Guest Lecture: towards a more sustainable energy society

Martien Visser
Energy Transition & Network Integration

30 October 2014
1. General introduction
2. Energy conservation, solar & wind
3. Matching demand & supply - storage
4. Sustainable energy production
5. Buying electricity and gas
6. EU policy
7. Summary
Ireland, UK, France, Belgium, Luxembourg, Netherlands, Denmark, Germany and Poland

Northwest Europe

We consume large amounts of energy

Average energy consumption per household: (direct and indirect)

100,000 kWh

Excluding indirect energy imports

NL: 125,000 kWh
Primary Energy Sources

Source: Eurostat

1 TWh = 1 bln kWh = 100 mln m3 gas = 600.000 barrels oil = …

CO2 reduction

Data: 2012

1 kWh = …..

- Solar
- Wind
- Hydro
- Biomass&Waste
- Nuclear
- Gaseous fuels
- Liquid fuels
- Solid fuels

9%
16%
24%
34%
17%
### Conversion of energy units

#### Electricity, Gas, Oil and Coal

<table>
<thead>
<tr>
<th>Energy</th>
<th>Unit</th>
<th>Equivalent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Electricity</td>
<td>kWh, MWh, GWh, TWh (x1000)</td>
<td>1 MWH ≈ 1000 kWh (electricity)</td>
</tr>
<tr>
<td>Gas</td>
<td>m³, mln m³, BCM – 35.17 in NL; 38 MJ/m³ international</td>
<td>100 m³ (gas)</td>
</tr>
<tr>
<td>Oil</td>
<td>barrels (159 liter), bpd, TOE (1 bbl = 0.14 TOE = ton oil equivalent)</td>
<td>0.6 barrel (oil)</td>
</tr>
<tr>
<td>Coal</td>
<td>Mton (TCE = ton coal equivalent)</td>
<td>120 kg (coal)</td>
</tr>
</tbody>
</table>

**Annual consumption households (NL)**

<table>
<thead>
<tr>
<th>Energy</th>
<th>Unit</th>
<th>Equivalent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Electricity</td>
<td>kWh</td>
<td>3500 kWh</td>
</tr>
<tr>
<td>Gas</td>
<td>m³</td>
<td>1500 m³</td>
</tr>
<tr>
<td>Oil</td>
<td>barrel</td>
<td>8 barrel</td>
</tr>
<tr>
<td>Coal</td>
<td>Mton</td>
<td>none</td>
</tr>
</tbody>
</table>

≈ 30,000 kWh

Upper (gas) and Lower (coal and oil) calorific Value!

Exact numbers differ: fossil fuels are products of nature – their properties differ
Conversion processes

Major losses in electricity production

Energy conversion causes energy losses

- Efficiency coal-fired power station: 40-45%
- Efficiency gas-fired power station: 50-60%
- Efficiency Refineries: 90-95%

Transport and/or storage of energy causes energy losses (as well)

- Electricity: ≈ 5-10%
- Gas: ≈ 1-3%
- District Heat: ≈ 10-30%

Also energy production requires energy; usually not in the statistics
A coal-fired power station produces 2x the CO2 of a gas-fired power station.

1 MMBtu ≈ 30 m3 gas ≈ 25 liter diesel
Not only CO2 is different

Comparison between diesel and LNG

From 2015 onwards, the usage of heavy fuel oil for shipping will be reduced
Development of “Small Scale LNG”

Various examples worldwide

A rapid expansion may be expected, but infrastructure is lacking and taxes are a risk.

Current wholesale natural gas prices are 50% of current diesel prices (ex tax)
For electricity, network costs are about equal to the energy costs!

For households, infrastructure costs are fixed. For business, they depend on the annual peak demand.
Typical demand pattern of gas and electricity

City of Groningen, data 2012

On average, peak demand for gas (heat) is 10x peak demand for electricity
Gas usage for heating purposes scales with ambient temperature
Design effective temperature in NL: -17 °C

Data city of Groningen in 2012
Contents

1. General introduction
2. Energy conservation, solar & wind
3. Matching demand & supply - storage
4. Sustainable energy production
5. Buying electricity and gas
6. EU policy
7. Summary
Why is energy conservation not popular?
An example about energy conservation

Subtropical swimming pool in Zuidlaren

- Research by Hanze University
  - Savings: 10,000 m3 annually, costs €7000
  - How many solar panels would be needed to achieve the same result?
    - All-in costs for a solar panel about €400,-

The annual production of a solar panel is about 100 kWh
Energy Conservation in Practice

Many small measures, continuous efforts

Pay-Back: 3 years ....

How to make fun of energy conservation?

- Operational Measures
- Isolation of external slide
- HeatSavr to reduce evaporation
- New Ventilation System
- New Heating System
- ......
Energy Conservation

Cascading Energy

• The use of the residual heat in liquids or steam from one process to provide heating, cooling, or pressure for another process; e.g., the use of steam from an electric power plant in a district heating system

• Energy at higher temperature is more valuable than energy at a lower temperature

• Combustion of fuels creates temperatures of 1000-1500 C
  – Cogeneration: waste heat (500 C) from power production to generate steam
  – District Heating waste heat (typically 100 C) for heating houses
  – Use waste heat to pre-heat combustion air
e.g. condensing boilers at home

Energy can not disappear = law of physics!
Rapid development of solar energy worldwide

Growth figures are similar to computer industry

Current annual production capacity of solar panels is 50,000 MW
Cost development roof top systems

Germany; large scale solar PV is much cheaper!

For more than 30 years, any doubling of solar capacity results in a 20% price reduction.
Solar Production: geography matters

Europe is not an ideal location for solar energy

Look for solar energy developments in China, India, Africa, USA, Australia, ....
Prospects of wind energy in Europe

North Sea area, the UK and Ireland

Wind Energy ≈ (V)^3

- location
- vegetation
- height (!)

- standard: 3 MW @ 85 m
- new: 6 MW @ 120 m

Wind energy expected to grow substantially

Dutch Government wants to have built 10.500 MW of wind by 2023
To compare: the average Dutch electricity demand is 15.000 MW

Significant expansion of wind energy in UK, Germany, Denmark and NL: North Sea Area
Wind production and wind speed

Typical curve for a wind turbine

In Europe, wind patterns may extend over 100 km or more
Economics of Wind energy are difficult

An example of a possible future

If the wind around the North Sea blows everywhere, the wind turbines will cause an over supply of electricity and electricity prices will drop; will subsidies be needed forever?

Economics of solar will be similar
1. General introduction
2. Energy conservation, solar & wind
3. Matching demand & supply - storage
4. Sustainable energy production
5. Buying electricity and gas
6. EU policy
7. Summary
Comparison between wind and solar energy in Northwest Europe

Measurements in 2012 at airport Groningen

Production characteristics solar
Annual ≈ 1100 x peak capacity
Summer ≈ 10x winter

Production characteristics wind
Annual ≈ 2200 x peak capacity
Winter ≈ 1.5 x summer

Note: Solar and Wind are predictable, but not controllable
Energy Demand and Production

Energy storage is needed

Assumed: in 2035, Groningen has become an all electric city and all houses and commercials use heat pumps to heat their houses.

The energy demand for transport has been neglected.

Research by Hanze University: potential energy demand and wind production pattern in Groningen in 2035; on an annual basis, 200 wind turbines produce enough energy for the city.

Back-up required from conventional power stations, or energy storage.
Energy storages of various forms

Beware of the double log scale !!
Storage of electricity is still (?) extremely expensive.

Costs for storage of electricity >1000x gas.

- **Car Battery**: <1 kWh
- **Norg Storage**: 5 BCM (= 50 bln kWh)

Investments:
- Costs of E-storage: car battery: € 100,- per kWh
- Costs of gas storage: “Norg”: € 0,10 per kWh
- A gas storage has a life time of 50-100 years...
- A household requires about 2000 kWh of E-storage (or 500 m3 gas)

If you want to become a multi-billionaire, invent a cheap and reliable electricity storage!
Contents

1. General introduction
2. Energy conservation, solar & wind
3. Matching demand & supply - storage
4. Sustainable energy production
5. Buying electricity and gas
6. EU policy
7. Summary
Renewable Energy Production

Mainly biomass

- Biomass
- Wind
- Solar
- Hydro
- Geothermal
- Wave energy
- ...

About 65% of renewable energy in EU is biomass and 15% is hydro – NOT SCALABLE
Should we co-fire biomass in coal-fired power stations?
Buying (green) Energy

System with Certificates

- **Green Certificates**
  - Sustainable electricity: CertiQ
  - Sustainable gas: Vertigas

- **Sustainable energy production**
  - Certificates granted per kWh of m3 green energy produced
  - European system
  - Including Scandinavian hydro

- Green energy = normal energy + green certificates

- Discussions about Scandinavian hydro & co-firing of biomass
1. General introduction
2. Energy conservation, solar & wind
3. Matching demand & supply - storage
4. Sustainable energy production
5. **Buying electricity and gas**
6. EU policy
7. Summary
Price formation of electricity and gas commodity on spot markets

Electricity and gas are different

- **Natural gas is an energy source**
  - You have to be lucky to find it
  - You can only produce it once
  - State controlled companies: Statoil, GasTerra, Gazprom, ...

- **Electricity is an energy carrier**
  - You can produce it (or not)
  - It requires an energy source to produce
  - Usually, private companies (power generation): E.On, RWE, Vattenfall, Eneco, EdF, ..

- **Gas, oil and coal**
  - International markets & geopolitics
Spot markets are in development

Example of TTF, the Dutch gas spot market
Global wholesale Natural Gas Prices

10 $/mmbtu ≈ 10 \times 0.8/30 = 23 \, \text{€ct/m3} = 2.3 \, \text{€ct/kWh}

Current gas price is 25 €/MWh

What is a reasonable natural gas price?
Wholesale electricity prices
Governed by the merit order

Due to the introduction of renewables, electricity prices tend to decrease.

Current E-price is 50 €/MWh

Renewables’ effect on the electricity pool price

Pool price
A relatively small amount of wind power displaces the higher bids, and can mean the highest bid accepted under the previous scenario is no longer needed, so the overall electricity pool price is lowered.

Offers are still accepted in order of price, but the entrance of renewables shifts the stack across.

50 €/MWh
Energy Price formation occurs on spot markets

Many different spot products are traded

- Within day, Day ahead
- Week, weekend,
- Months: November, December, ...
- Quarters: Q1 2015, Q2 2015,
- Years: 2015, 2016, 2017

- Electricity: base load and peak load
- All spot products are ‘flat’

- Real energy usage has a pattern – aggregators

See websites of APX and ICE-Endex
Buying Energy

An energy bill is rather complex

<table>
<thead>
<tr>
<th>Category</th>
<th>Component</th>
</tr>
</thead>
<tbody>
<tr>
<td>Commodity</td>
<td>Volume</td>
</tr>
<tr>
<td>Network costs</td>
<td>Peak capacity</td>
</tr>
<tr>
<td>Distribution costs</td>
<td>Peak capacity</td>
</tr>
<tr>
<td>Metering Costs</td>
<td>fixed, size dependent</td>
</tr>
<tr>
<td>Connection costs</td>
<td>fixed, size dependent</td>
</tr>
<tr>
<td>Certificates or CO2 credits</td>
<td>Volume</td>
</tr>
<tr>
<td>Service Margin</td>
<td>Volume or peak capacity</td>
</tr>
<tr>
<td>Ecotax</td>
<td>Volume (in tranches)</td>
</tr>
</tbody>
</table>

( VAT Volume and capacity )

Lowering your energy bill: reduce volume or peak capacity
1. General introduction
2. Energy conservation, solar & wind
3. Matching demand & supply - storage
4. Sustainable energy production
5. Buying electricity and gas
6. EU policy
7. Summary
Regulations to reduce CO2

EU policies – World wide results needed

- Small energy users
  - Regulations, incentives, …
  - LED lights, cars, vacuum cleaners etc..

- Large energy users
  - CO2 trading, permitting, ‘voluntary’ agreements

- Carbon Emission Trading Scheme (ETS)
  1. Industries get CO2 emission rights (for free)
  2. Amount of CO2 permits decreases in time
  3. Industries may sell unused permits or buy additional ones
Price of traded CO2 emission rights

CO2 prices are low: why?

A CO2 price of about €50/ton is required to convert coal to gas in power generation.

- 1 m3 gas => 1,8 kg CO2
- 10 €/ton => 1,8 €ct/m3
EU environmental policy

Levels compared to 1990

- **Current policy**
  - 2020
    - 20% less CO2
    - 20% energy conservation
    - 20% sustainable energy

- **Proposed by the EU leaders**
  - 2030
    - 40% less CO2
    - >27% energy conservation
    - >27% sustainable energy

Discussions on a global level in Paris 2015: China, India, USA, ....
1. General introduction
2. Energy conservation, solar & wind
3. Matching demand & supply - storage
4. Sustainable energy production
5. Buying electricity and gas
6. EU policy
7. Summary
Summary

1. Limit demand for energy through rational use of energy
2. Use renewable energy to fulfill remaining demand
3. Use fossil fuels, if necessary, as efficiently and cleanly as possible

Trias Energetica