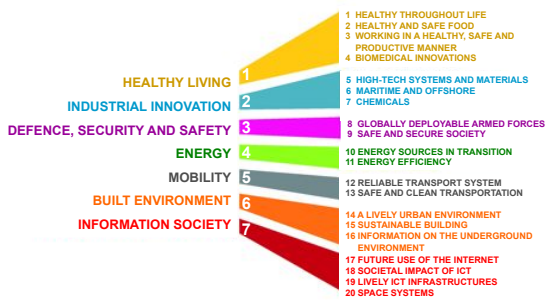

## TNO – Nederlandse Organisatie voor Toegepast Natuurwetenschappelijk Onderzoek

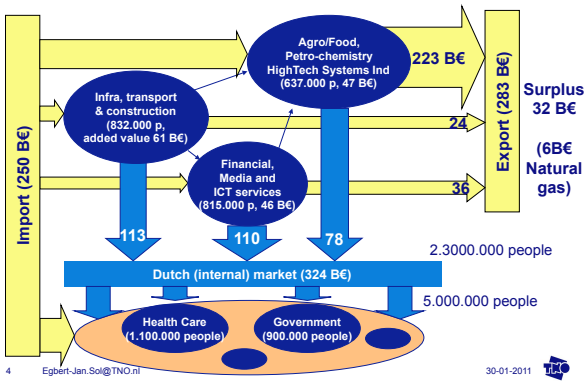
- Mission: *TNO connects people and knowledge to create innovations that boost the sustainable competitiveness of industry and well-being of society*
- *Established: 1930 by law*
- *People: 4000+*
- *Turnover: 500M Euro public*
  - *100M Euro in TNO startup*
- *Business model (10%, 40%, 50%)*
  - *Own research (IP at TNO)*
  - *Joint Programs (IP as in Holst)*

## Our areas of innovation



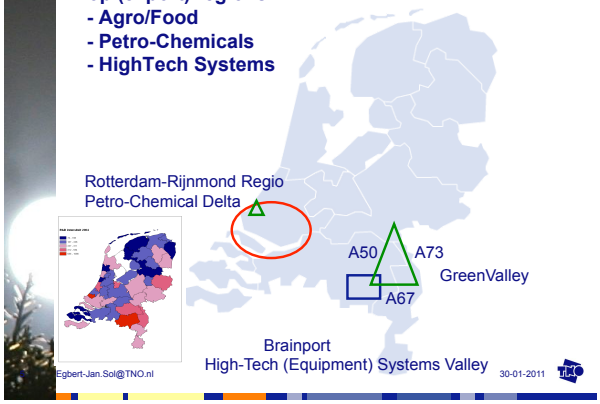



## Where do we create & consumer value in the Netherlands






## Top (export) regions
- Agro/Food
- Petro-Chemicals
- HighTech Systems




## Content


- Introduction
  - TNO, added value, region
  - History & Long-term economy
    - 6th Kondratieff - sustainability
- Agro/Food
  - Food Jetter
  - Energy Farm
- Chemergy Rotterdam
  - Adding value to bulk streams
  - From fossile to C-1 economy
  - Super Systems
- HighTech System Valley – Brainport
  - Regional specialized eco system
  - From semi to semi/LED/solar equipment
- Summary

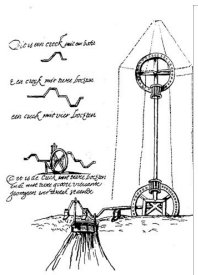

## Netherlands – 1500-1600

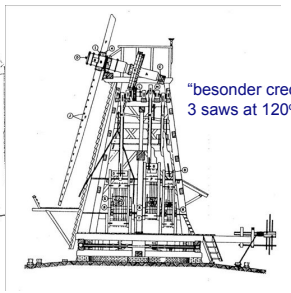
- Catholic Spanish King in Brussels
- Trading wood/grain with NW Europe for exchange with southern goods until blocked by the Spanish
- 80 years war in a cold swamp area in NW-Europe
- Republic of the 7 Provincien




## Cornelis Corneliszoon van Uitgeest

1593 basis patent sawing mill, 6 dec 1597 the improved crankshaft





"besonder creckwerk"
3 saws at 120°

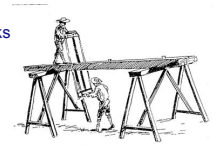


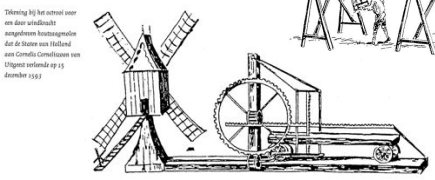
## Cornelis Corneliszoon van Uitgeest

inventor (1593) enabling Holland's Golden Age (1600-1750)

Sawing a tree took 2 men 30 weeks

A sawing mill took 1 week





Still today we know hardly anything on Cornelis van Uitgeest



## From Golden Age to Stagnation & Crisis of 1850

- 1500 Rotterdam 500 people and Erasmus
- 1580-1670 Upswing of the Dutch Golden Age
- 1670-1750 Height of Golden Age
- 1750-1850 Stagnation
- 1777 Nederlandse Maatschappij voor Nijverheid en Handel (Economische tak van Hollandsche Maat. Wetenschap.)
- 1793-1810 Franse overheersing
- 1813-1848 Willem I (1815-1830 Belgie, canals, railway 1839)

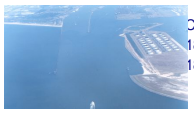
- 1760-1860 Rotterdam became isolated harbor
  - West via Hellevoetsluis & Kanaal door Voorne
  - East via Hollands Diep, Dordrecht, Oude Maas Vlaardingen, Nieuwe Maas to Rotterdam

- 1858 Idea of Caland to re-establish (concentrated) river flow
- 1863-1872 Nieuwe Waterweg through dunes at Hook of Holland



## From the Crisis of 1850 to 1900

- 1858 Idea of Caland
- 1863-1872 Nieuwe Waterweg through dunes at Hook of Holland
  - 450 m at end of Scheur to 900m at HvH
  - Criticism: you need locks as North Sea Canal in A'dam
  - 1872-1881 not 7 m, but 3 m deep, too wide
  - 1881-1895 8 m, and big success



- 1860 Suez Canal and larger (steam) boots which needed open access
  - Area of mass mobility started
    - Old "stapelhandel" changed into "transito" handel
      - Transito needed faster turnover
        - thanks to Caland Rotterdam became succesfull-winner
        - tonnage went from 0,3 Mt in 1850, via 6 in 1900 and 400 today
      - Amsterdam got stuck in "stapelhandel" & limited by lock size
      - Vlissingen got stuck in difficult (rail/road) connections to Germany
      - When Caland retired he got a nice letter, that's all



## Rotterdam, yesterday and today

- 1500 Rotterdam 500 people and Erasmus
- 1600 The Dutch Golden Age (Windmills 2 man in weeks 30 to 1)
- 1850 Isolated harbor – with Caland's idea and steam Nieuwe Waterweg
- 1900 Transito area - start of mass-transportation
  - 6000 ton grain transito took 126 men 882 workdays
  - Grain elevators took 14 men 56 workdays (16 to 1)
- 1950 Time period of "easy oil" and expansion Europoort
- 2000 Largest container harbor in a globalizing world
  - But 5 out of 6 habor labor jobs disappeared (6 to 1)

- Today: facing less growth in Europe, growth explosion in BRICKs, scarcity in rare materials, fossil energy and climate risks

- But also a very efficient and competitive complex of very large systems serving the energy supply and materials of hundreds of millions of customers; it's a 50 x 5 km area for 100-250 M customers

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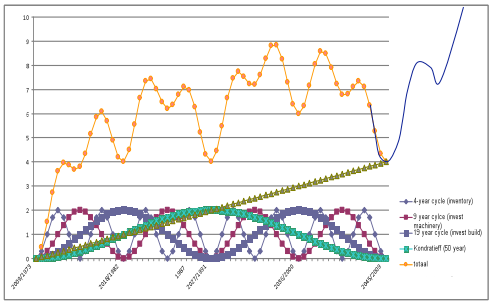
## Grote leugens, kleine leugens en computer grafieken

(5 jaar, 10 jaar, 20 jaar (bouw) en 40 jaar (Kondratieff)

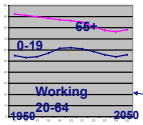





## Long term waves in economy: Kondratieff

(0-wave: Dutch + 0 Industrial Revolution (Wood/Wind, 1600-1750) ejs)
1-wave: French + 1st Industrial Revolution (Iron/Steam 1785-1845)
2-wave: Marx + Steel Industry (Steel/Railroad 1845-1900)
3-wave: Capitalism + Electricity (Chemistry/Car Engine 1892-1948)
4-wave: Consumption + Oil (1948-1990)

**5-wave: trigged by "*computer as communicator*"**
***value creation by handling information***
***cheaper and faster (from mainframe,***
***micro-computer to mobile devices)***

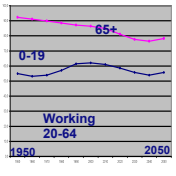


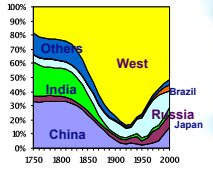

**Kondratieff:**
- a combination of technology & society
-during upswing a lot changes rapidly (1990-2010)
- after 20 years it gets quiet again,
as our society grows elder, 2010-2030

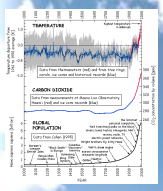


## Challenges for the next decades

Create value with less people,
with less materials and less energy



Learn from history: Kondratieff waves
improvements by Perez



## Metals 2030 : demand versus production

(Source: Institute for Futures Studies and Technology Assessment (IZT) / Fraunhofer ISI, 2009)

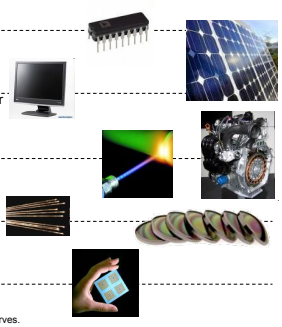
**Gallium** (used in LEDs, solar cells, IC's): 6 x

**Indium** (transparent electrodes in LCD, mobile phones and solar cells): 3 x


**Neodymium** (lasers, electrical power): 3 x

**Germanium** (fibre glass and IR optics) : 2 x

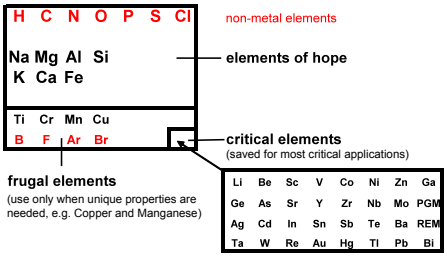
**Scandium** (fuel cells) : 2 x



China has 70% of Indium and 97% of Neodymium reserves.
Mid-African countries have monopoly of Cobalt (wear-resistant alloys) and Tantalum (capacitors).

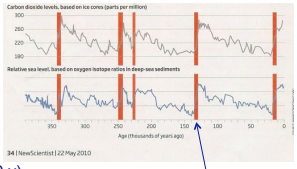


## The "Elements of Hope"




- Elements of Hope are abundant in Earth's crust, oceans and atmosphere
- The challenge is to realize desired functionality of products with Elements of Hope and to develop processes for production at an economic scale

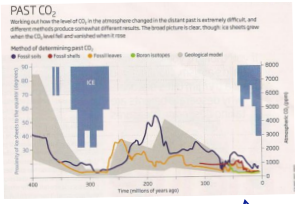
## Save the Planet (is really: save us)



- Mankind:
  - Lucy 4 My
  - more signs 1 M
  - Homo Heidelberg (300.000 y)
- Last 2 ice age (100.000 y) periods 6 m delta in less then 100 years of a period from max ice to no ice of 5000 years
- Last century: rise in order of decimeter, this century in order of meter?
- Today CO2 380 ppm and rising rapidly (max fossil 440 ppm)
- Back to Miocene (20My ago): 6 ºC warmer & 40 m sea rise in ?????y
  (New Scientist, 22 may 2010, p36 (and the good new is: no ice ages any more))



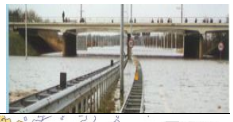
## Earth Climate: Moderate or Monster

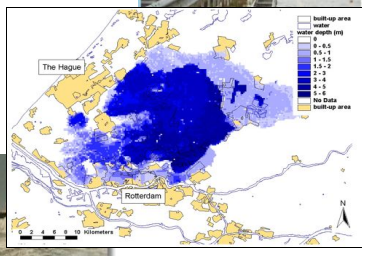



- Earth 4.5 Billion years old
- Sun heat increases by 40% over 10 Billion years, we are half way
- First Billion years, more CO2, creating a warm blanket when sun was still cold
- Ice ages 2.2B ago, then 1B year warm period, then the super ice age
- 300M y again huge period of ice ages with low CO2 (New Scientist, 26 jun 2010)
- Last 2M years ups & downs, last 1M years 4 period around CO2 220-280
- Sea level can be -120 m below and 75 m above today's level
- Antarctica and Greenland 15% of world area (Wikipedia) and 1500 m land ice, if melted 65 m sea level rise



## This is our problem: Water from 4 sides – sea, river, rain, soil








## What will happen by 2015-2020

- BRICKs economy will grow rapidly, increase in demand for energy and materials, not for 1B, but for 5B consumers
- Energy prices and minerals grow more the rapidly, because of minimal price elasticity: with huge demand, price explosion
- Then every country want to lower it dependency on fossil fuels, but installing sustainable solutions is too expensive,
- Need for more sustainable energy, even 10-20% in NL creates a huge demand for indium for 1000+ km2 solar cells or neodymium for high power magnets for 10.000+direct drive windmills
- And then models for land-ice melting in Antarctica gets accurate and CO2 reduction is desperately pursued to avoid wakening a climate monster.
- This is a prefect storm scenario



## Other scenarios

| | |
|---|---|
| Black Swan | Surprising invention and we live happy after |
| Gran Traditionne | More of the same, but with some tensions |
| Closed continents | Europe is lacking resources (depleted), cost welfare |
| Perfect Storm | Tensions all over, drop in welfare, some win, many loose |
| WO III | Everybody looses |

- Fixed
  - BRICKs will (at least initially) continue to grow fast
  - Fossil fuels and minerals will get more expensive
- Scenario invariance – postpone/delay hitting the wall
  - Lower consumption patterns (less usage, smaller products)
  - Secondary mining (recycle) and cradle to cradle designs
  - Substitution and Elements of hope
  - Early start and rapid deployment of transition to sustainable energy

- Technology will play a key role, so we better take the lead, develop innovative solutions and accelerate the introduction of those greener solutions
- By 2040 clean energy become more and more abundant available, recycling works as planned
- There is enough for everyone's need, but there is not enough for everybody's greed



## Improvements on Kondratieff waves

- Kondratieff (1930) – basic mechanism
  - Predictions in Stalin period resulted in death in Goulag
- Perez (2000)
  - Improvements in interactions in technology and financial mechanisms within a Kondratieff cycle of 40-50 years
    - (2010 financial crisis, next one is technological crisis)
    - (2000 was Internet bubble, 2020 ?? Energy scarcity??)
- Current Kondratieff wave – end of 5th – depression/stagnation – then 6th
  - 5th digitalization (computers, mobile telephony, Internet, mobile data)
  - Global economy, open innovation, but also looming scarcity issues, elderly population, climate risks
  - (relatively) Less growth for many years to come (debt restructuring, high(-er) prices for energy and raw material, wealth shifts)
- Note (ejs): nr 0 took 150 years, then 60, 55, 50, 40, 30

## 6th Kondratieff 2020-2050 Sustainability

- Nr 5 from 1990-2020 society adapts fast to new tech
- New tech takes/took 25-30 years from idea to 1% use and another 30 years from 1% to massive use
  - Internet 1960-1985, now 2010 everywhere
  - Co-operative driving 1990-2015 (1%), 2040 standard
- The 6th is about sustainability – (you can't predict the future:Jules Verne)
  - if company, region adapts to sustainable before 2020 and full sustainability by 2050, they continue to growth, else they dissolve in history (too expensive, etc)
  - Renewable energy, green/biobased energy/raw materials, nano-technologies (small products)
  - Rotterdam, is not sea containers, but Chemie+Energy=Chem/nergy
  - The Caland of 2050 is working now on that technology



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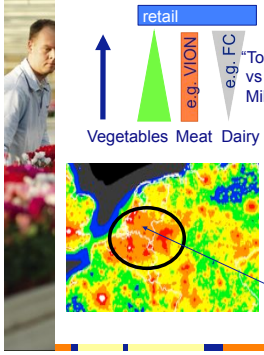
## From Agro/Meat/Dairy to … Food Value chain



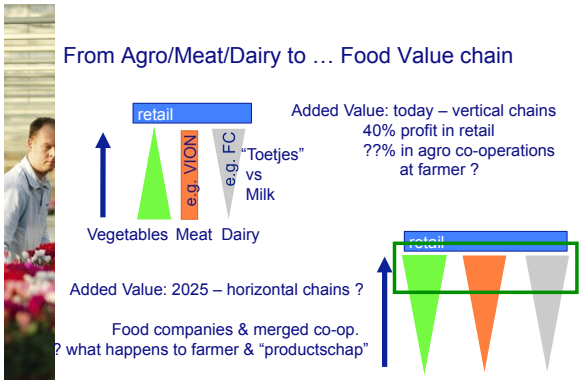

## State-of-the-art for printing food

sugar structure made with (crude) Rapid Manufacturing (Printing)

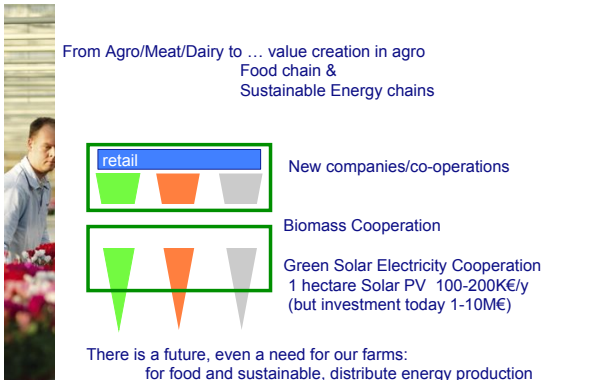

writing on toast

Food Printer (picture from MIT)
(TNO food senseo - jetter)

## From Agro/Meat/Dairy to … Food Value chain




## From Agro/Meat/Dairy to … value creation in agro Food chain & Sustainable Energy chains



## Energy Storage: Chemergy Industry

Photons
Free Electrons
→ Big-Bang (few sec.)

Hydrogen ($H_2$) — Sun (100 Million °C)

Hydrocarbons → Earth with our T and pressure

methane ($CH_4$), Ethane ($C_2H_6$), Propane ($C_3H_8$), .., Petrol ($C_8$...$C_{10}$), Diesel (~$C_{12}$)



## Agro Future: Energy Farms

**Solar in => Energy out**

Energy values grades

100% Solar

- Energy for Humans
  - Food

1%

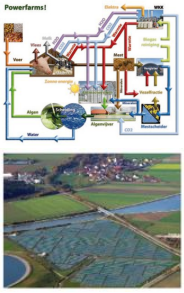
- Energy you can storage & transport
  - Biomass
  - Biofuel

10-20%

- Energy you can transport
  - Electricity
    - Solar panels (PV)

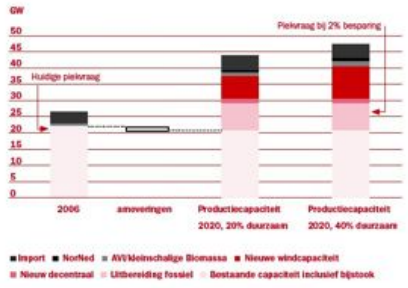
50%

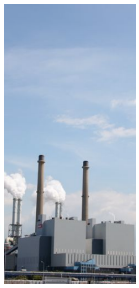
- Energy you must local
  - Low caloric heat
    - (Solar collectors)






## Electrical Power production – Challenges: capacity





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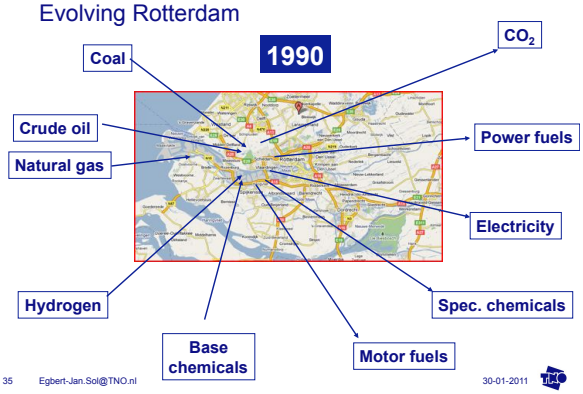
## Evolving Rotterdam



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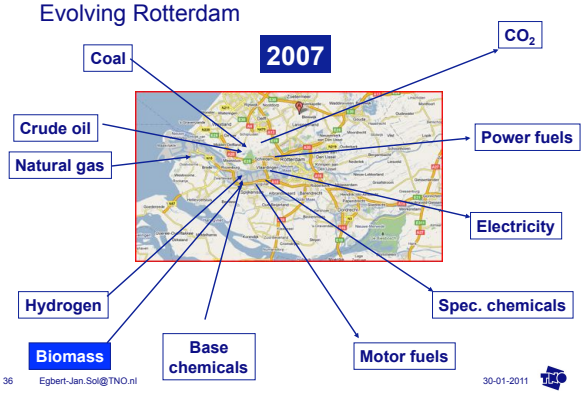
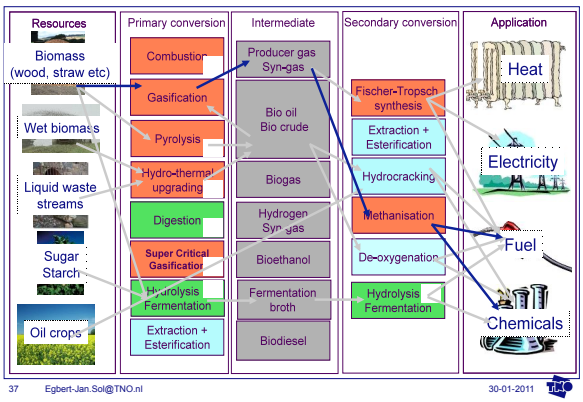
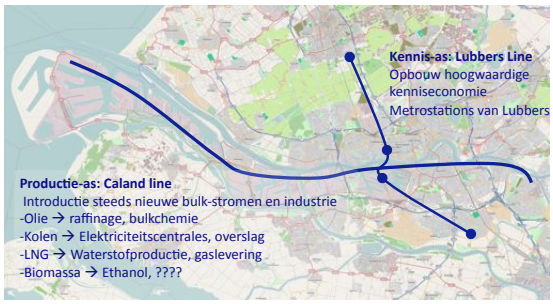







## Contouren van de visie



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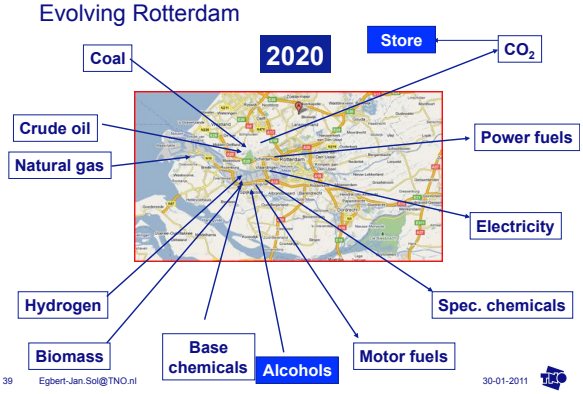




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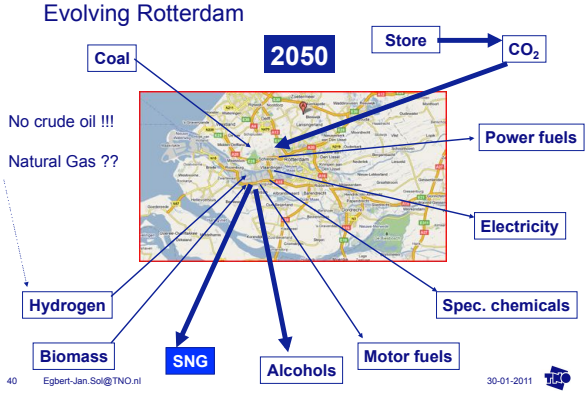




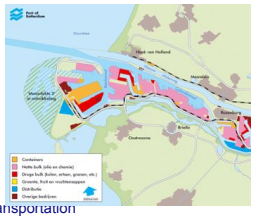

## Super Systems:
## Large Installations of 1+ BEuro & 40 years lifetime

(Not discussed, but also needed)

- Mix into refinery becomes more complicated
  - More sour oil, mixture of biomass
  - Old designers and skilled operators grow old (retirement)
  - Inter dependencies grow future
  - New technologies as process intensification
  - Larger mix in output request
  - Safety requirements become more complex (In overregulation fire department becomes over powerful)
  - Maintenance only possible with simultaneous shutdowns
- We need a new paradigm of super systems with a plant captain (gezagvoerder) with all the (digital) tools to control (monitor & plan) production, safety & maintenance in one hand
- This requires a generations of (digital) plant CAD-alike models



## Rotterdam, another 50 years



- 1500 Rotterdam 500 people and Erasmus
- 1600 The Dutch Golden Age
- 1850 Isolated harbor
- 1900 Nieuwe Waterweg and start of mass-transportation
- 1950 Time period of "easy oil" and expansion Europoort
- 2000 Largest seacontainer harbor in a globalizing world

- **Still a very efficient and competitive complex of very large systems using the economy of scale in processing large volumes**
- **Why invest in a Betuwe line to lower the transaction costs for the Chinese to sell theirs goods in Germany**
- **2050 The leading sustainable Chemergy/Chenergy Delta of the world**

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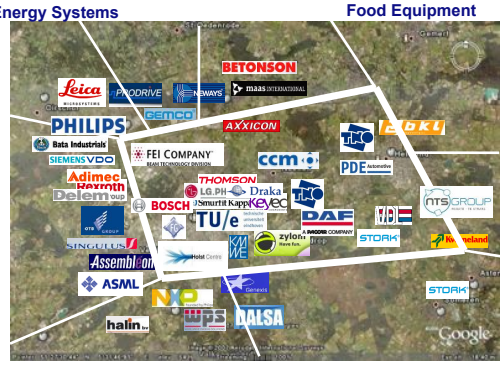
## High Tech Industry clusters in Europe


Bron: IPTS/ETEPS/MERIT (SC36)

Energy Systems

Food Equipment




Electronics

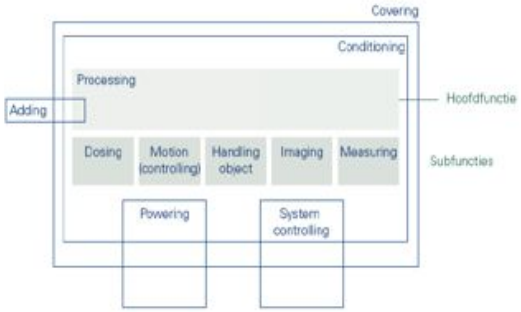
Automotive

45

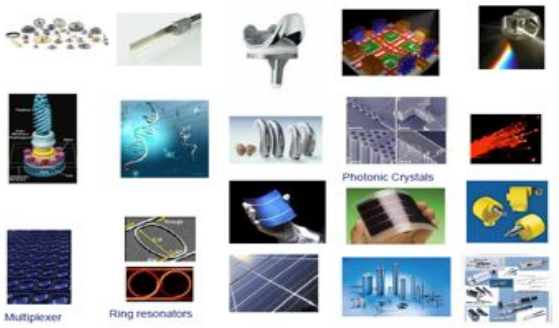
## High-Tech (Equipment) Systems Valley of Europe


## High-Tech (equipment) Systems

## Architecture for High-Tech (equipment) Systems



## Components & Modules for High-Tech Systems




## Manufacturing technologies for HTS

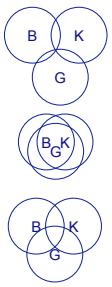
- Assembly
- Joining (welding)
- Metrology
- Cleaning
- Molding
- Removing (milling, etc)

- Additive

Note: At TNO we made a choice –
stop research on anything above 1 millimeter
focus only at additive processes at micro/nano/atomic level

## The Triple Helix model

**from open innovation to open governance**




B=Business/Companies
K=Knowledge/Uni's & Labs
G=Government

Sub-optimal – too less, no help

State monopoly – too rigid,
over-regulated

Balanced Triple Helix
e.g. accelerating co-operation
to acquire public/EU funds

The challenge is the tricky balance, not too much or too less with three parties (with two it will not work!!)



## I want my factories back

- Prof Westkamper: 13 april 2010 Valencia
  - "Lost factories never come back"
- Why factories back?
  - Not a smoking chimney as on the road sign, but
  - A **factory** is where a society **concentrated** its **value creation**
  - Social & political attention is on consumption, i.e. cost creators
  - But how much attention is spent on **value creation**
  - No factories, no value creation, no welfare
    - "and lost factories never come back"

## The grand challenges & value creation

energy and material savings/healthcare and aging society/low hydrocarbon eco./
sustainable mobility/sustainable consumption & productions/and JOBS, JOBS, JOBS

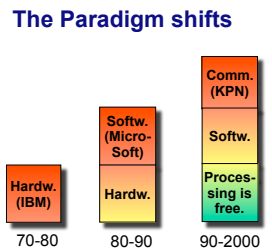
Avoid losing factories by improving them: factory with a (digital) future
And create new factories for new products: factories of the future

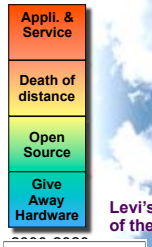
- **Factories with a future – the high-performance, digital factory**
- **Down-town production: onsite configuration, customized**
  sustainable consumption, sustainable mobility in mega cities, minimal transport
- **Green factory: low to zero emission, close loops (C2C)**
  sustainable production, energy & material saving/recyling
- **Next Gen IT for production: RFID, Robotics, Aging society**

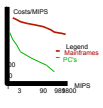
- **Factories for the future –**
  **volume production and resource lacking, knowledge rich Europe**
- **Key Enabling Technologies**: photonics, nanoelectronics, nanotechnologies, biotechnologies, advanced materials
- Creating macro value by adding material at nano-micro scale
- Semicon fabs (chips), Photonics fabs (SSL (O)LED, Solar PV), Pharma, ..)

Factory of the future = Factories with & for the future

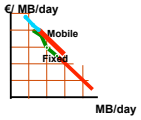
## The Paradigm shifts



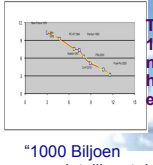




Moore's Law



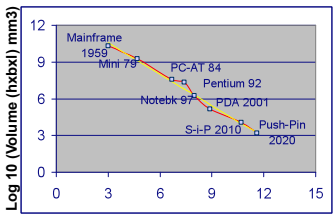

"A dollar a day"



"1000 Biljoen intelligent devices"

## Learning curve for smart devices

(from mainframe to ambient push-pin computer)



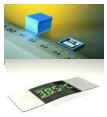

Log 10 (Cum. Amount of devices) 6=1M, 9=1B

Note: SiP = System in a Package

9 = 1B 10x10x10 cm (1 liter) devices by 2000

10 = 10B 5x5x5 cm PDA/phones by today

11 = 100B 1 cubic" (2,5 cm) devices by ? 2010



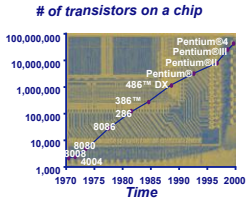
25 mm x 25 mm x 25 mm

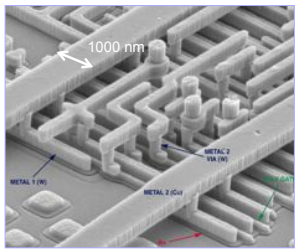
1 mm thick x 125 mm x 125 mm

12 = 1000 B 1x1x1 cm devices by ? 2020

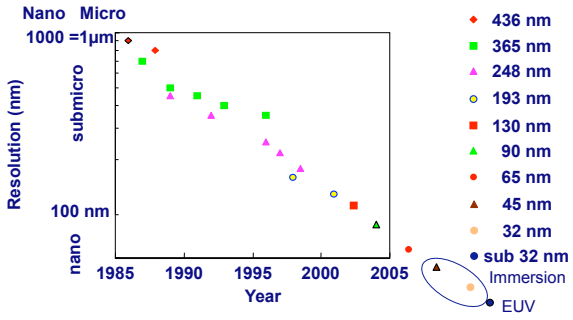


## Moore's law for Integrated Circuit build up



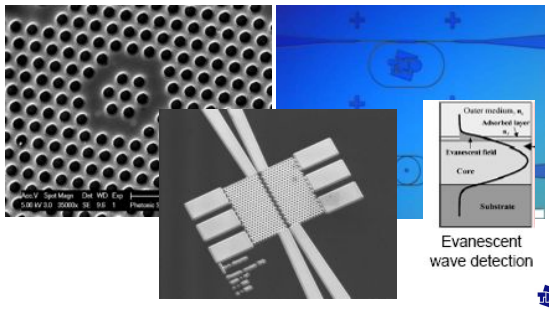

## From Micro-Electronics to Nano-Electronics




## And from NanoElectronics to NanoPhotonics

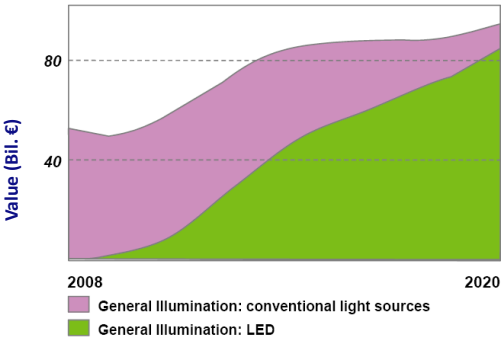
Photonic Crystal Cavity Sensors

Ring Resonator Sensors

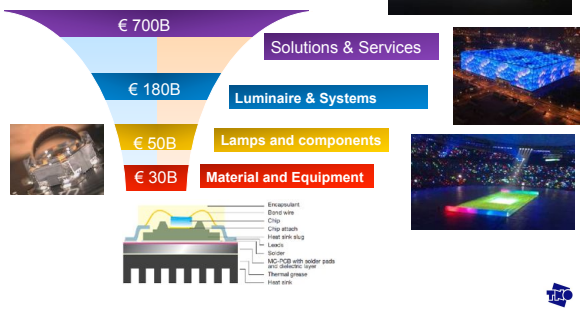



Evanescent wave detection

## Lighting Industry Transformation



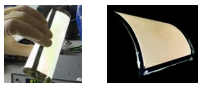

## Lighting's Economics (2020)



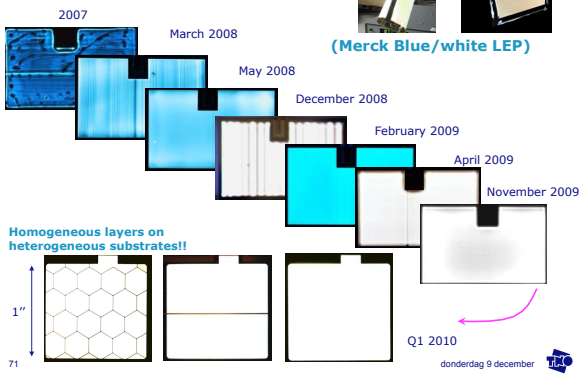
LED GaN based


## PRINTED ORGANIC LIGHTING (OLED)

Progress in Inkjet Printing of OLEDs



(Merck Blue/white LEP)




Homogeneous layers on heterogeneous substrates!!

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donderdag 9 december

Signage devices:

Safety and Healthcare: Stair Lighting

United Kingdom:

250.000 accidents/ year, stair fall every 2.5 minute

100 fatal, 100.000 injuries

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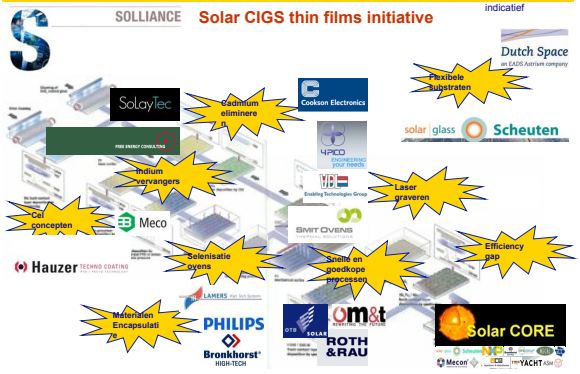
donderdag 9 december

## SOLAR

indicatief



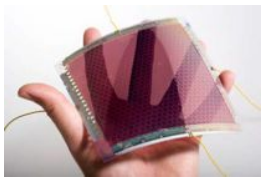
Efficient flexible solar cells:


**Light weight, building integrated: >$10^5$ km²/year required**



## ORGANIC PHOTOVOLTAICS

- Program by ECN and TNO in frame of Holst Centre
- Focus on Roll-to-Roll technologies for Organic PhotoVoltaics
- Transfer ideas and concepts between R2R OLED and R2R OPV



Holst Centre

ECN

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## Trend: From Meter via Millimeter, micro to nano meter

Trend Manufacturing: Meter sized metal constructions (pre 1950)
Value creation at Electronics tubes at millimeter precision
Micro electronics
Nano lithography

Trend Processes: Meter sized vessels and refinery columns (400 years)
Value creation at Process Intensification with millimeter Lab-on-Chips
Micro droplet printing, or jetting
Nano manipulation at molecule level

Trend Food Preparation: Mixing in pots & pans to …
Value creation at controlling food & nutriënts at millimeter level

**Chocolate & sugar structure made with (crude) Rapid Manuf. printing**


## From mainframe to smart push-pins 3-times an order of 1000

Scale log mm³:
1890 US census (human & electro-mech)
12 1940 relay based cryptography 1000 m3 (= 10 x 10 x 10 m)
11 1955 vacuum-tube 100 m3 (= 5 x 5 x 5 m = 125 m3)
10 1959 mainframe discrete transitor Appollo 10 m3 (=2.5 x 2.5 x 2.5 m = 15,6 m3)

9 1970 minicomputer integrated circuit 1 m3 = 1000 dm3 = 10^6 cm3 = 10^9 mm3
8 1979 microcomputer = human body 100 dm3 =(50 x 50 x 50 cm3)
7 1984 AT 36 liter, 1988 Pentium 22 liter 10 dm3 =10 liter (15 lt = 25 x 25 x 25 cm3)

6 1992 notebook 2 lt 1 dm3 = 1000 cm3 = 10 x 10 x 10 cm3
5 2000 PDA = appx 5 cm3 100 cm3 = 5(12,5) x 5 x 5(2) cm3
4 2008 SiP = appx 2,5 cm3 cubic inch 10 cm3 = 2,5 x 2,5 x 2,5 cm3
1 mm x 12,5 cm x 12,5 cm

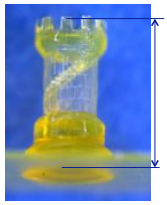




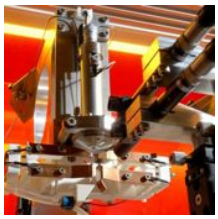
3 2017 cubic centimeter 1 cm3 = 1000 mm3 = 10 x 10 x 10 mm3
2 2025 intelligent push-pin (punaiske) 100 mm3

- Dimensions: pin length 10 mm by 1 mm
  top 10 mm diameter by 1 to 2 mm thickness
  volume: pi x 5 square x 1 + 10 = 100 mm3

## TNO Jetters (Ink-Jet Printing)

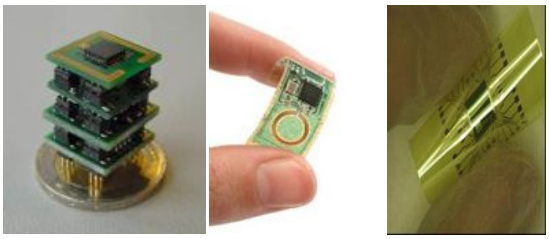


3 mm high

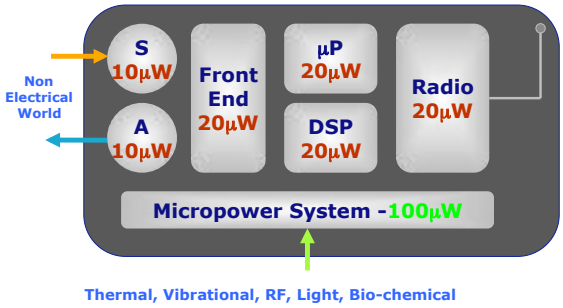


## WATS – SIF integration

- Many smart autonomous sensor devices in various shapes, networked together…



## Low power electronics: The Challenge



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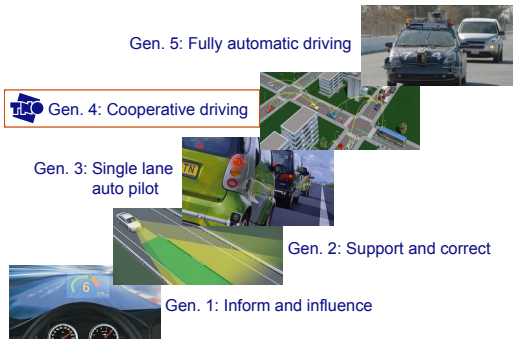
## The grand challenges & value creation

energy and material savings/healthcare and aging society/low hydrocarbon eco./ sustainable mobility/sustainable consumption & productions/JOBS, JOBS, JOBS

Avoid losing factories by improving them: factory with a (digital) future
And create new factories for new products: factories for the future

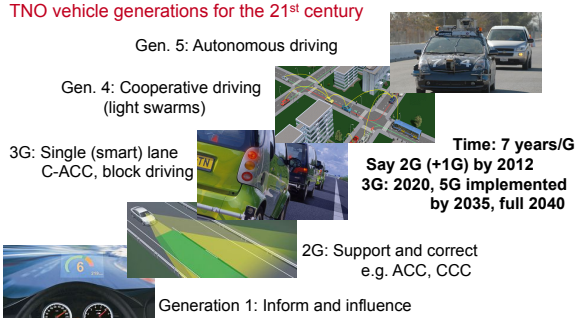
- **Factories for the future – in resource lacking, knowledge rich Europe**
  - **Key Enabling Technologies**:
    - Photonics — create value with photons (LED, Solar, PICs)
    - Nanoelectronics — electrons (Semicon, IC)
    - Nanotechnologies — atoms (layers for TV,OLED)
    - Biotechnologies — molecules (PI & BioBased)
    - Advanced materials — nano structures
  - Creating (macro) value by adding material at nano-micro scale
  - Using less material (size) in semicon, LED, solar volume markets

## Mobility - vehicle generations for the 21st century





TNO vehicle generations for the 21st century




**Time: 7 years/G**
**Say 2G (+1G) by 2012**
**3G: 2020, 5G implemented by 2035, full 2040**

Note: nG=1G+..nG, e.g. 3G=1G+2G+3G


"Frankly sir, we're tired of being
on the cutting edge of technology."
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Egbert-Jan.Sol@TNO.nl
30-01-2011