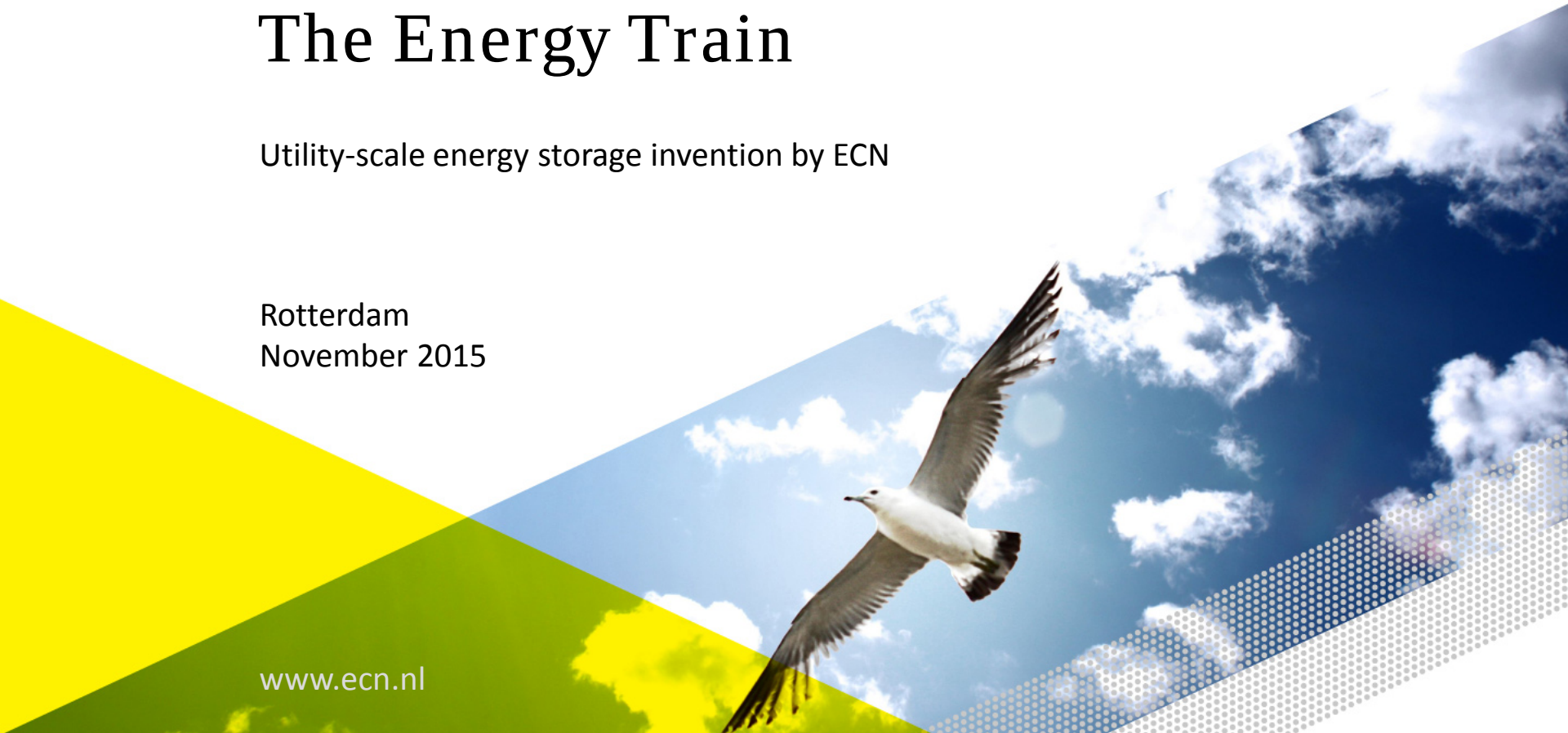
ECN
Your energy. Our passion.

The Energy Train

Utility-scale energy storage invention by ECN

Rotterdam
November 2015



www.ecn.nl

Why store energy?

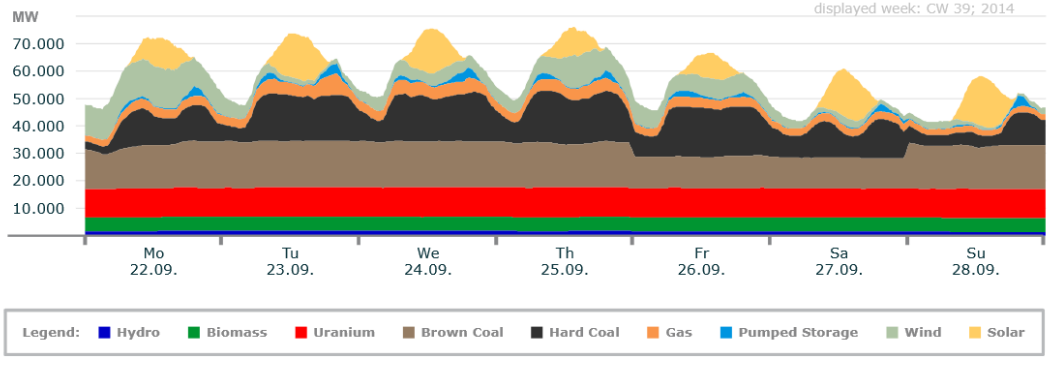
Today

1/3rd of total energy demand = electric (NL)

Managing grid:

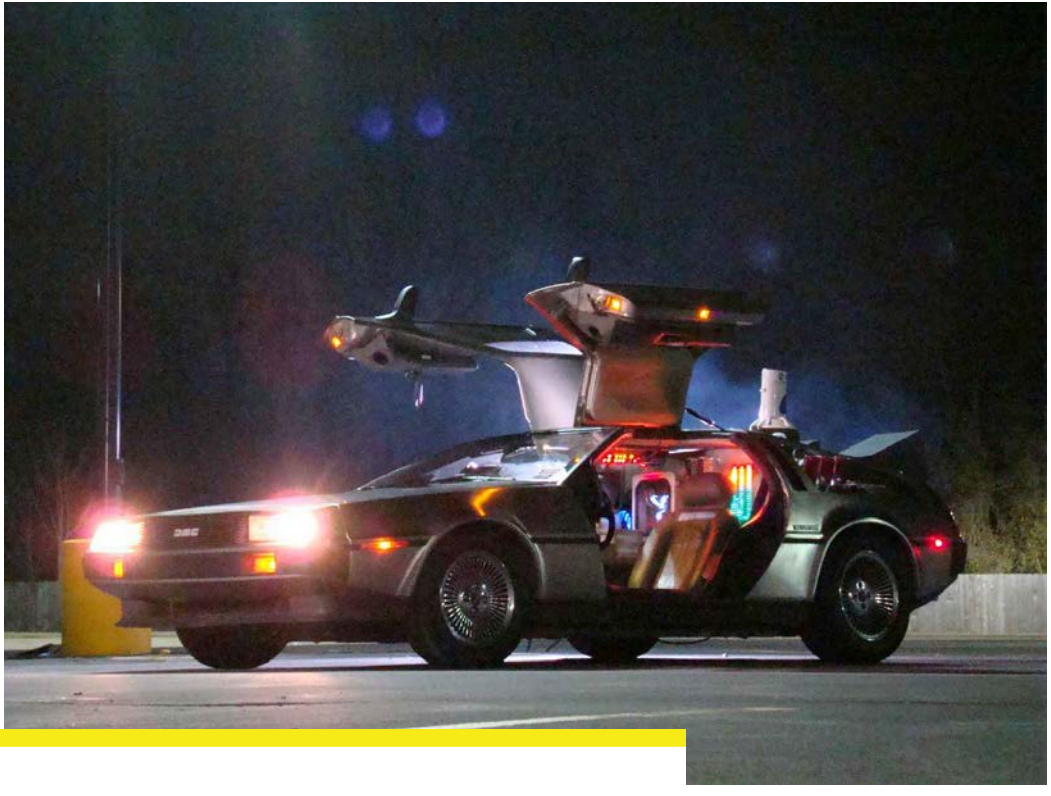
- Variability in demand > variability in supply
- Wind and solar are predictable but variable
- Goal: demand = supply
- Control:
  - Export/import
  - Reduce/increase gas/coal

Electricity production in Germany – September 2014



	Hyd	Bio	Uran	BC	HC	Gas	PSt	Wind	Solar
min. power (GW)	1.31		10.04	10.97	2.65	2.03	0	0.4	0
max. power (GW)	1.86		10.67	17.19	18.84	7.93	3.98	14.57	18.18
weekly energy (TWh)	0.27	0.86	1.78	2.49	2.04	0.59	0.13	0.89	0.66

Graph: Bruno Burger, Fraunhofer ISE; Data: EEX Transparency Platform



Let’s have a look at the future

Why store energy?

Future energy system ~ 2050:

- Transition to ~100% renewable energy sources
- Much more energy is electric

In the Netherlands alone:

- Up to 50 GW wind + 150 GW solar (peak capacity)
- Peak power capacity >> required power

Why store energy

- Variability in supply >> variability in demand

- Control:
  - Export/import (capacity?)
  - Demand side management (capacity?)

  - Reduce production if needed
    (operate wind farms as power plants)

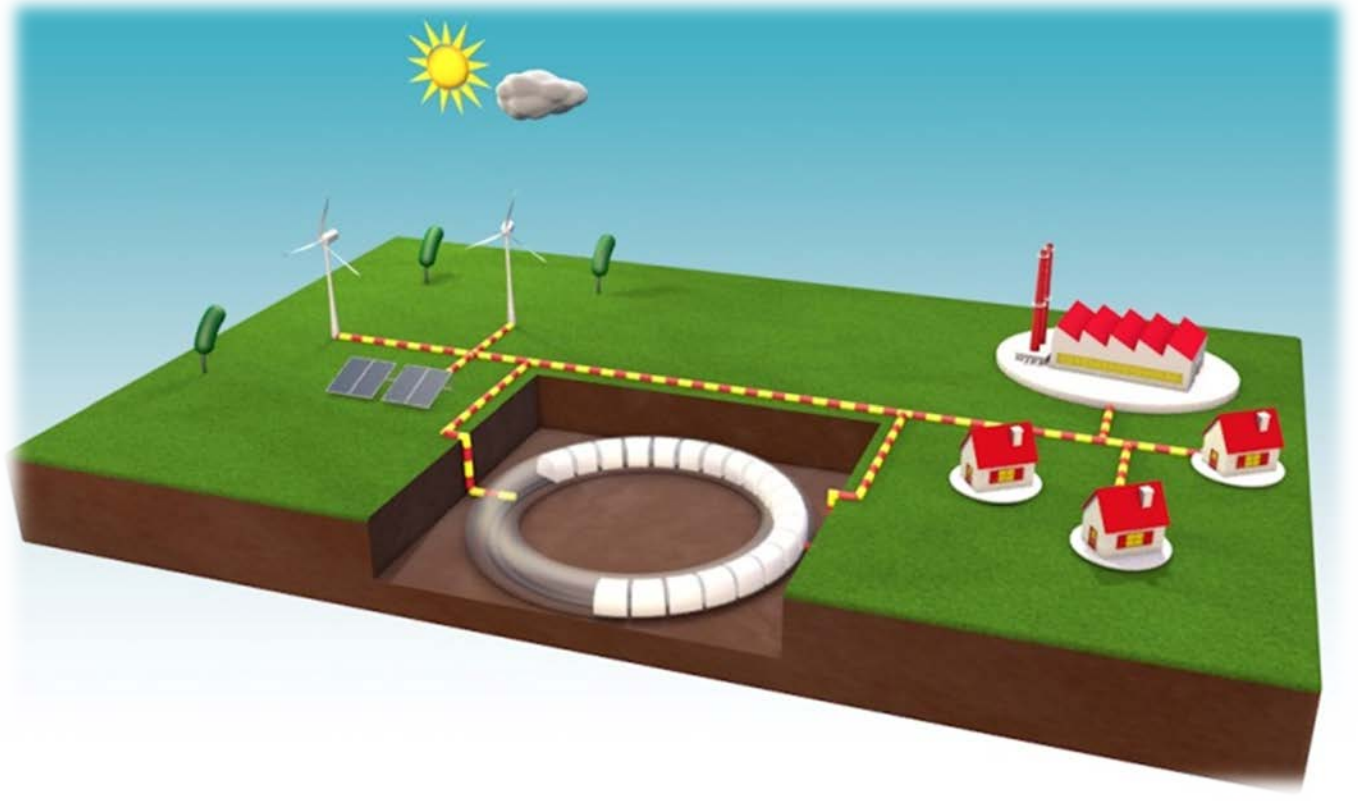
How much energy storage is needed?

- Short term: 10% of the daily Dutch electricity demand (estimate)
- Ca. 20 GWh = 72 TJ
- Equivalent to:
  - 10 kton coal (~10 000m^3) for electricity
  - 40 hrs. 500 MW offshore windfarm @ full load
  - Ca. 2 million households for 1 day (or: all households in Rotterdam for 1 week)

Ideal solution

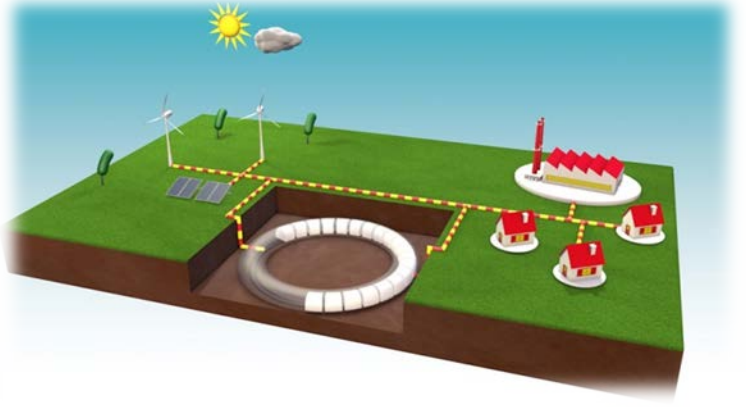
- Any loss = cost => very high efficiency
- Reacts fast
- Flexible location, little impact on land use
- Lowest cost of “energy”

The energy train



Main specifications Energy Train

- Power:
  - 2500 MW
  - 8 hrs charge/8hrs discharge
- Size:
  - Ring diameter: 5 km
  - Tunnel size: 5m diameter
  - Moving mass: 600 000 tons
  - Speed: up to 500 m/s
  - Acceleration:
    - max 10 g lateral
    - max 0.03 g tangential
- High efficiency:
  - Friction loss: <2%/day
  - Electro-mechanical propulsion
  - Maglev suspension (permanent magnets)
  - Vacuum



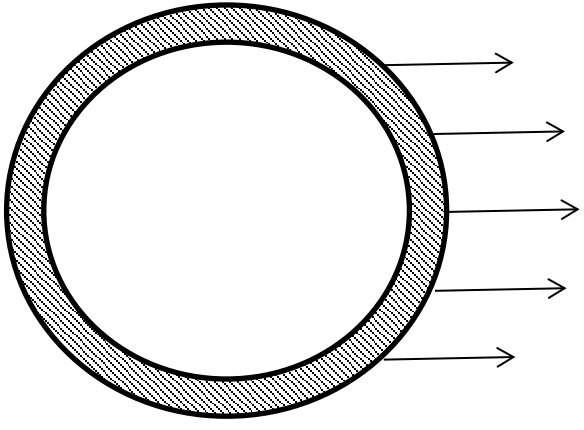
Building it now?!

- Existing technology
- But applied at a **very** large scale

- Technical challenges:
  - Maglev
  - Propulsion
  - Tunnel
  - Vacuum technology

- Socio-economic challenges:
  - Safety system
  - Environmental impact
  - Business case

Energy train in the under ground

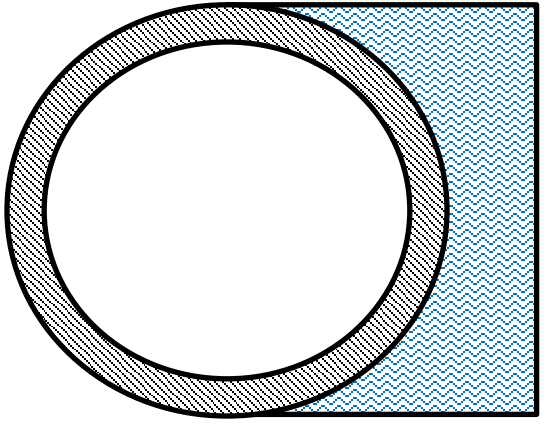


- 5 km diameter -> 15 km tunnel
- Tunnel size -> 5m
- Depth -> 10m?
- Volume displaced soil: ~0.5 Mm^3

- Tunnel not self containing for loads
  - Cyclic sideways loading:
    up to 800 kN/m^2 = 8 atm.
  - Piling?

Energy train in the under ground

- Safety buffer
  - Is it needed?
  - What will it look like?
  - Water/gravel



- Environmental impact?
- Water level?
- Other challenges?

Plan – Technical challenges

Technical trajectory

January 2016
Start Technical Feasibility

Technical feasibility
remove technical risks establish specifications for demonstrator and rough specifications for the final design

January 2018
Start small test facility design

Small scale test facilities
verify that the main technical risks are removed

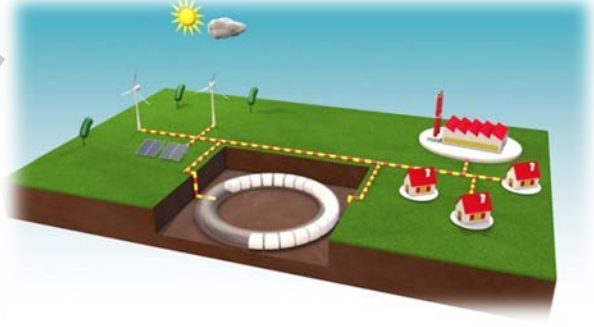
January 2020
Start Demonstrator Design

Demonstrator
design and build one or two demonstrators (scale ca. 1-5% of full scale) test whether the main specifications are met

January 2022
Start Optimisation Phase & Final Design

Testing phase
use demonstrators to optimise the system and finalize specifications for the energy train

ECN Energy Train
~2025 (start construction)



Question?

Are you ready to jump
on the energy train?

We need your help!