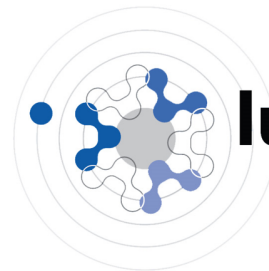


# The Five Technologies That Will Change the Way We Use Energy

Arij van Berkel, PhD  
Research Director

Prepared for:  
Lux Executive Summit  
April 5 2017



**lux executive summit**

**Boston • April 4-6, 2017**

# New energy technologies...

## What people are talking about

Jim O'Toole



SOLAR POWER

### Scientists Have Broken the Efficiency Record for Mass-Produced Solar Panels

Science Alert - DAVID NIELD



ELON MUSK

### Tesla's solar roof tiles will be available to order starting in April

TechCrunch - Darrell Etherington

The Tesla solar roof tiles the company unveiled last year, which look like regular roof tiles and yet have roughly equivalent efficiency of traditional solar power gathering cells, will be up for order starting



Clockwise from top left: Robert Galbraith/Reuters, J...

### Trump's Climate Views: Denying, Conflicting and Confusing

The New York Times - By JOHN SCHWARTZ

Scott Pruitt, the head of the Environmental Protection Agency, drew criticism on Thursday for saying that carbon dioxide was not

Add comment ▾

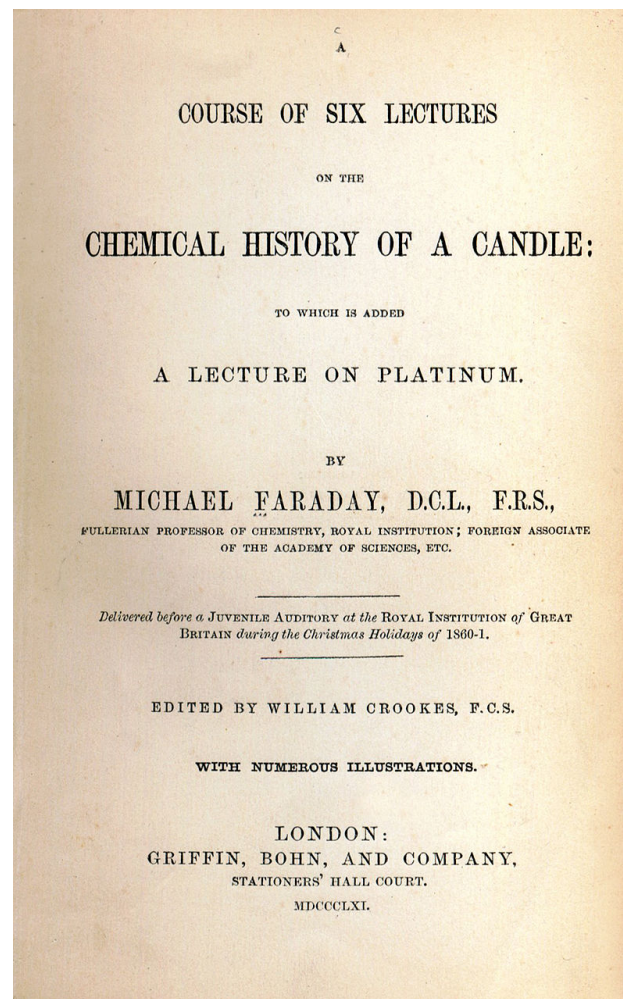
RENEWABLE ENERGY

### Harnessing the power of wind still years away for New Jersey

David Matthau

Almost seven years ago, Gov. Chris Christie signaled the state was ready to move boldly forward to

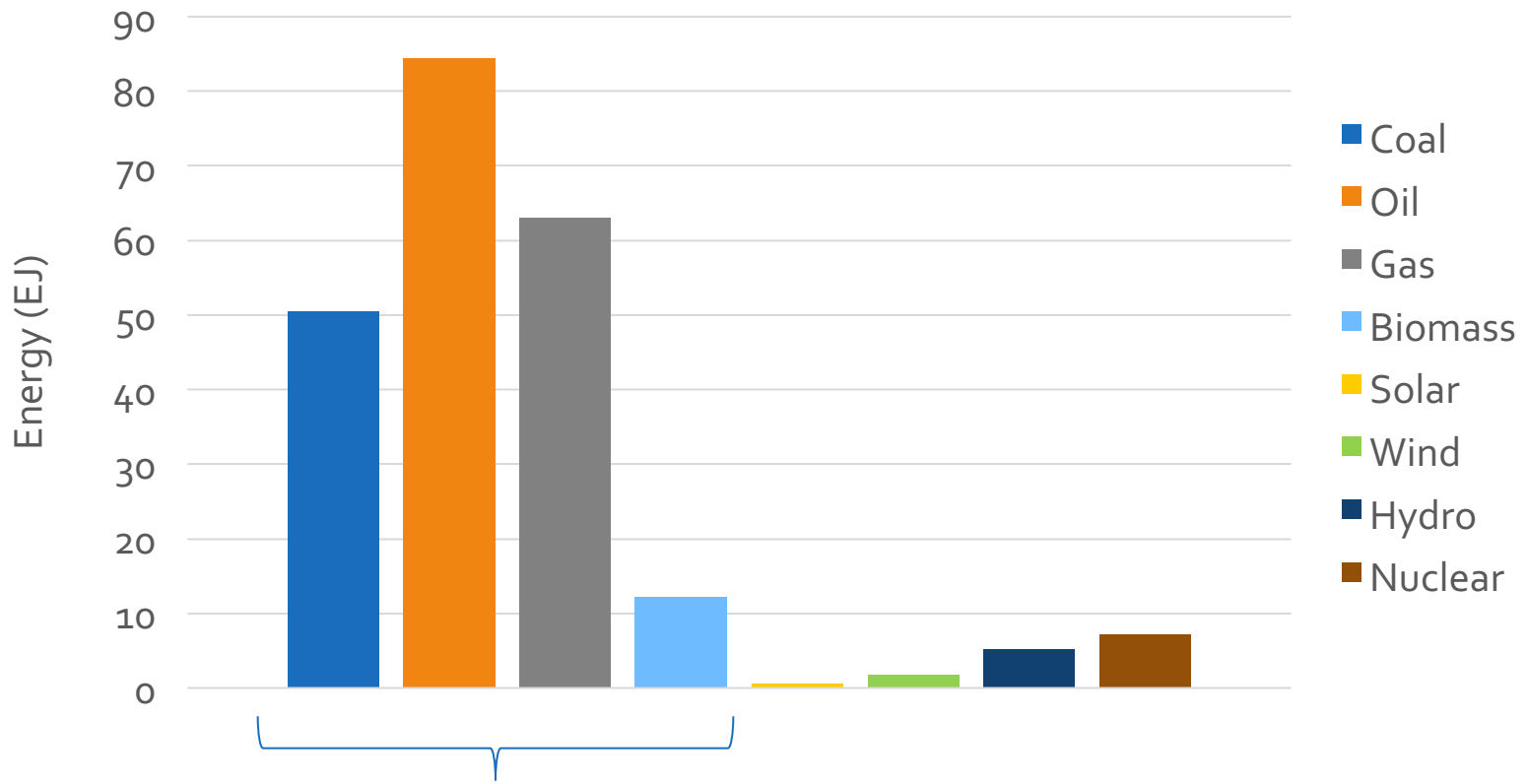
# Faraday's Christmas lectures



1848 - 1860

# The way we use energy today

Energy by primary source, OECD 2014



93% combustion based



# Combustion has its limits



$$\eta = 1 - \frac{T_0}{T}$$



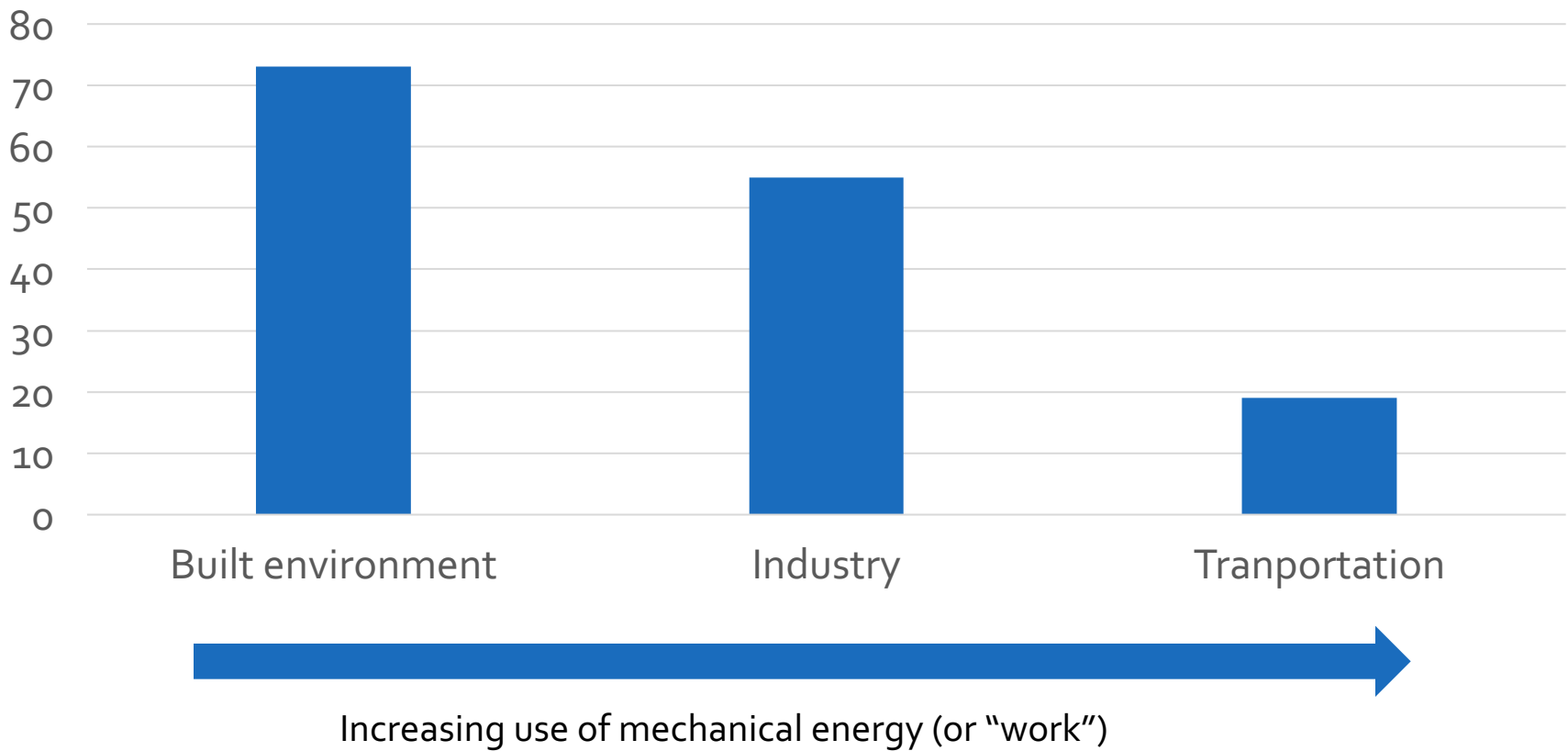
London 1952



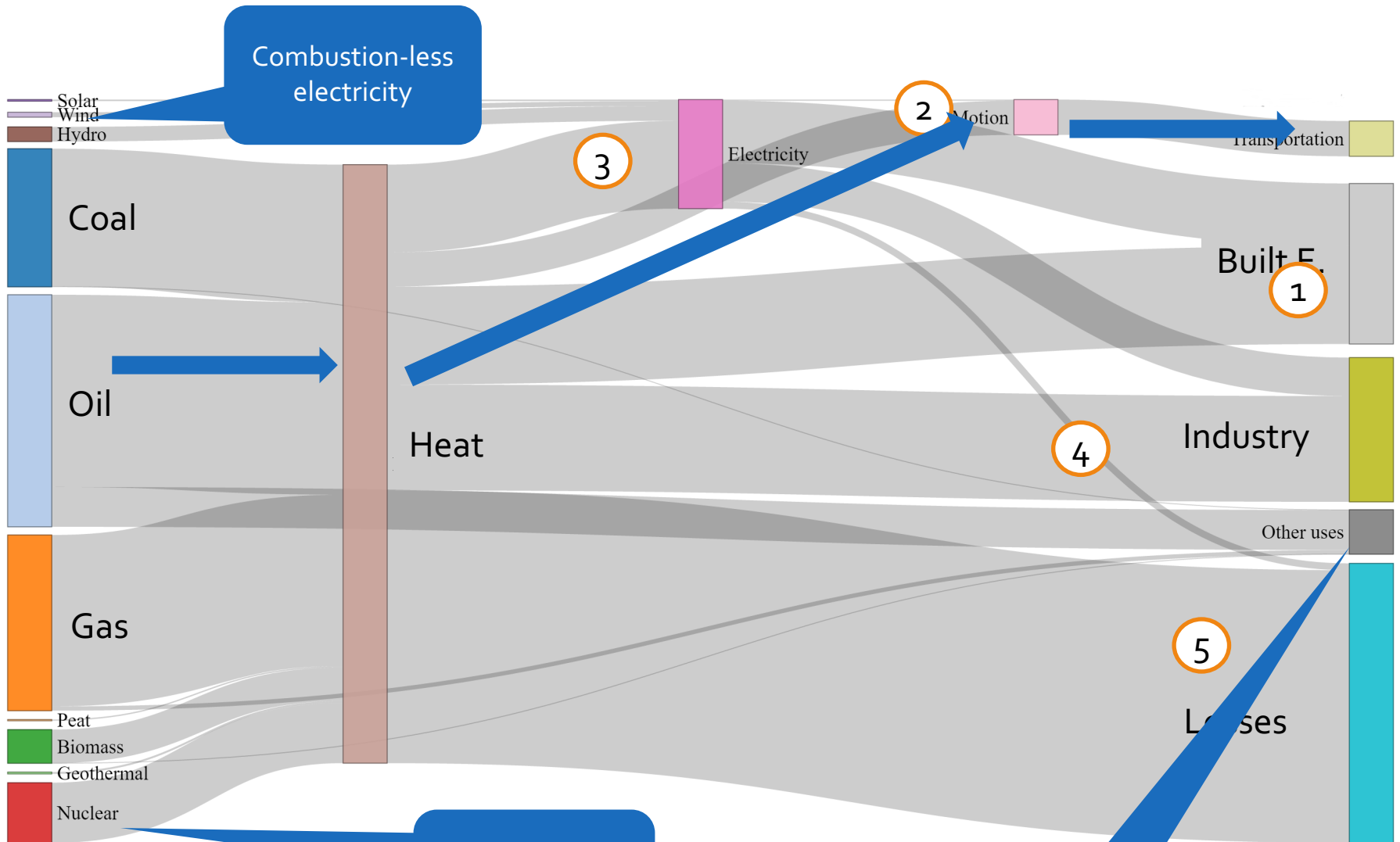
Beijing 2015

# Carnot's limit is very real

Energy efficiency of main energy users



# A closer look



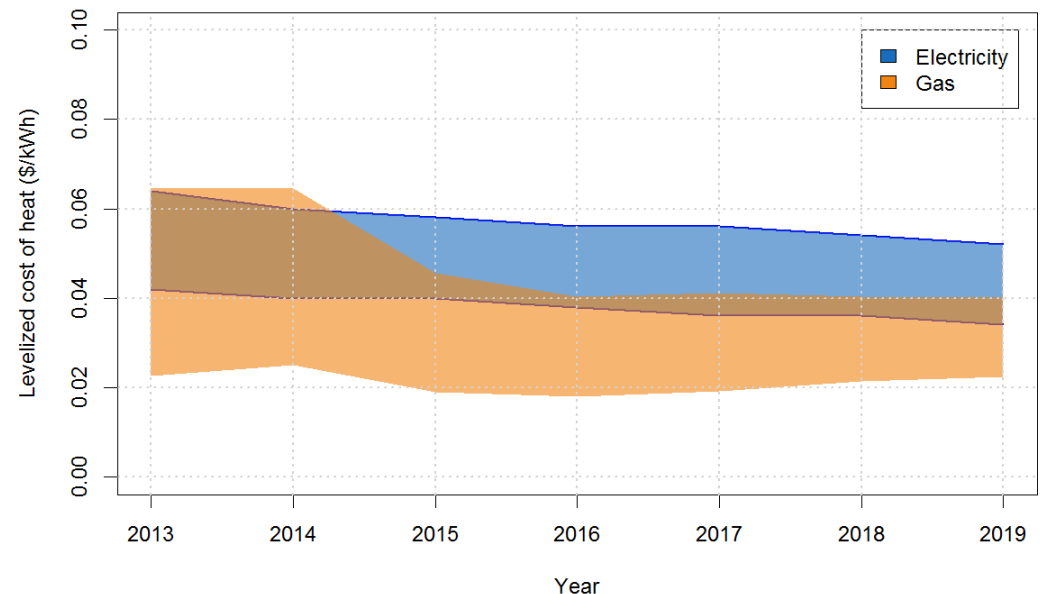
1

# Heat pumps to avoid combustion

New heat pumps for use in buildings generate on average 5 kWh of heat for every kWh electricity input



Cost of heat using heat pumps

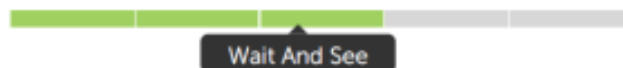




# Naked energy



## LUX TAKE



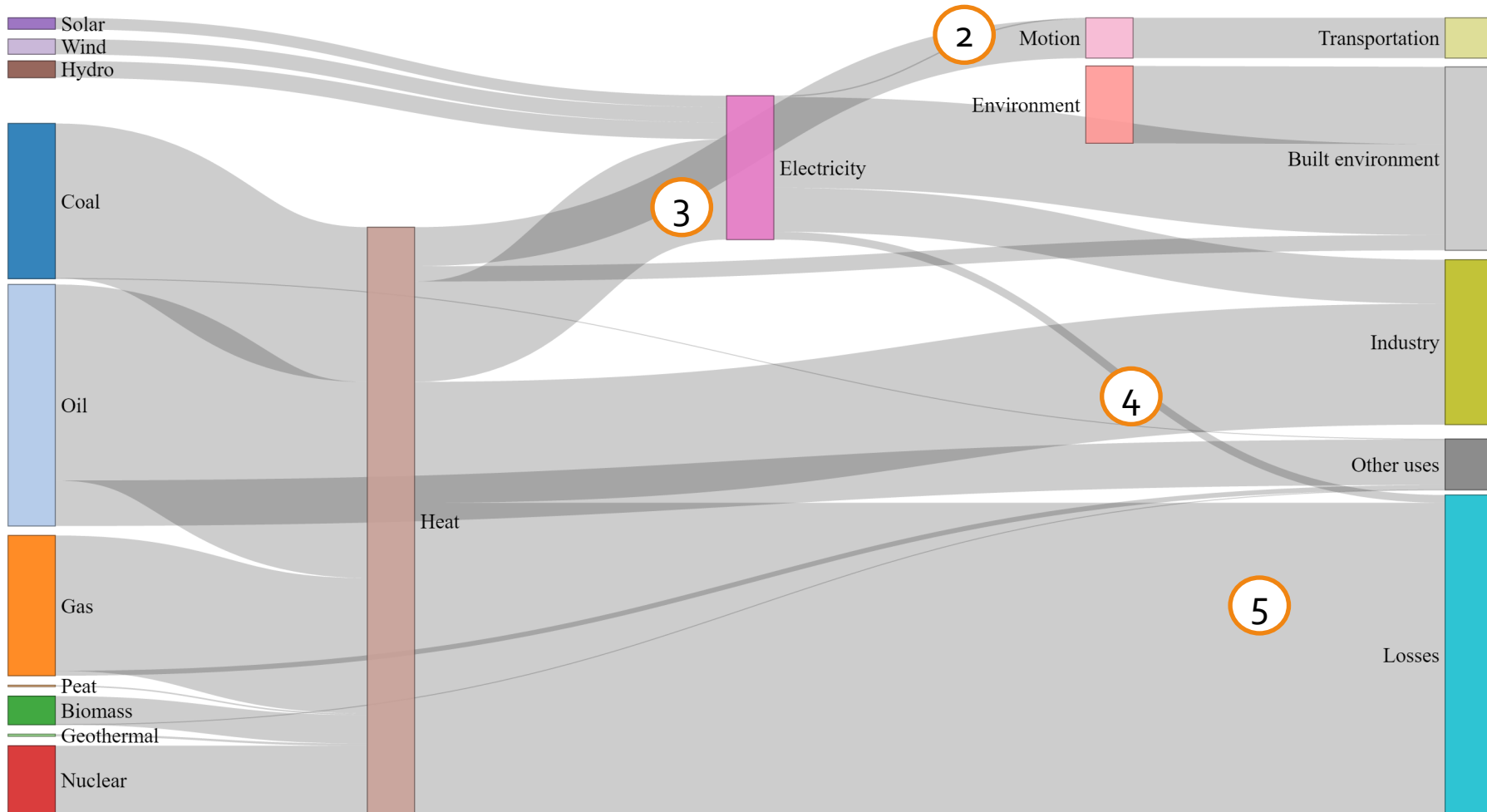
## STAGE OF DEVELOPMENT



Headquarters:	United Kingdom
Founded:	2009
Business Model:	Sells Product
Employees:	5
Cash:	<i>\$625,000</i> Estimate based on 6-month runway
Revenue:	\$0
Website:	<a href="http://nakedenergy.co.uk">nakedenergy.co.uk</a>

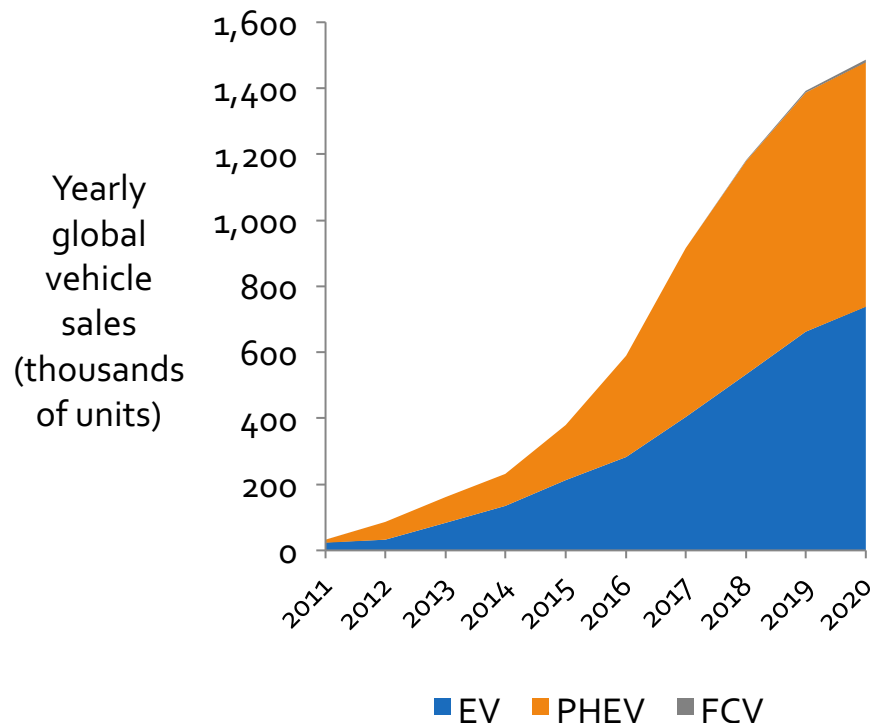
*Italics indicate Lux Research estimated value*

# Replaced natural gas, lpg, coal and biomass for heating by heat pumps

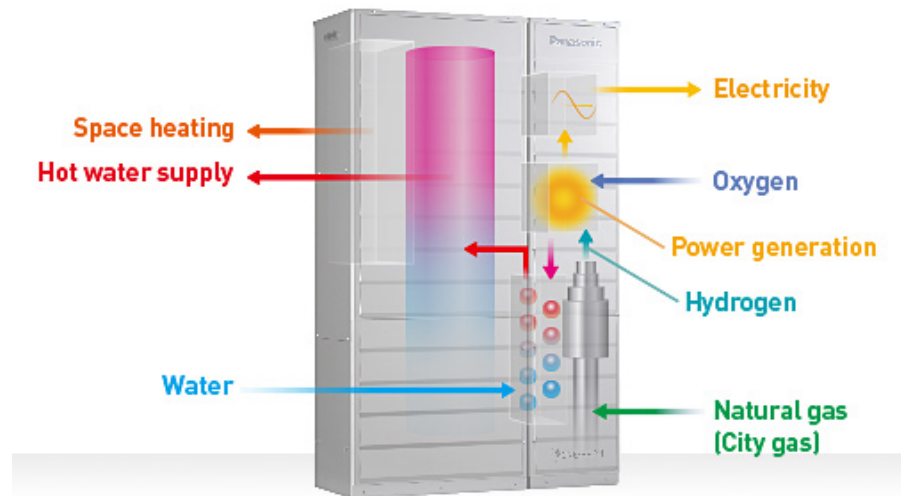


## Combustion-less cars are taking off

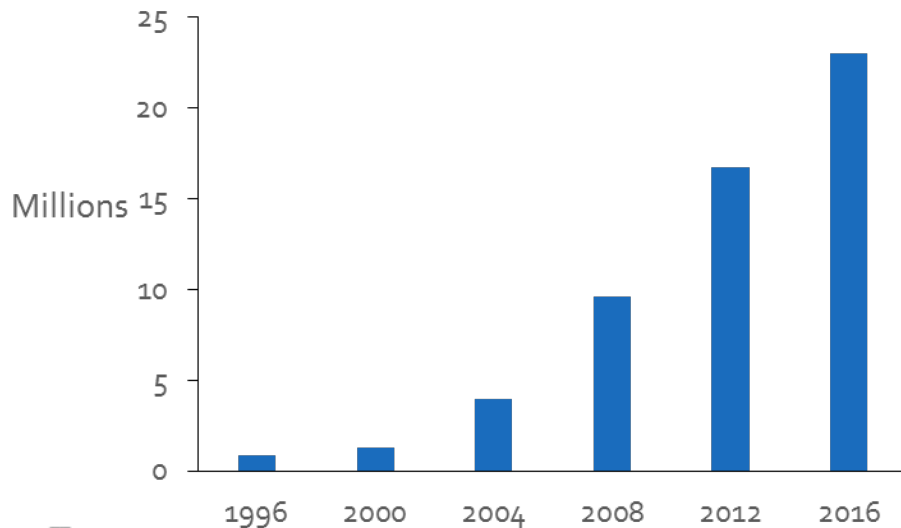
Full electric vehicle sales to exceed 600,000 by 2020. Total electric vehicles more than 1.4 million. Air quality in cities is the most important driver



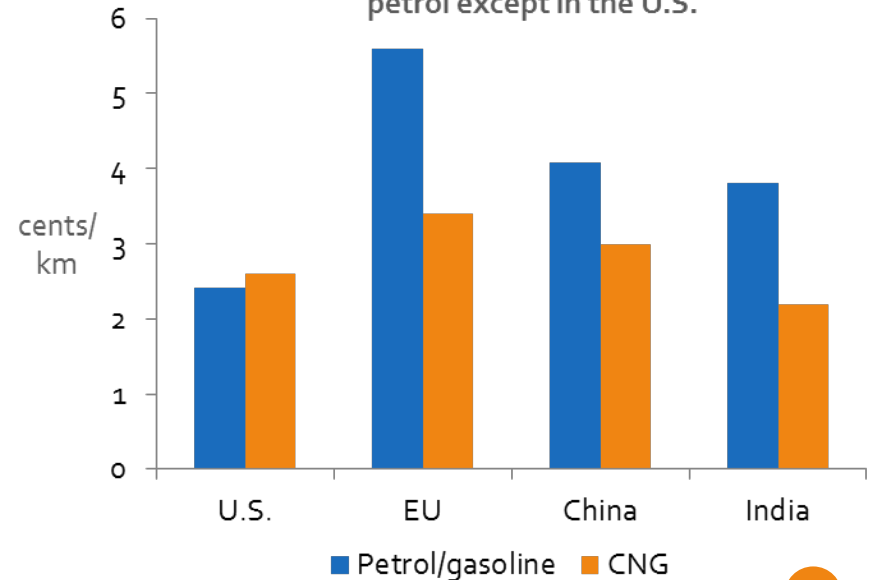
# Natural gas shows the way to combustion-less heavy transport



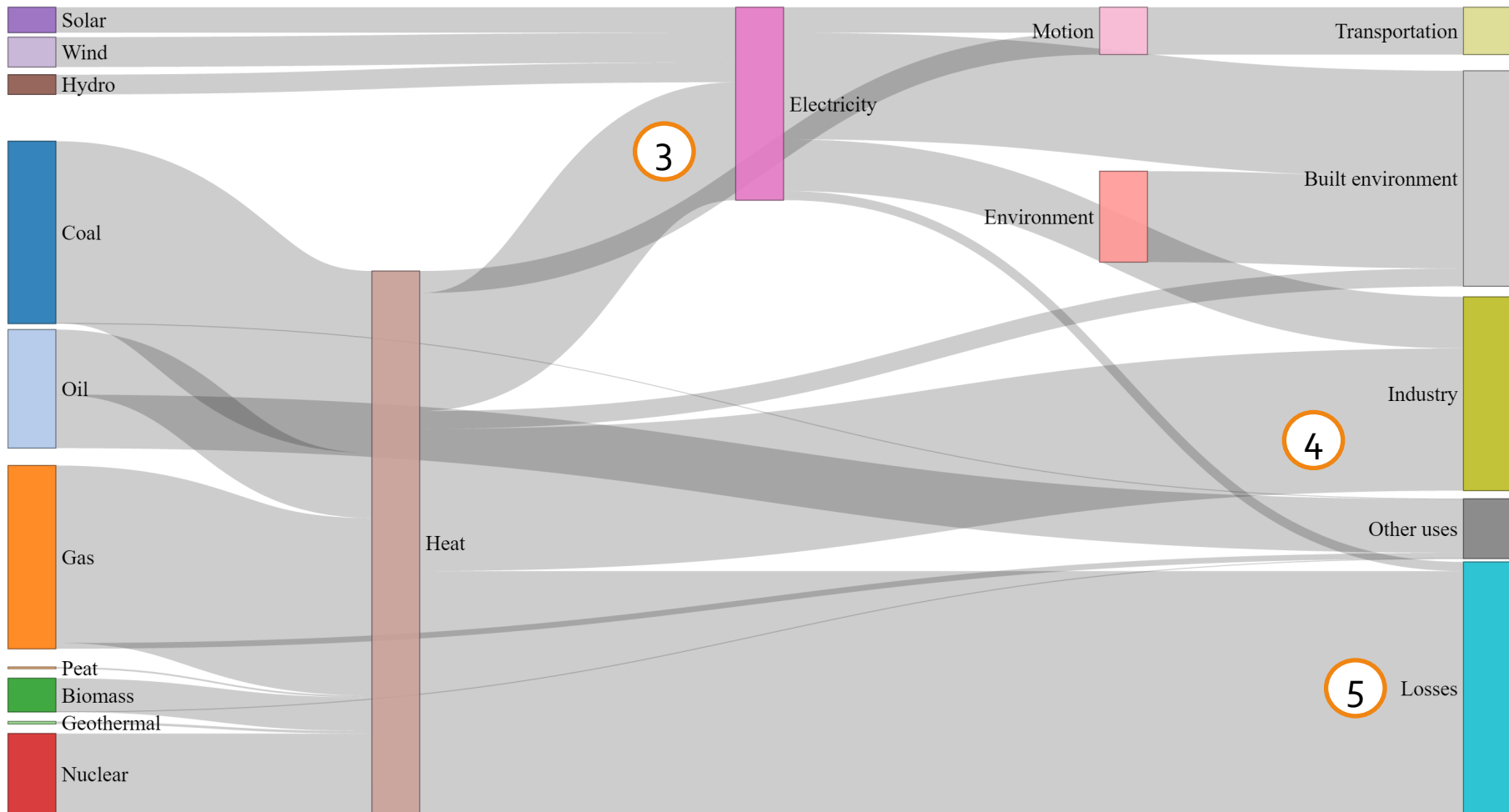
NGV adoption has grown despite the low oil prices



CNG offers higher fuel economy over petrol except in the U.S.

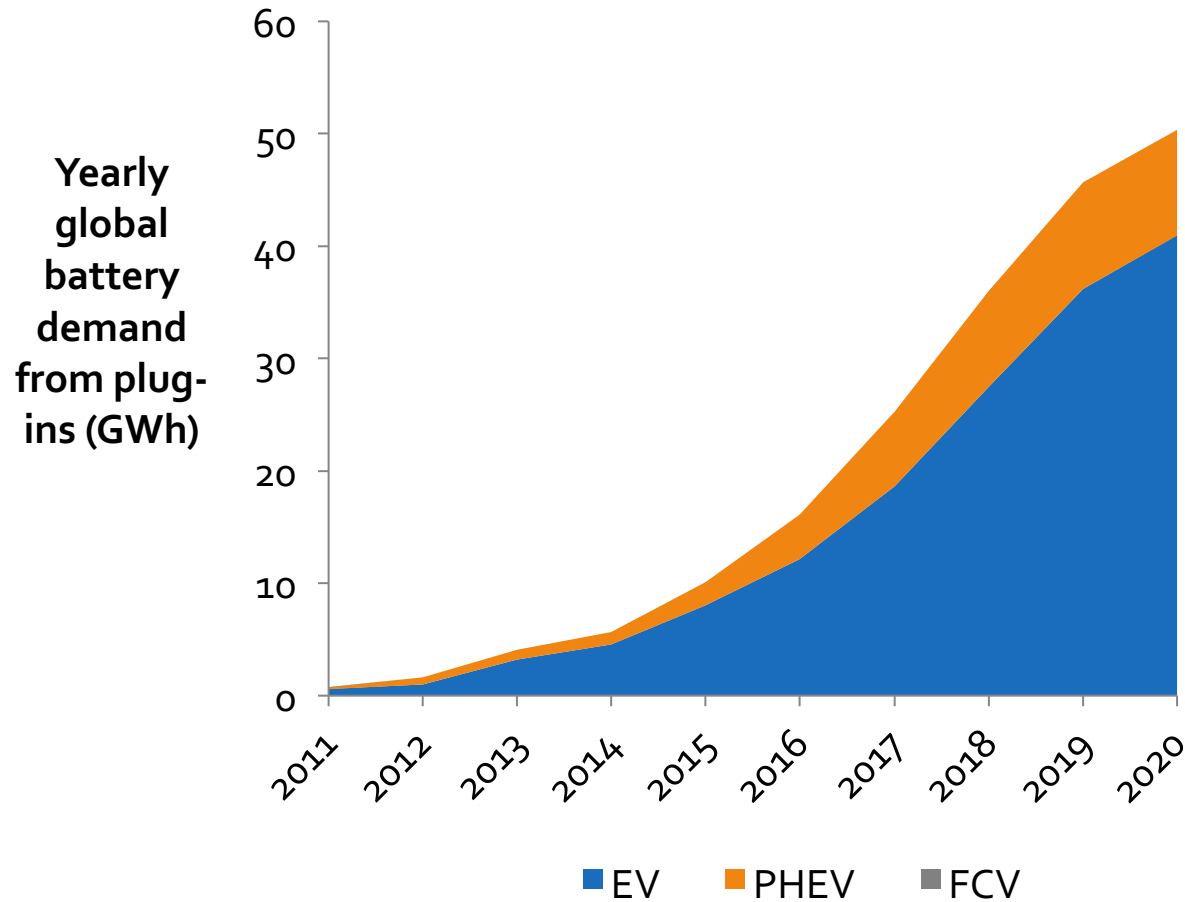


# Replaced all gasoline and diesel vehicles by electric and natural gas



3

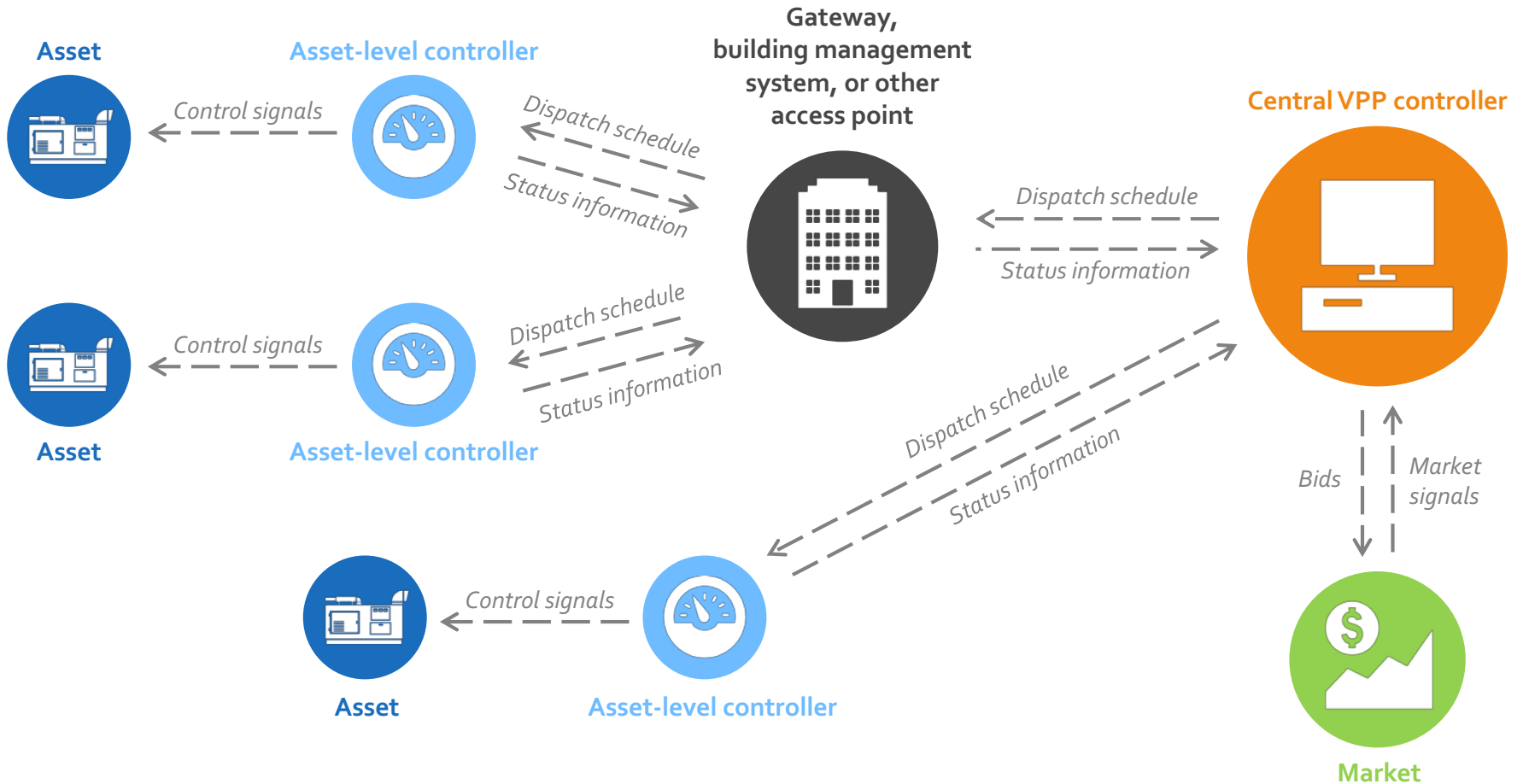
# Batteries are needed to support these developments



Electric vehicles lead to an unprecedented battery capacity



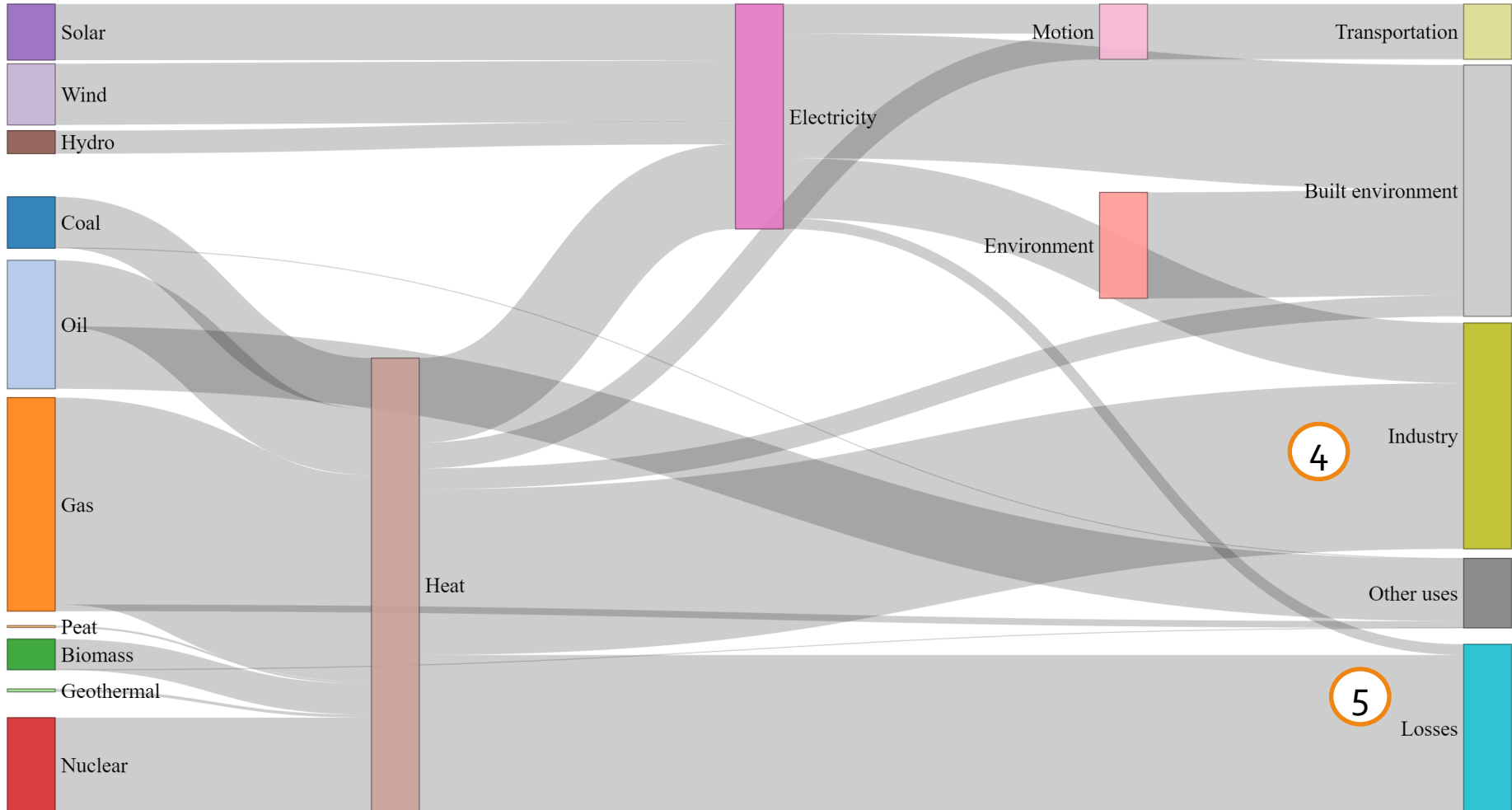
# Paving the way for virtual power plants



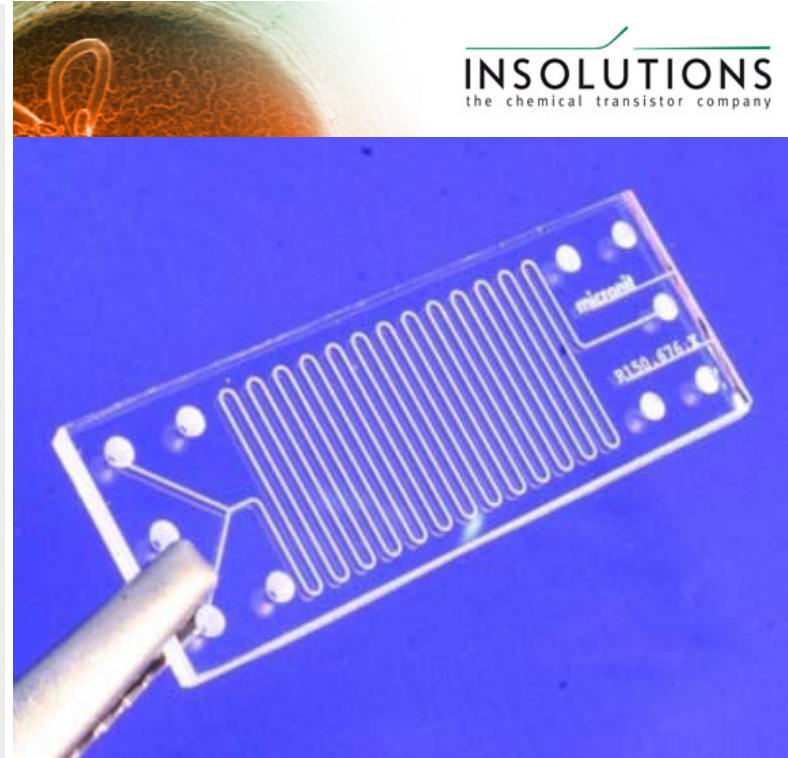
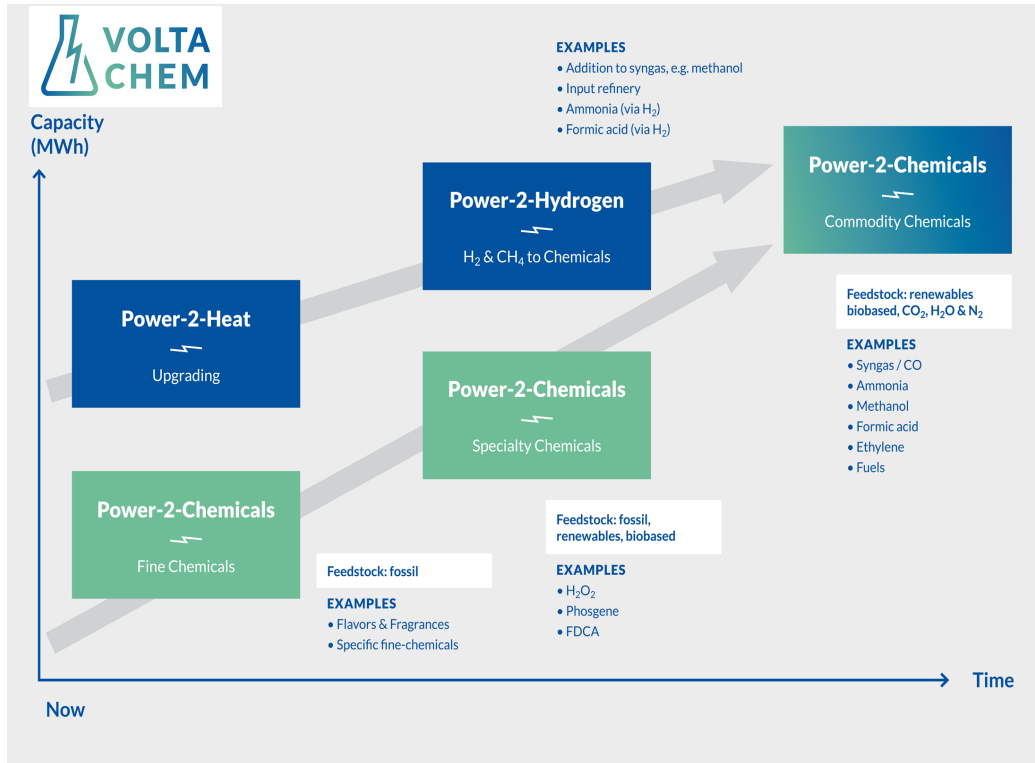
Source: Lux Research

Getting More Out of Distributed Resources: Finding Technology and Strategy Differentiation in Virtual Power Plants, September 2016

# Replaced coal fired power plants by solar and wind



# Converting industry is the major challenge



Several public private partnerships are aligned on the same roadmap to create an electricity based (chemical) industry

# Yet sometimes combustion is inevitable



Cement kiln: 1450 °C



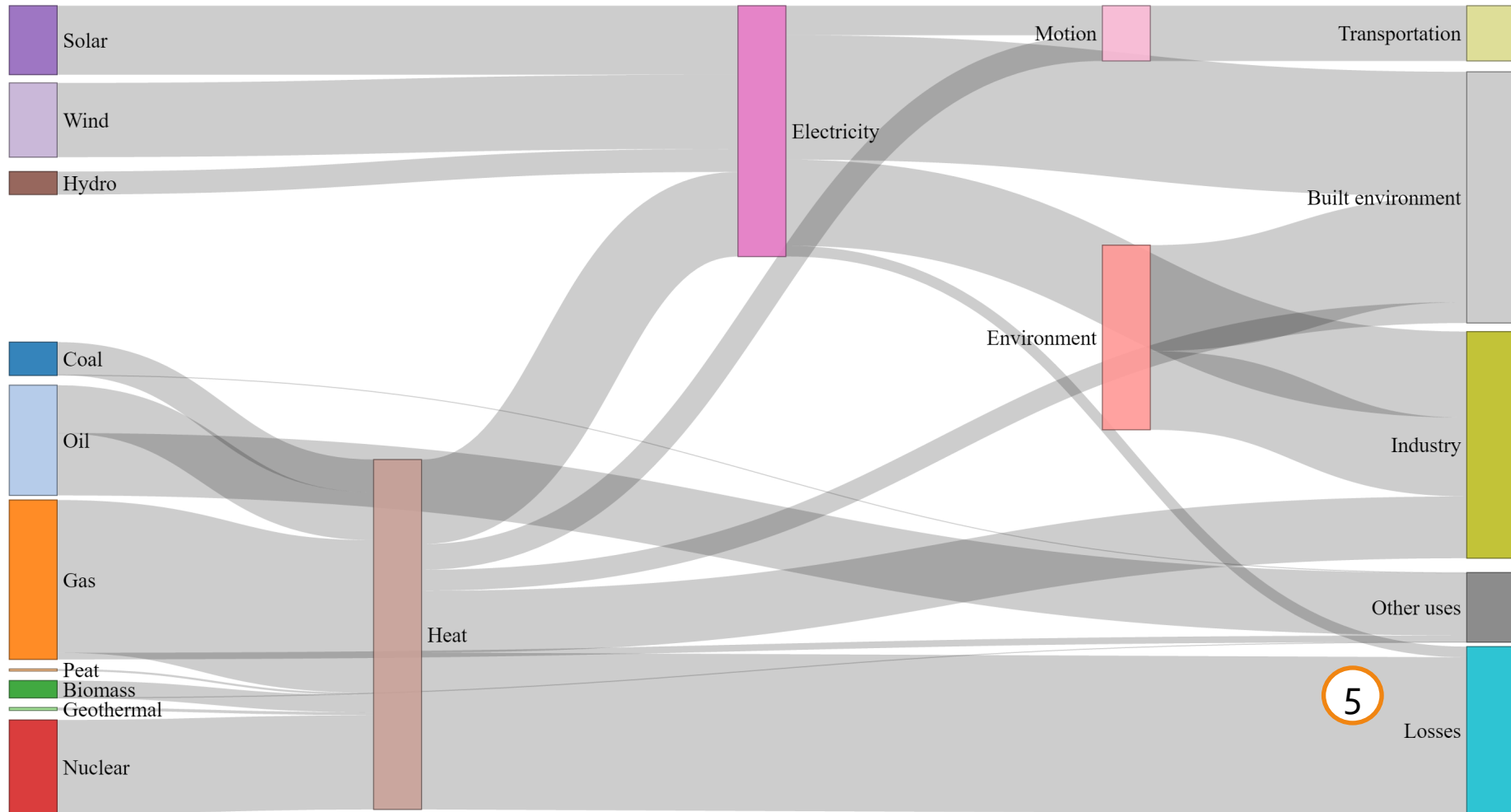
Blast furnace: 1400 °C



Glass furnace: 1850 °C

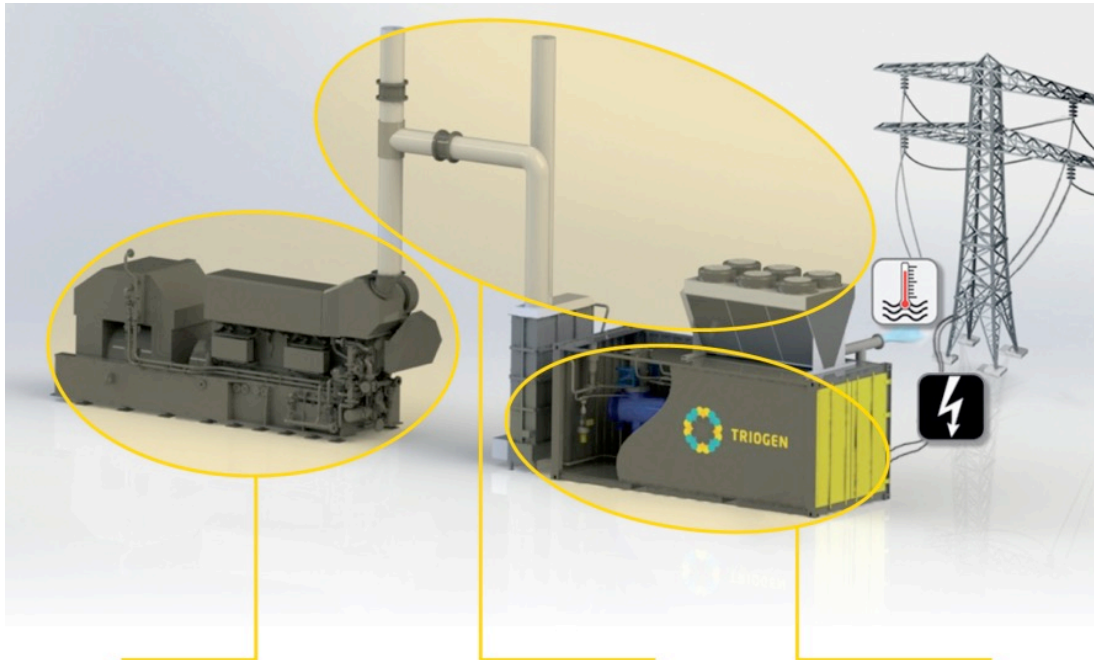
Processes requiring phase changes and chemical reduction have to use high temperature heat.

# Replaced heat to industry partially by electricity



5

# Waste heat to electricity: the inverse CHP



Heat source:  
Customer supply

Periphery (flue gas, pipes, valves, heat rejection system, etc):  
Supplied by Triogen or local Partner

ORC (Process room, incl. Turbine, evaporator, control cabinet):  
Triogen supply



## LUX TAKE



## STAGE OF DEVELOPMENT

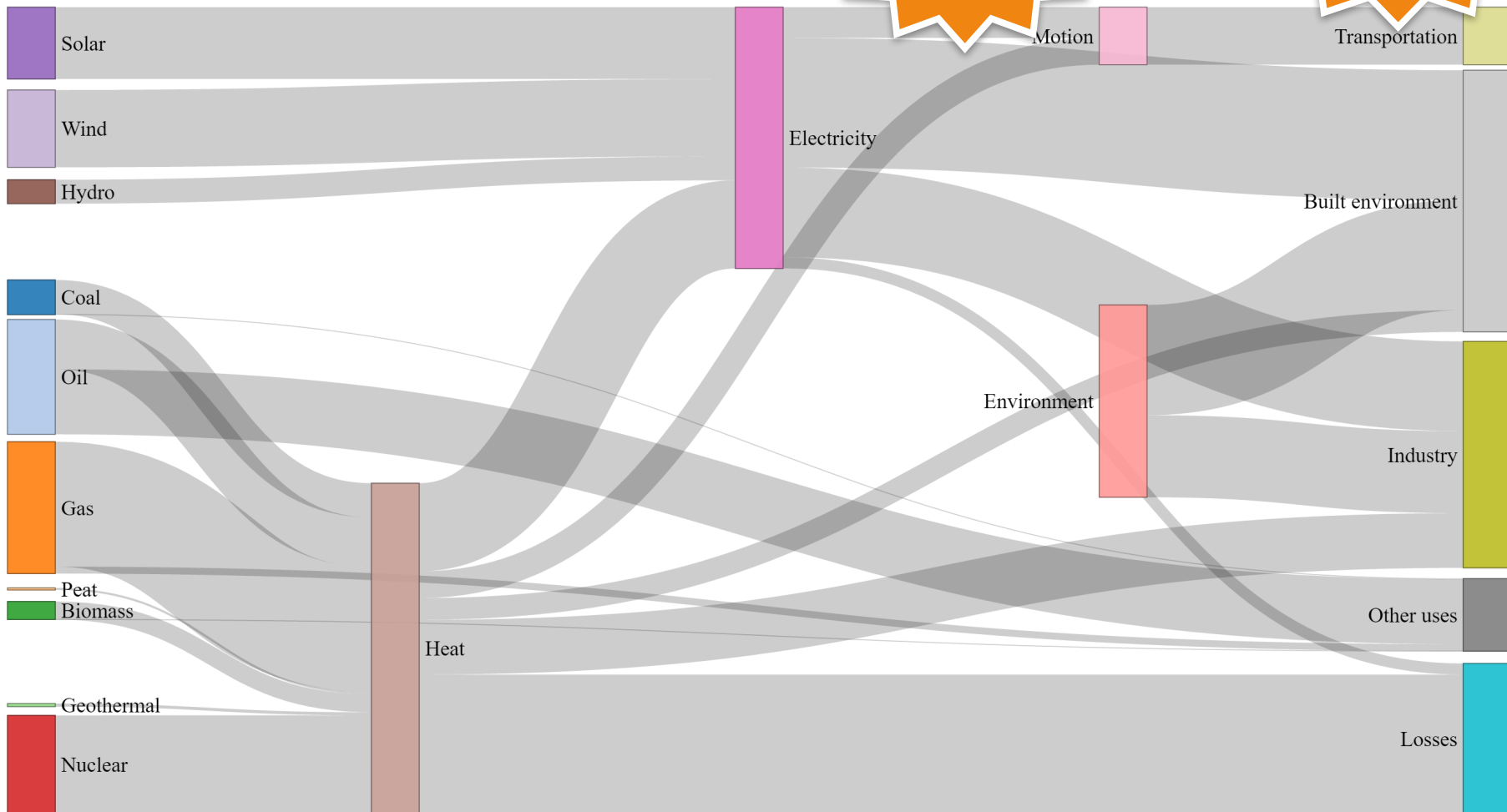


Headquarters:	Netherlands
Founded:	2001
Business Model:	Provides Services; Sells Product
Employees:	25
Cash:	\$1 million
Revenue:	\$6 million 2015 revenue
Website:	<a href="http://www.triogen.nl">www.triogen.nl</a>

*Italics indicate Lux Research estimated value*



# Replaced some gas fired power generation by waste heat utilization



# Key take-aways

- › The energy system is highly optimized and must be analyzed as a whole
- › Inefficiencies related to combustion are driving the use of new technology
- › Many, not obviously related, technologies interact to create the transition
- › Fossil resources are very stable and resilient

## Finally:

- › **Technology is showing and paving the way**
- › **Government policy sets the pace**
- › **To do this in 25 years will require ~2% of GDP every year**



# Thank you



**lux**research

Arij van Berkel, PhD

[arij.vanberkel@luxresearchinc.com](mailto:arij.vanberkel@luxresearchinc.com)