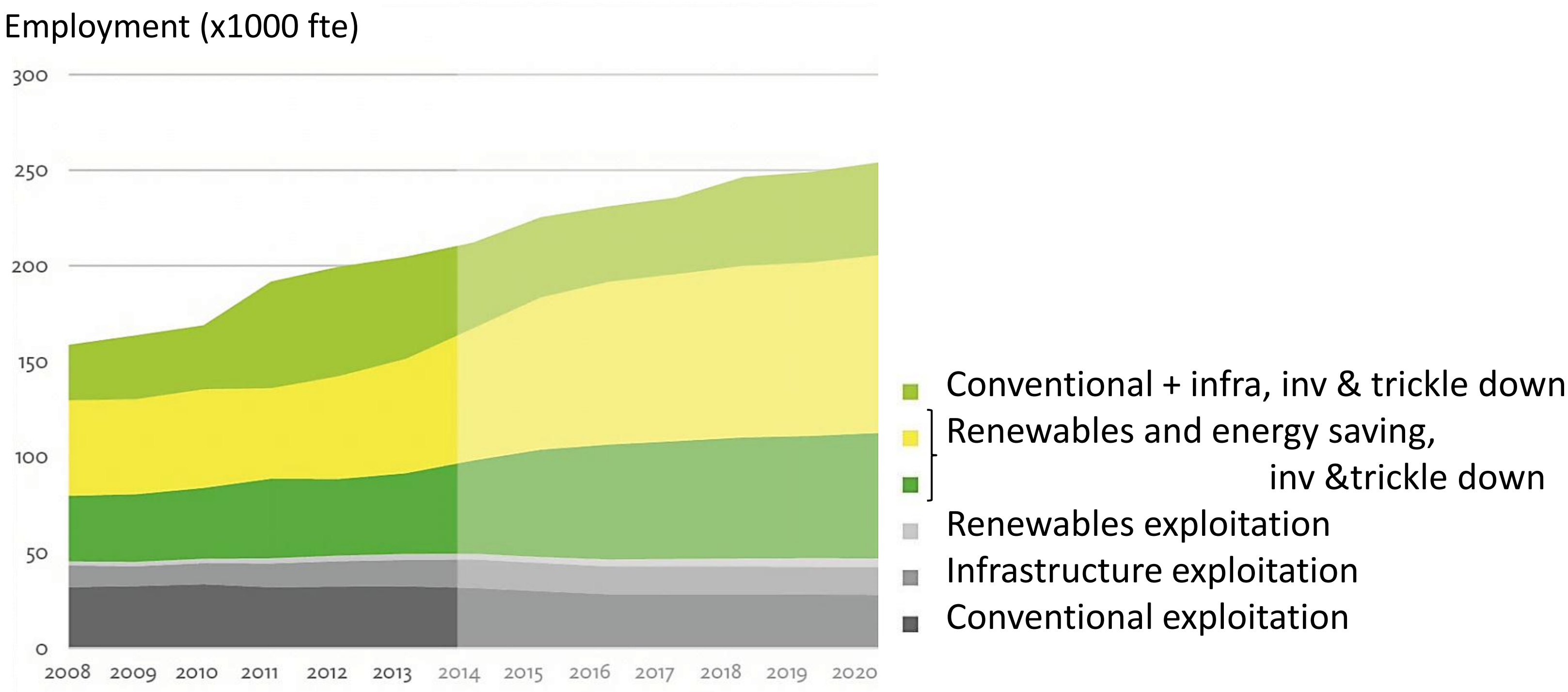
Greenhouse gas emissions declining



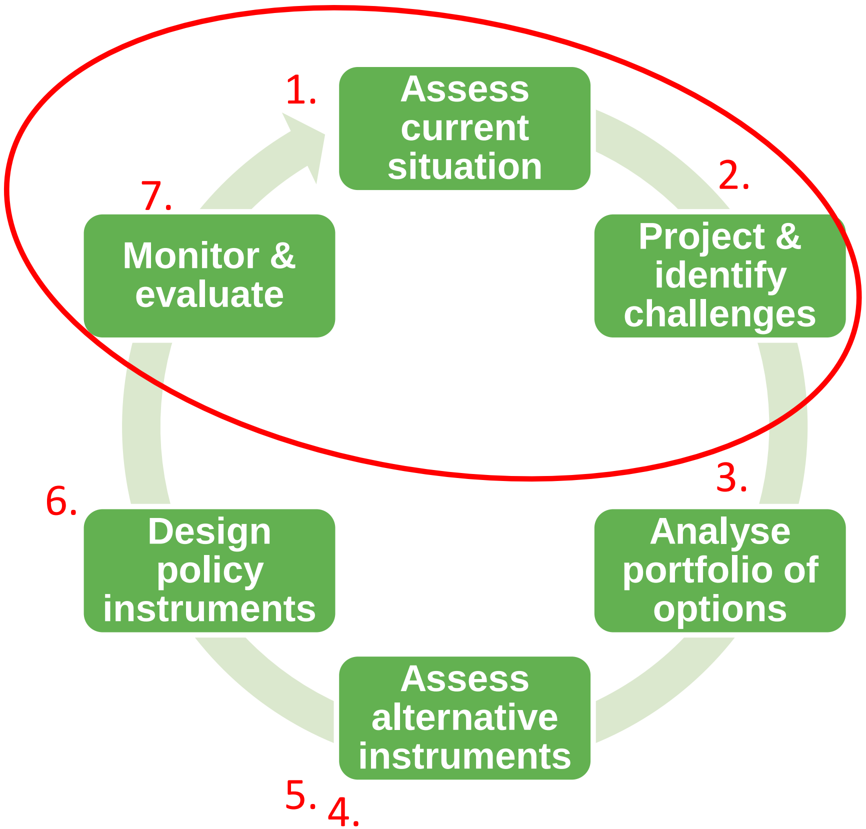
The Netherlands becomes net consumer of natural gas



Investments generate substantial employment



NEO forms backbone for policy support



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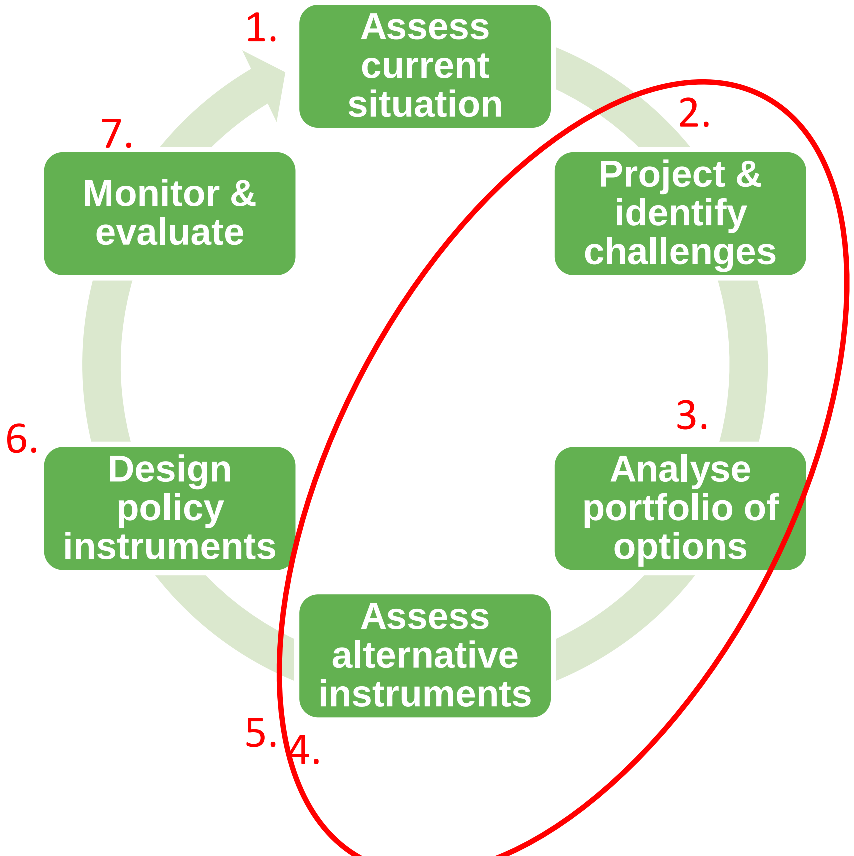
Models for Energy strategy

OPERA model supports strategy formation



- Optimization model to assess technology portfolios for (deep) decarbonization
  - What is the most efficient way to achieve a given GHG reduction target?
  - What technologies should / could play a role?
  - What costs do alternative targets imply?

The OPERA model

- OPERA "Option Portfolio for Emissions Reduction Assessment"

- 'Top down' approach – Exploratory optimization model
- Finding lowest cost energy system configuration(s) given:
  - System requirements (e.g. total demand, balance, seasonal patterns, potentials)
  - Emissions constraints
  - Targets for renewables
  - Other peculiarities of policies
- 'Time slice' representation of hours of the year
- 280+ technologies
  - Supply – conversion – transport – storage – demand

Marginal abatement cost curves

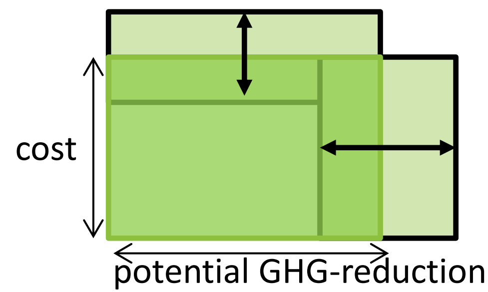
- "Options": technologies that could be part of future energy system
  - Technical potentials
  - Inputs – outputs
  - Investment costs
  - O&M costs

- Potentials and costs depend on national circumstances

- Ordering options from lowest cost per ton CO2 to highest gives national 'marginal abatement cost curve'

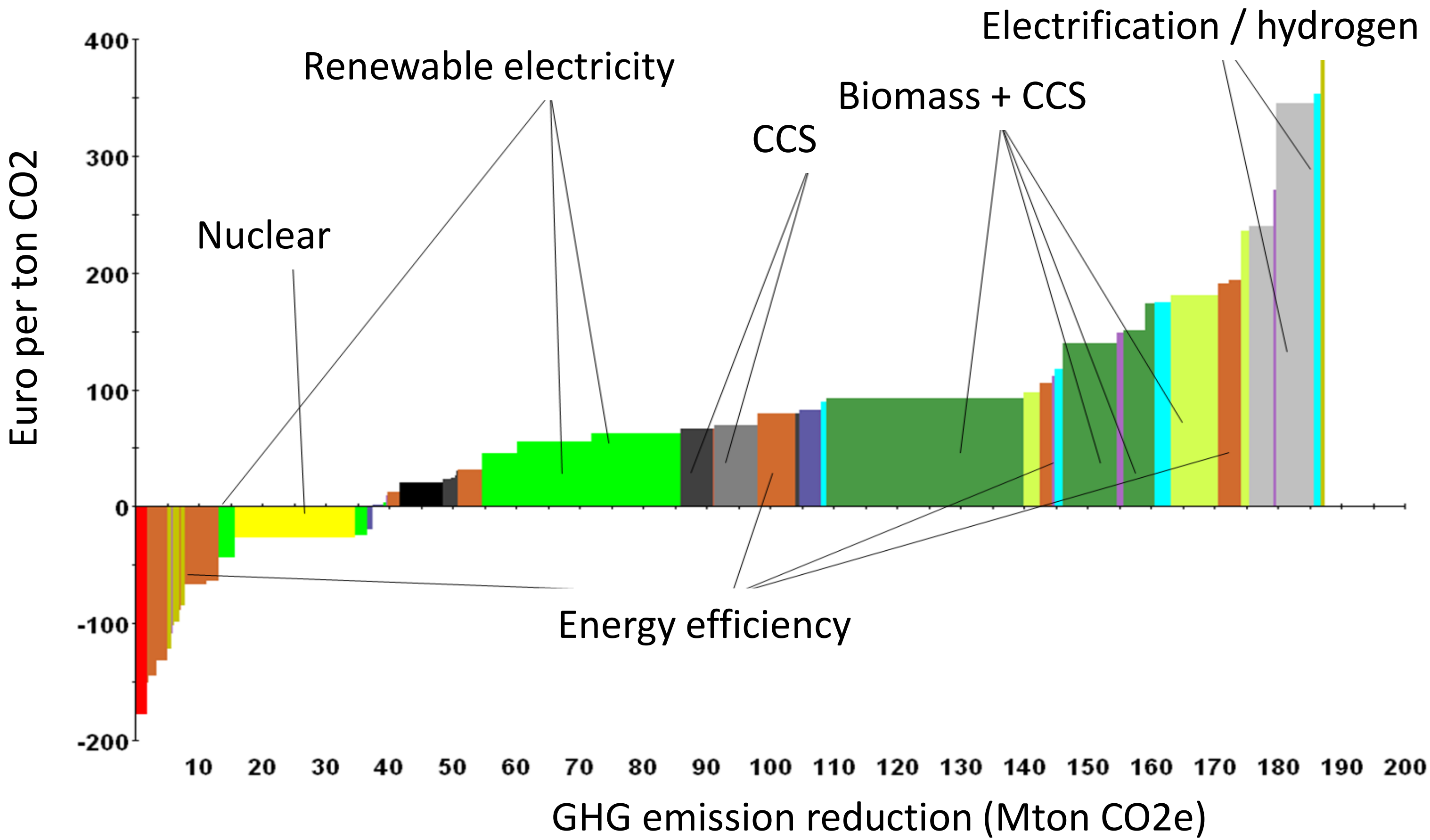
Dynamic marginal abatement cost curves

- Interactions and cobenefits between options influence potentials and costs, which can shift the order in the MACC
- Uncertainties in prices, costs, resource availability and potentials for the future are typically large



- OPERA
  - generates integrated, internally consistent MACC
  - also generates integrated, internally consistent image of the resulting energy system
  - allows comparison of different scenarios

Cost of options for CO2-emission reduction



Example studies for energy strategy

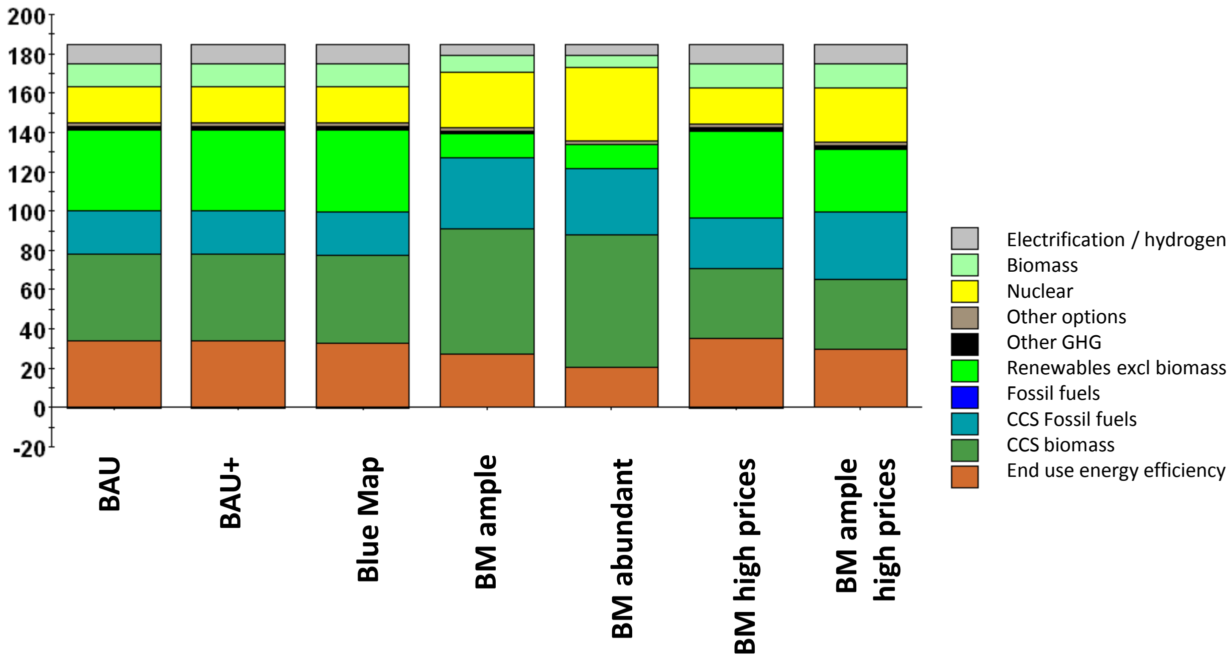
Example study:
Cost benefit analysis of deep decarbonisation

ECN

- Question: what societal costs are to be expected when GHG emissions in the Netherlands need to be reduced by 80% in 2050
  - Subquestion: what technologies will play a role?
- Helps to get a good understanding of what technologies are needed
  - Innovation policy!
- Effects of uncertainties

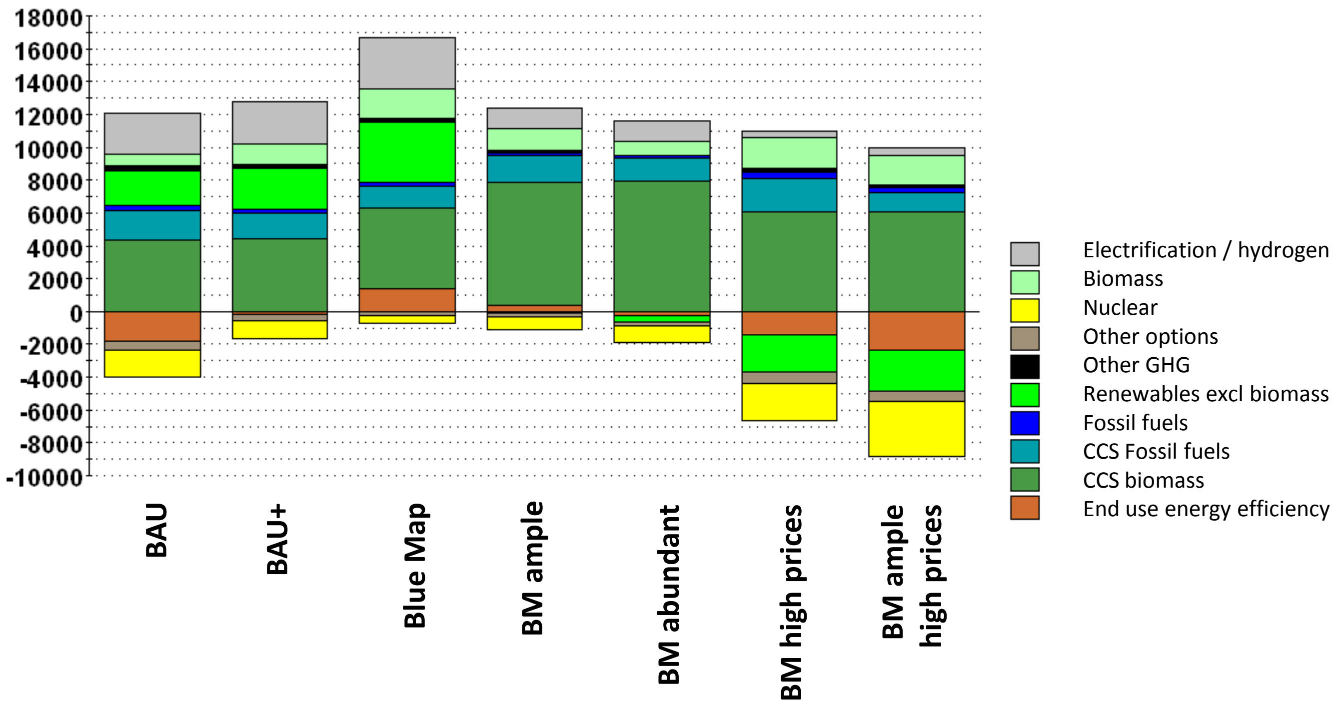
Cost benefit analysis of deep decarbonisation

Effect Greenhousgas
emissions (Mton CO2-eq)



Cost benefit analysis of deep decarbonisation

National costs per categpry, additional to reference scenario (mln euro)

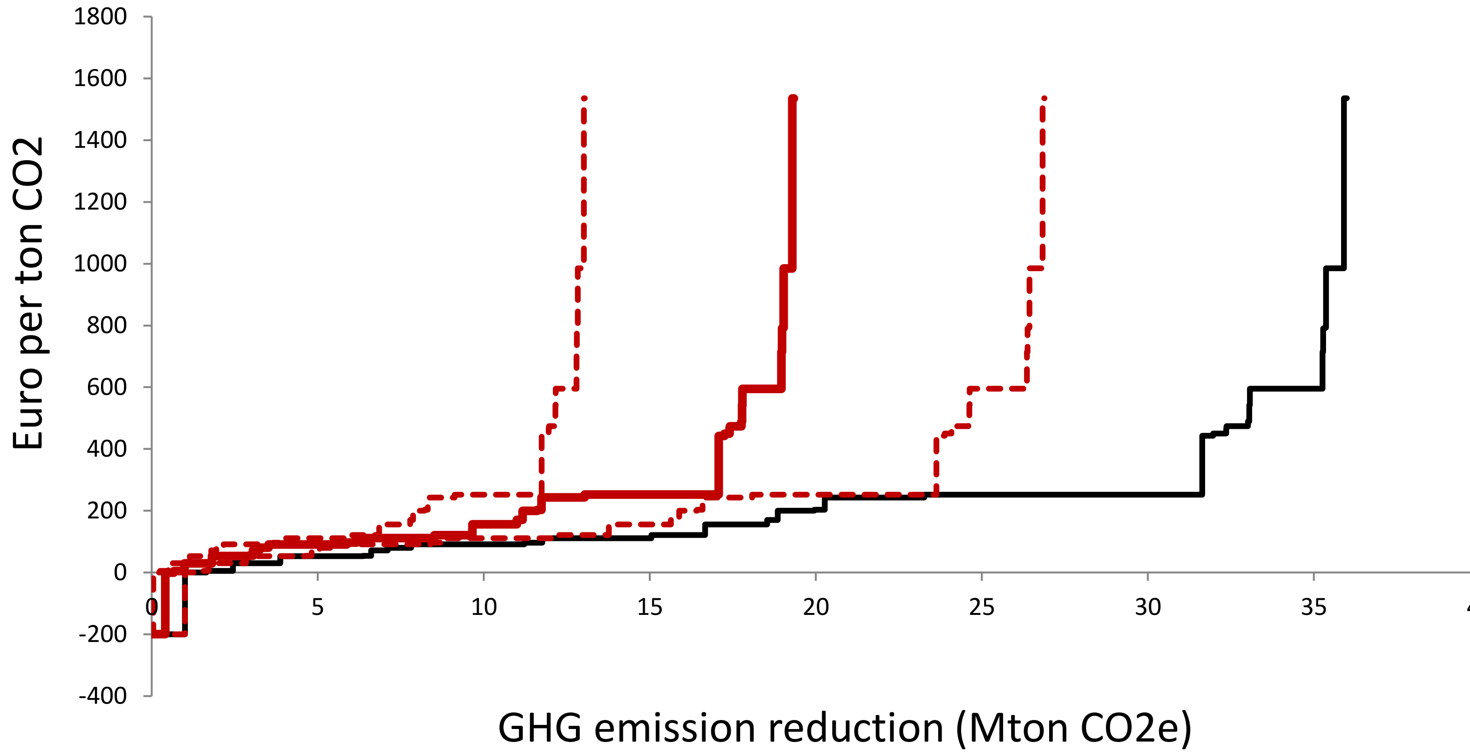


Example study:
EU negotiations on 2030 climate targets

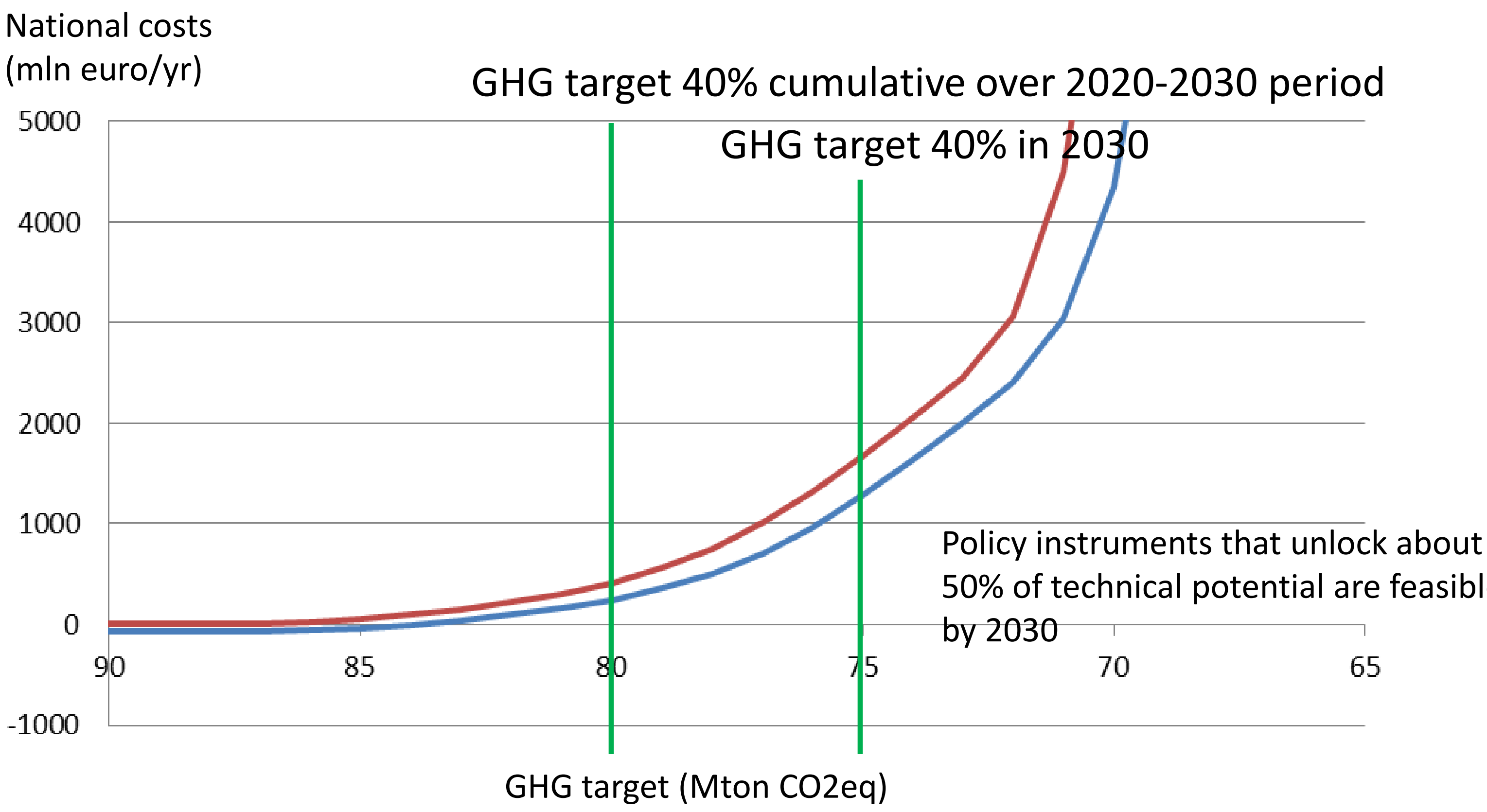
ECN

- UNFCCC requires countries to submit Intended Nationally Determined Contributions (INDCs) before COP in Paris in December
- EU discussion revolved around three themes: GHG emission reduction, renewable energy, energy efficiency
- What would various outcomes mean for Dutch policy?
  - Costs, policy instrumentation, interaction between different goals, pathway to 2050

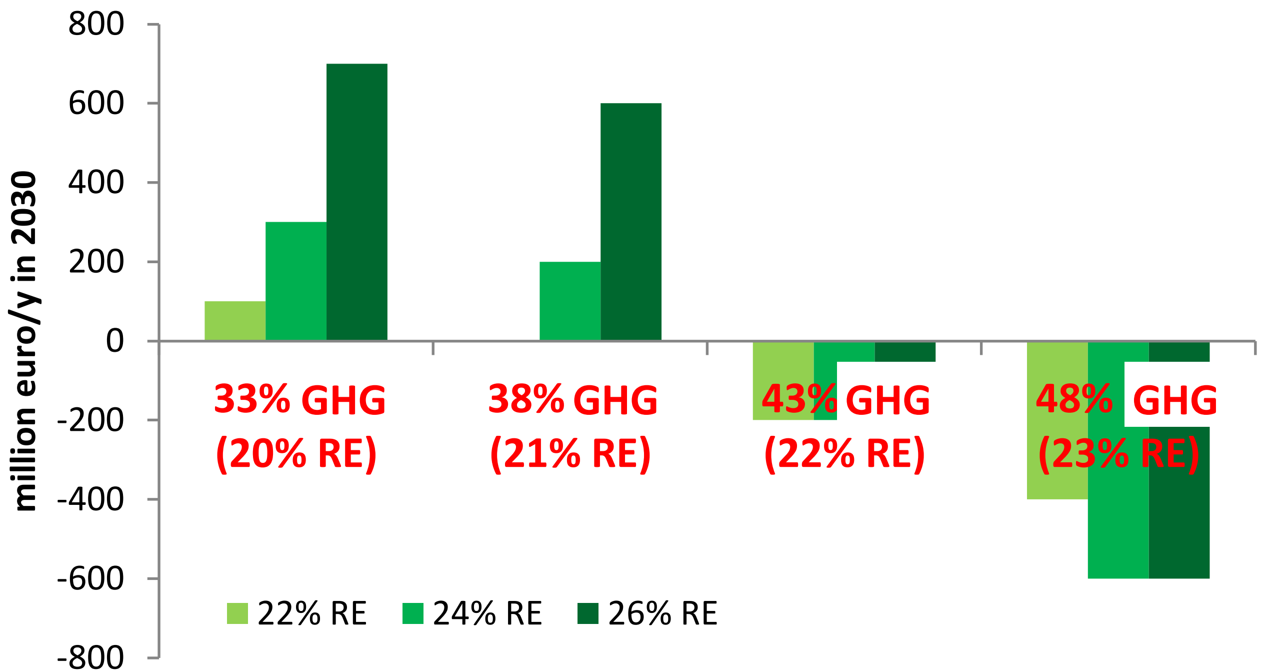
Technical vs achievable potential



Consequences of Non-ETS target: costs



Additional costs for separate RE target



RE-target: Minimum percentage of gross final energy use

Two opposing effects, net effect depends

- Higher costs because additional boundaries reduces options for optimization
- Lower CO_2-price at higher RE target: the Netherlands are net user of ETS-rights

Example study:
The role of “power to gas” in decarbonization

ECN

- Given the intermittent nature of Wind & Solar, there will be abundance of ‘clean’ electricity during parts of the day/year, and shortage in other times
- More flexibility needed in the system to allow high penetration of wind / solar
- What role can power to gas play in this issue?

Power-to-Gas Systems Analysis was supported by:

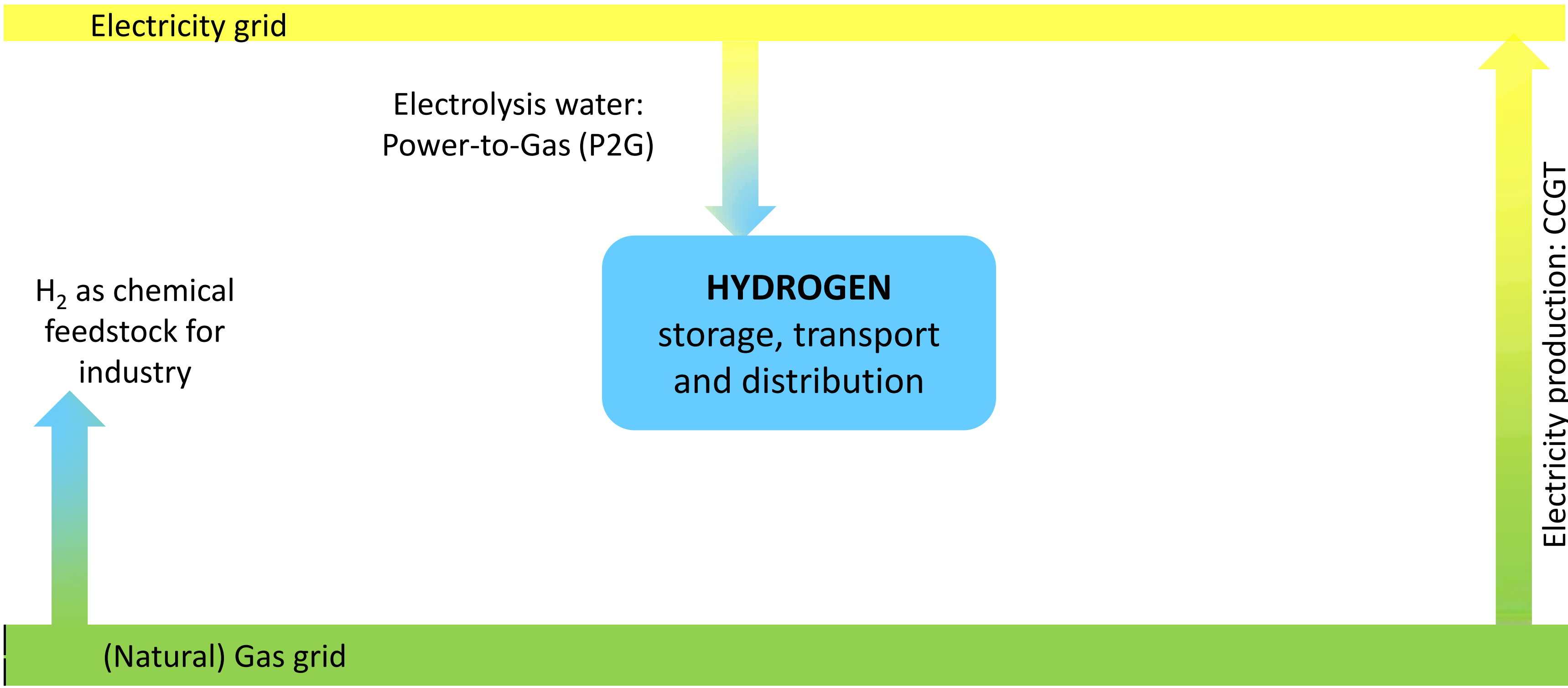
alliander, ebn, ENEXIS, energy valley, gasunie, ROTTERDAM CLIMATE INITIATIVE, SIEMENS, TAQA, TenneT Taking power further, NUON Part of VATTENFALL, Agentschap NL Ministerie van Economische Zaken, Landbouw en Innovatie

The research leading to these results has received funding from the Dutch Top Sector Knowledge and Innovation (TKI) Programme.

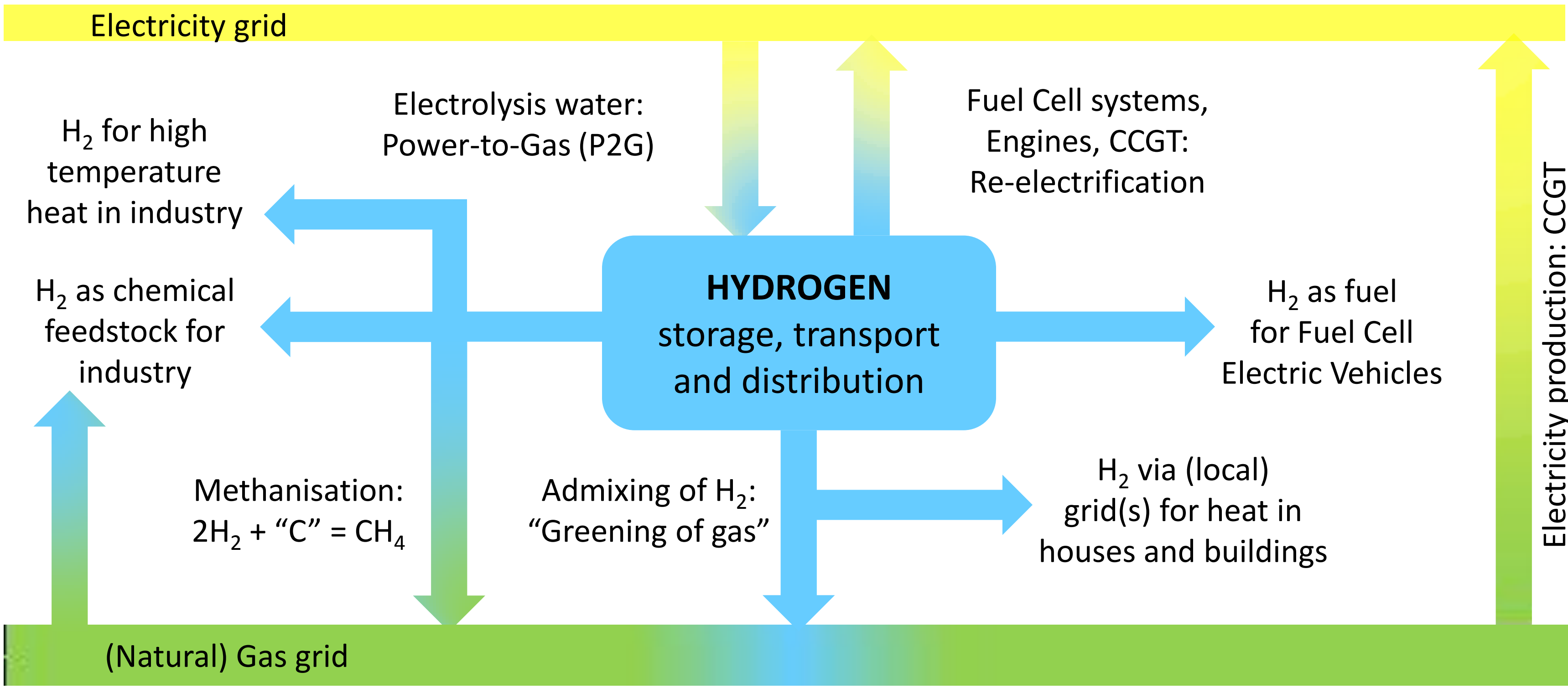
P2G, the broad definition

P2G, the broad definition
The first step is always electrolysis

ECN



P2G, the broad definition
Full overview of options



Conclusions

1. Deep CO2 emission reductions are the main driver for P2G

2. The need for flexibility alone is an insufficient driver for P2G

3. P2G mainly concerns hydrogen, to a lesser extent synthetic methane

4. Although P2G is not considered a cost-effective option from a public perspective in the short to medium term, a positive private business case for a specific, local niche application of P2G may still prove feasible

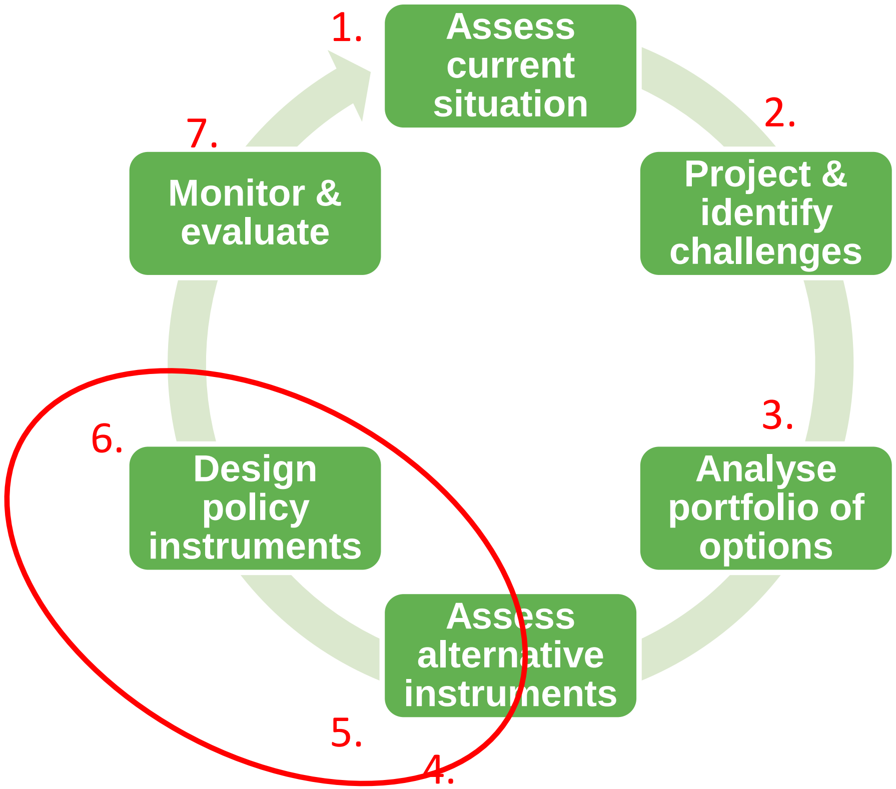
Conclusion

- Models can contribute to identifying the national possibilities, to map consequences of GHG reduction targets

- Similar approaches could be valuable for making well informed INDCs

Specific tools for policy implementation: SDE+models

Hands on tools for policy implementation



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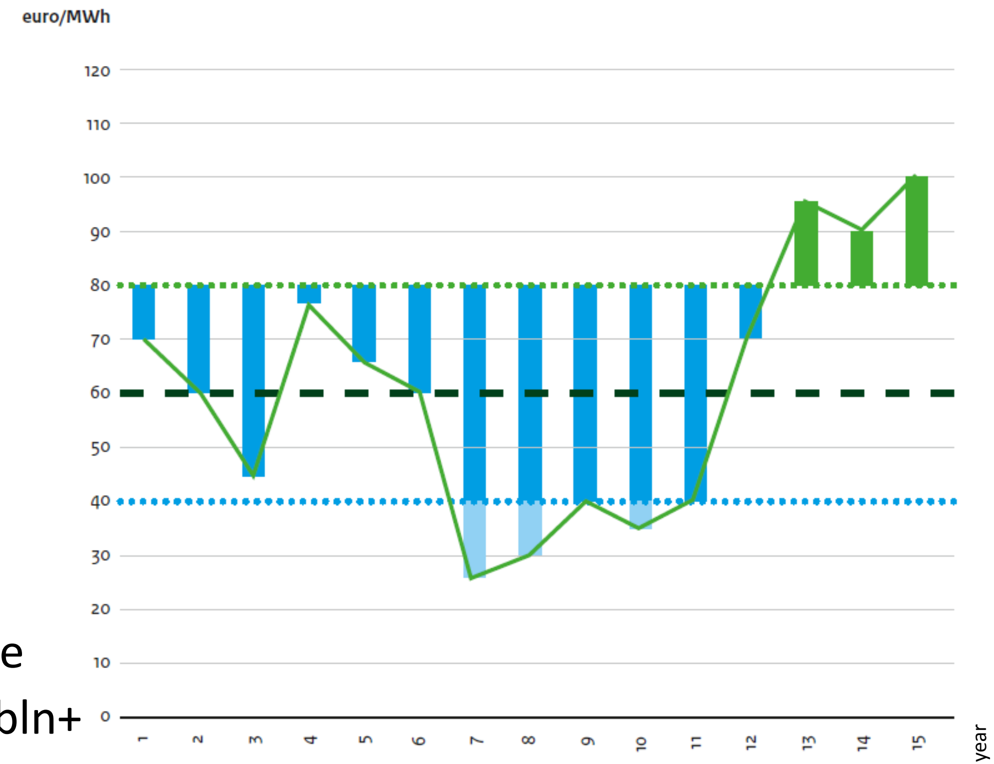
SDE+: Subsidy scheme for renewable energy

- Base rate
  - Production cost
- Correction rate
  - Market price of electricity
- Base (electricity) price
  - Floor in the correction rate
- Category specific values, annually updated

- SDE+ payment is difference:
  Base rate *minus* Correction rate
- Annual budget reservation €3 bln+



Models and data

- Base rate model (~LCOE):
  - Standardized cash flow model for energy technologies
  - Technical parameters for reference installation (inputs, outputs, capacity)
  - Cost parameters (investments, O&M, input resources (biomass), capital)
- Base price: ex ante energy prices from day-ahead trading floor and NEO electricity market model
- Correction rate: ex post trading floor statistics

Market consultation as a means of data validation

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Draft advice

- Research on technology market developments
- Model calculations leading to subsidy rates

Market consultation

- Open consultation for market parties to provide feedback
- Preferably backed up by (confidential) data

Final advice

- Research on remaining elements

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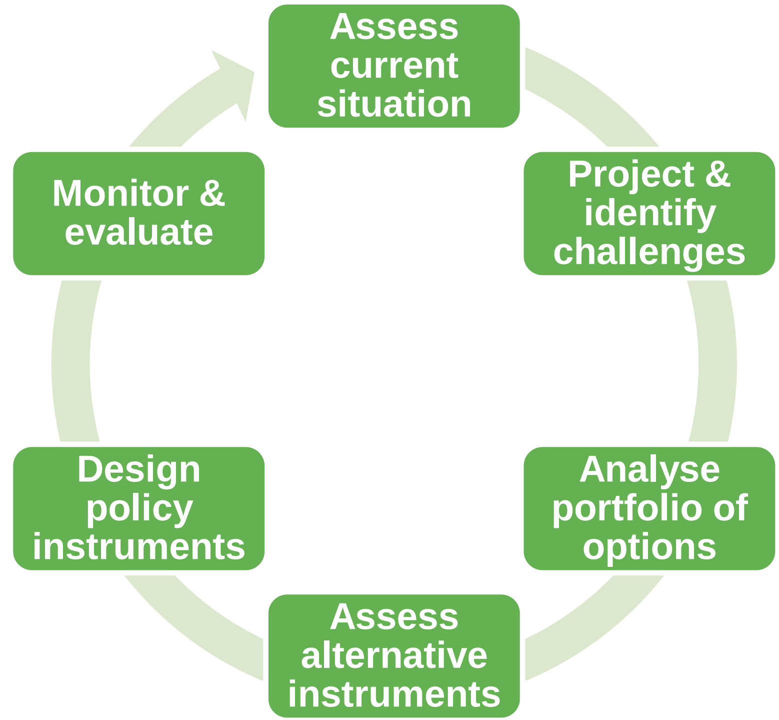
Numbers

Category	Energy carrier	Advice baserate SDE+ 2016 (€/kWh)	Full load hours-
Hydropower, height ≥ 50 cm	Electricity	0,175	5700
Osmosis	Electricity	0,612	8000
Solar PV, ≥ 15 kWp	Electricity	0,137	950
Solar thermal ≥ 100 m2	Heat	0,119	700
Wind onshore	Electricity	0,073 – 0,096	-
Geothermal heat, depth ≥ 500 m / ≥ 3500 m	Heat	0,052 / 0,055	5500 / 7000
Heat, woodpellets	Heat	0,054	7000
Thermal conversion of biomass, 10-100 MWe	CHP	0,084	7500

Building an integrated energy modeling toolbox

Models support policy

- Models are indispensable for successful energy policy making throughout the policy cycle
- Various levels of complexity possible
- Qualitative conclusions backed by quantitative assessment



What should you put in your model toolbox?

- Policy instrumentation questions require specific / sectoral approaches
  - Start with details for specific topic, and bring more and more together over time
- Energy strategy questions (e.g. INDCs) require integrated approaches
  - Start at highly aggregated level and specify details over time
- Quality data and expertise are key: "Garbage in is garbage out"

Inspirations, suggestions, questions?

Thank you for your attention

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