

Shifting paradigms in energy and industry

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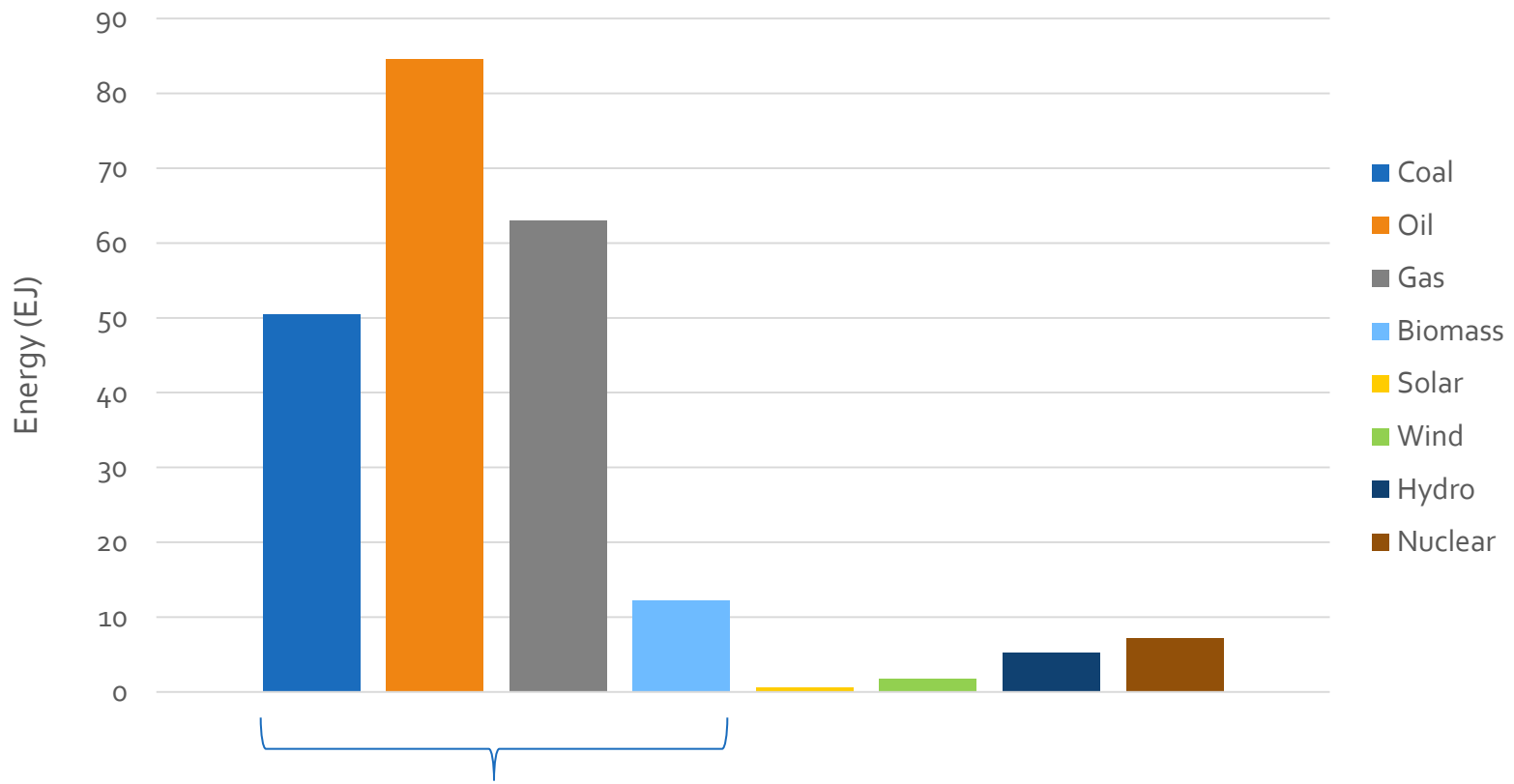
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luxresearch

The way we use energy today

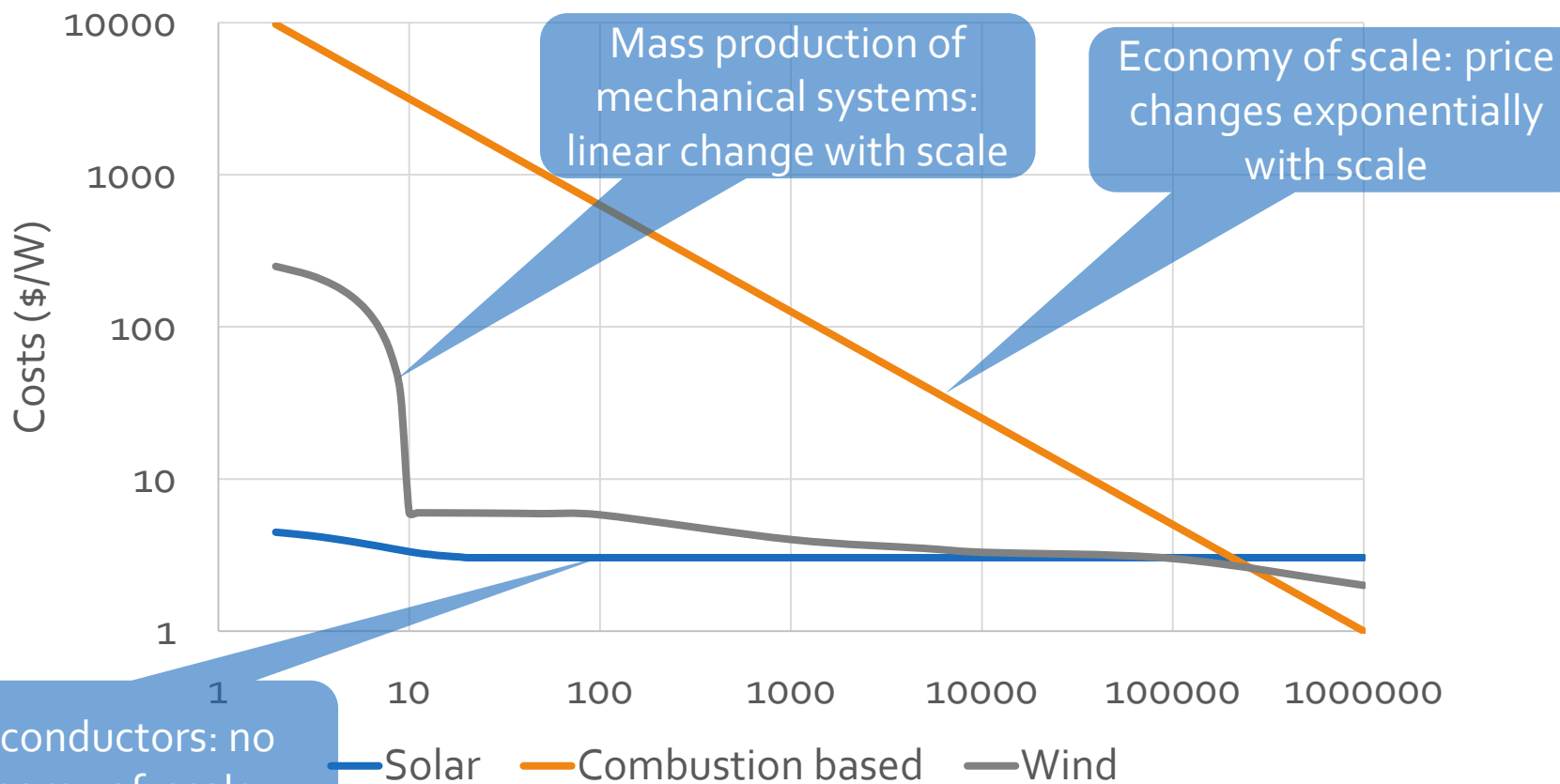
Energy by primary source, OECD 2014



93% combustion based

Combustion creates economy of scale

Investment costs for various generation options

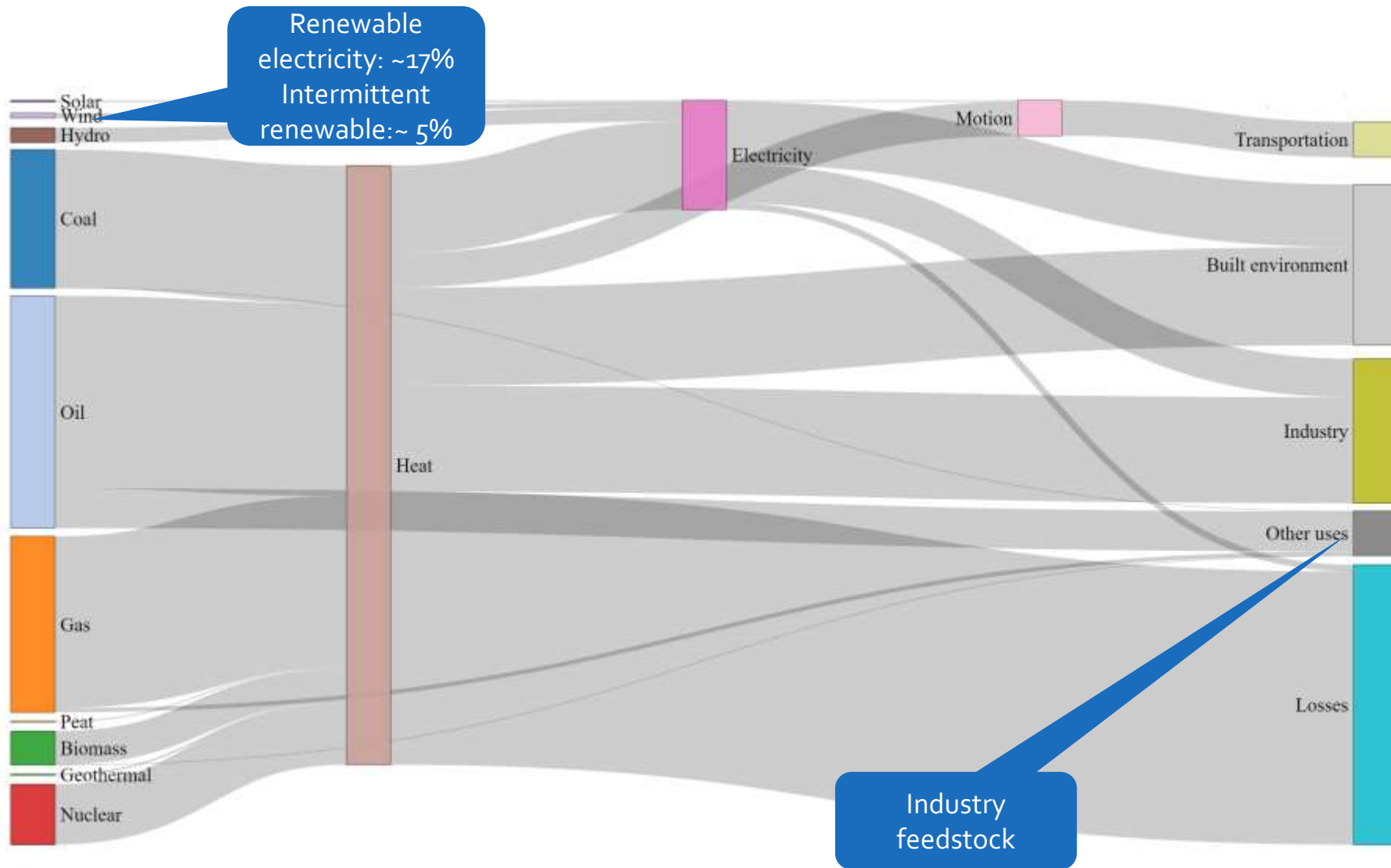


Semiconductors: no economy of scale

Mass production of mechanical systems: linear change with scale

Economy of scale: price changes exponentially with scale

Our current energy use



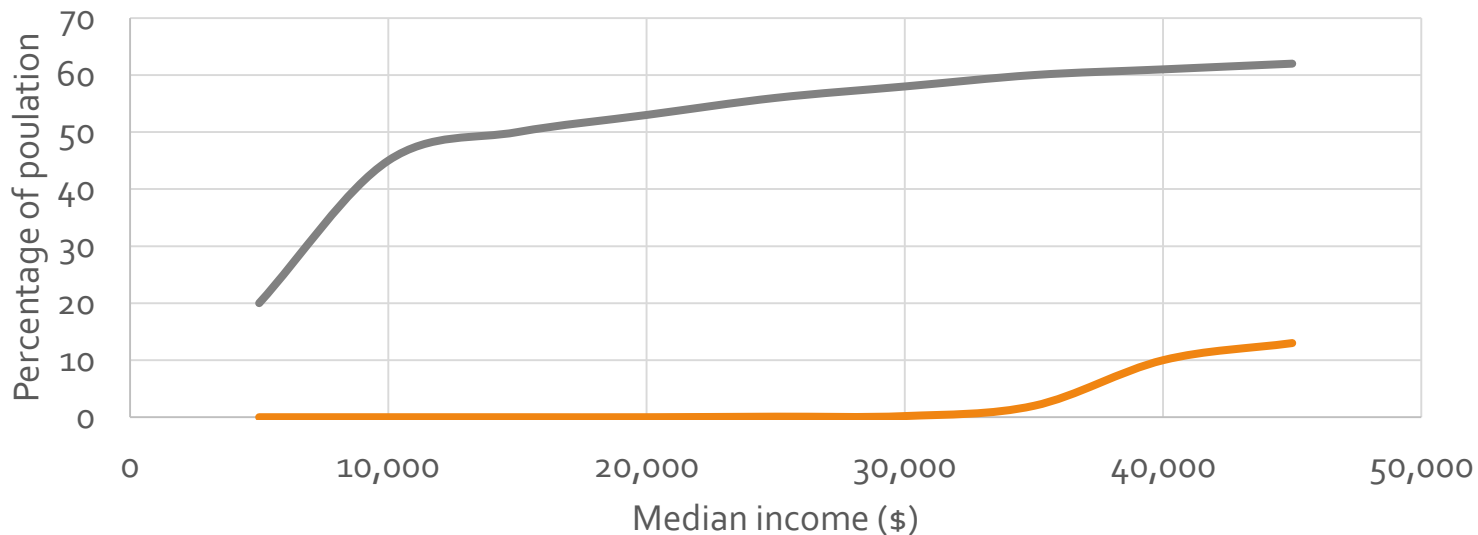
Renewable electricity: ~17%
Intermittent renewable: ~5%

Industry feedstock

The power of the people

- One power plant: 1 GW
- One solar installation: 3 kW
- Investment in one solar installation: \$ 8000
- A million such installations is equivalent to the 1 GW power plant

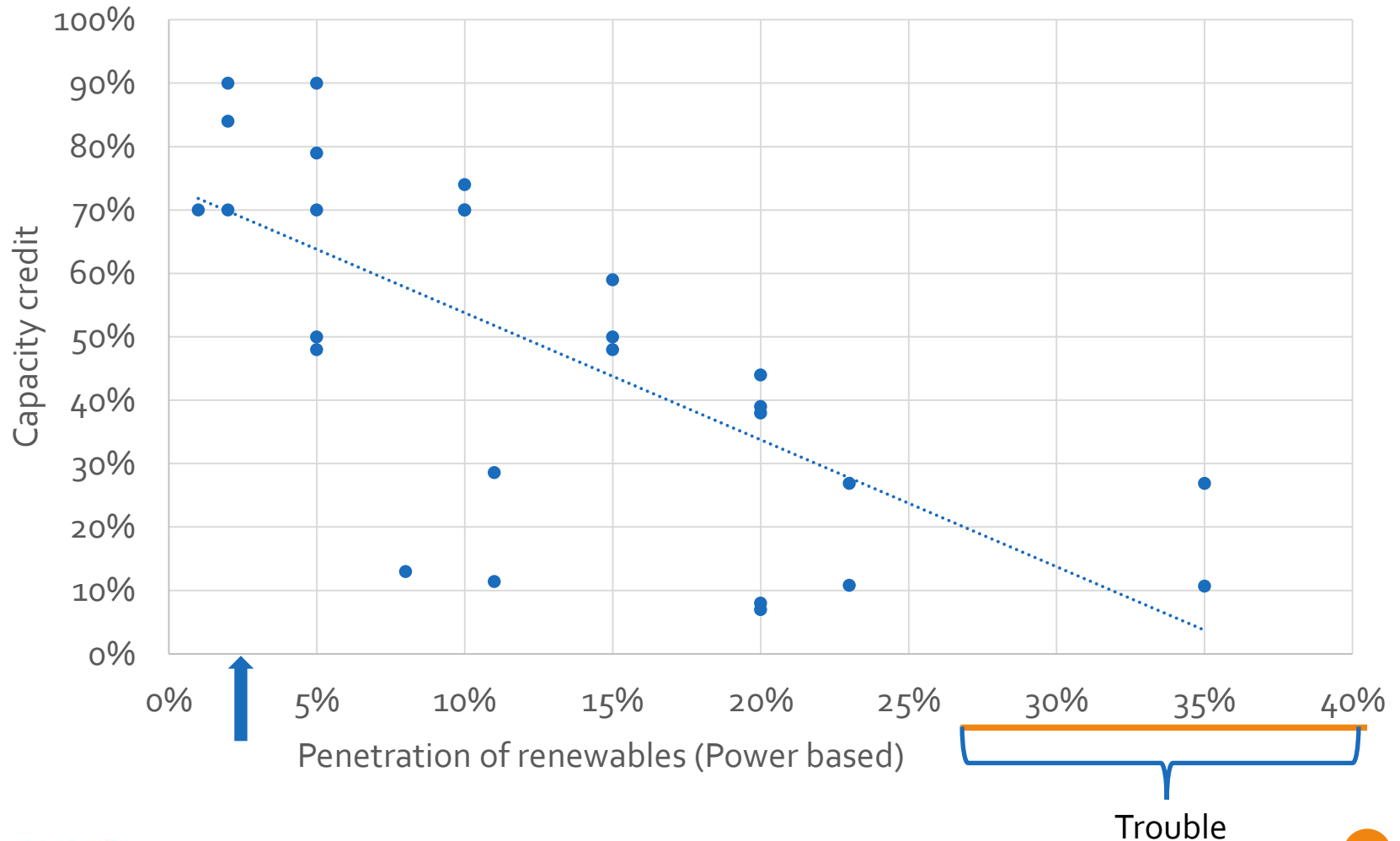
Amount of people able to afford solar PV



— Without financing — With financing

Stressing the grid

Limit to introducing renewables



Phases of introducing wind and solar

› Phase 1: Growing share

The investment in renewable exceeds investments in fossil-based

› Phase 2: Shrinking capacity credit

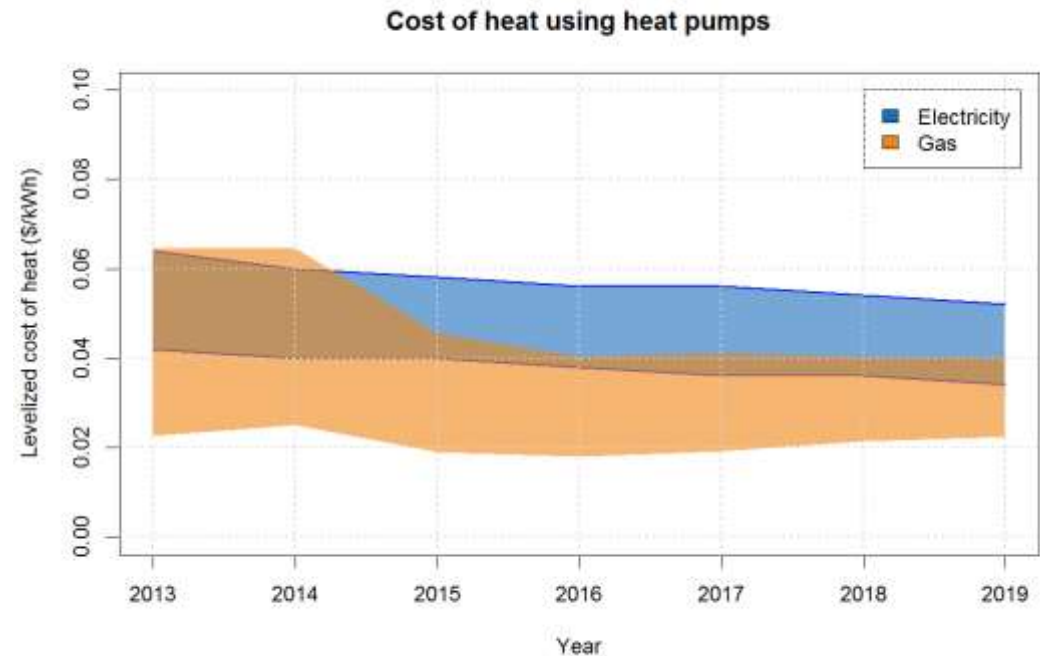
Up to about 40% the need for backup power increases. After 40%, 100% backup power for installed renewables is required

› Phase 3: Reduced payback

Above 50% – 75% renewables production regularly exceeds demand. Only storage can save the day

Heat pumps to boost demand

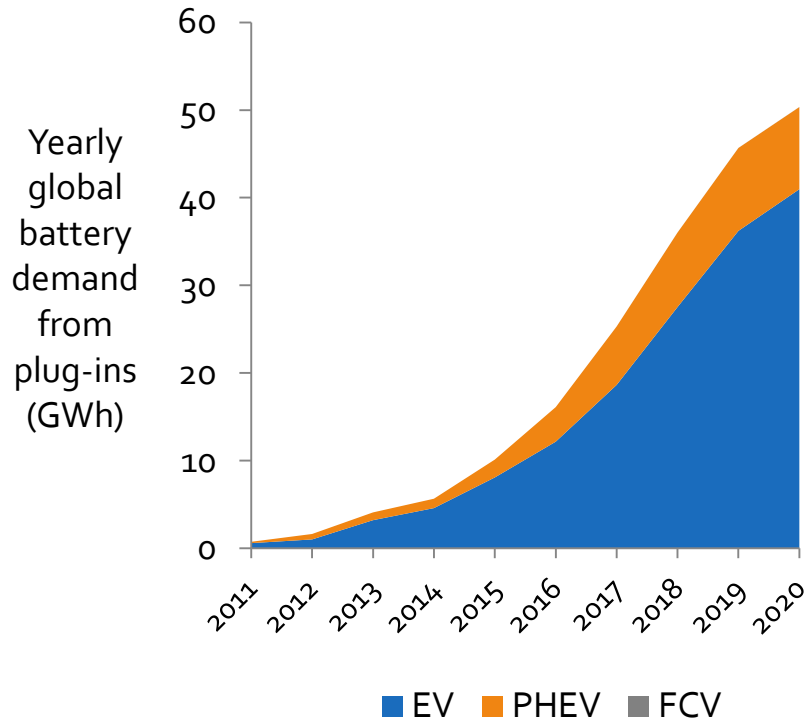
New heat pumps for use in buildings generate on average 5 kWh of heat for every kWh electricity input



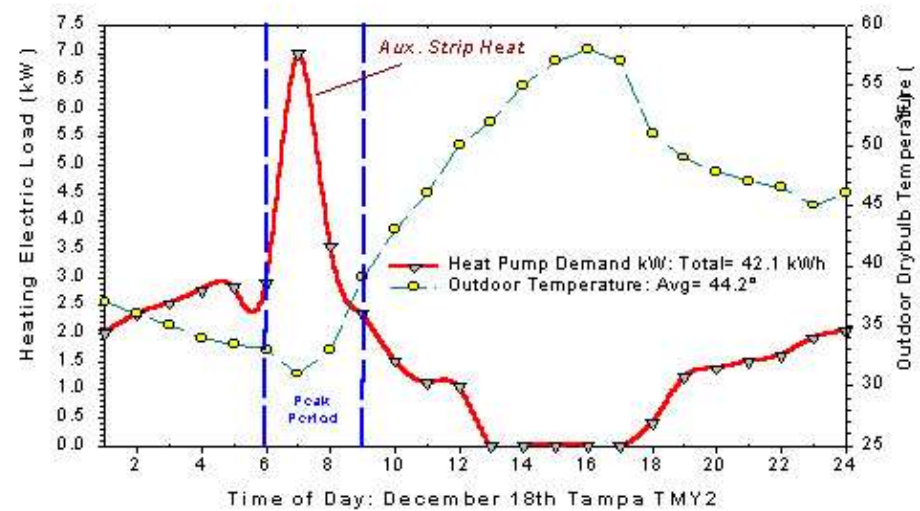
Example: heat battery



Batteries are introduced for alternative reasons

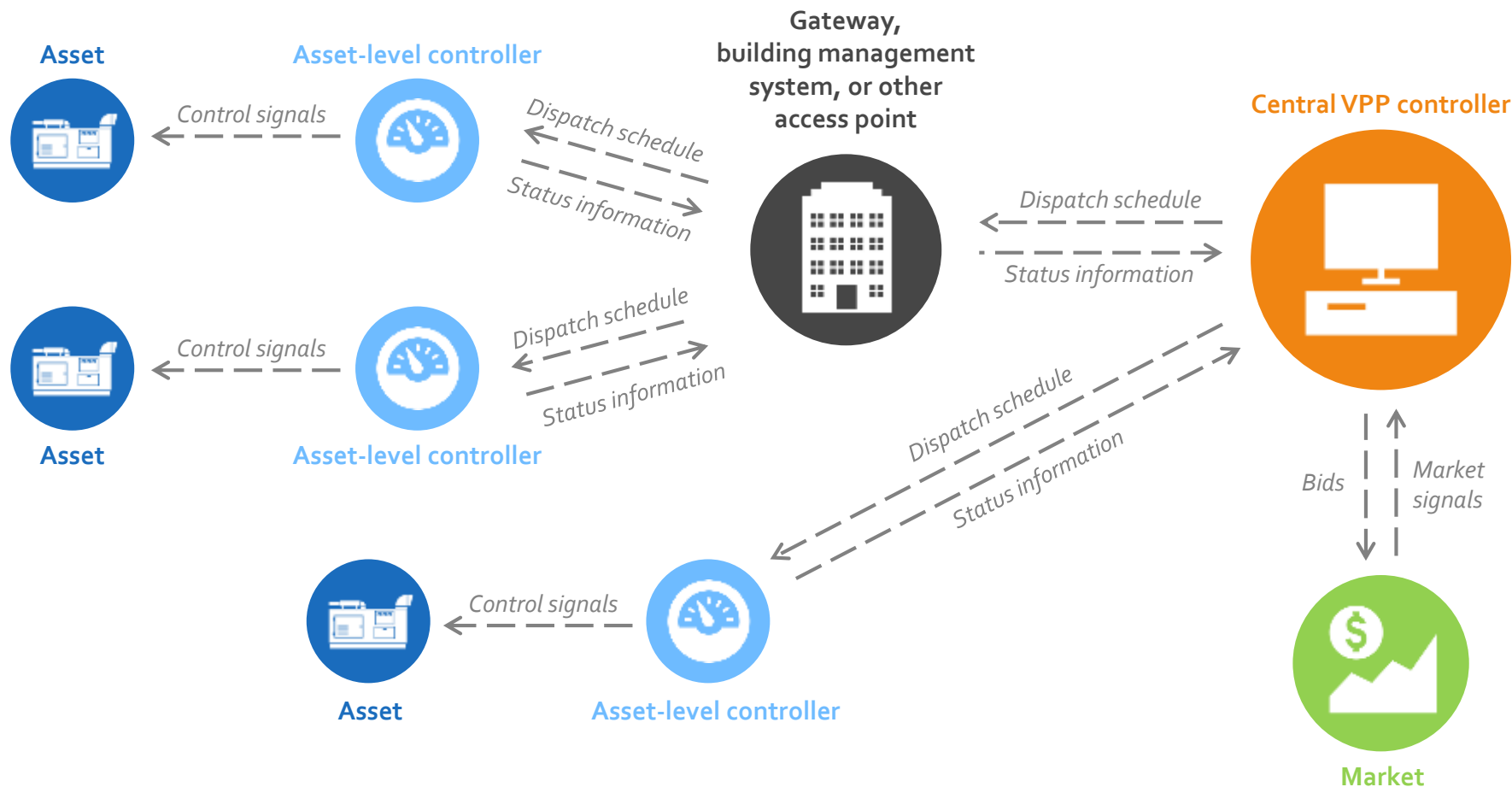


Electric vehicles lead to an unprecedented battery capacity



Domestic electricity applications require batteries to support peak demand

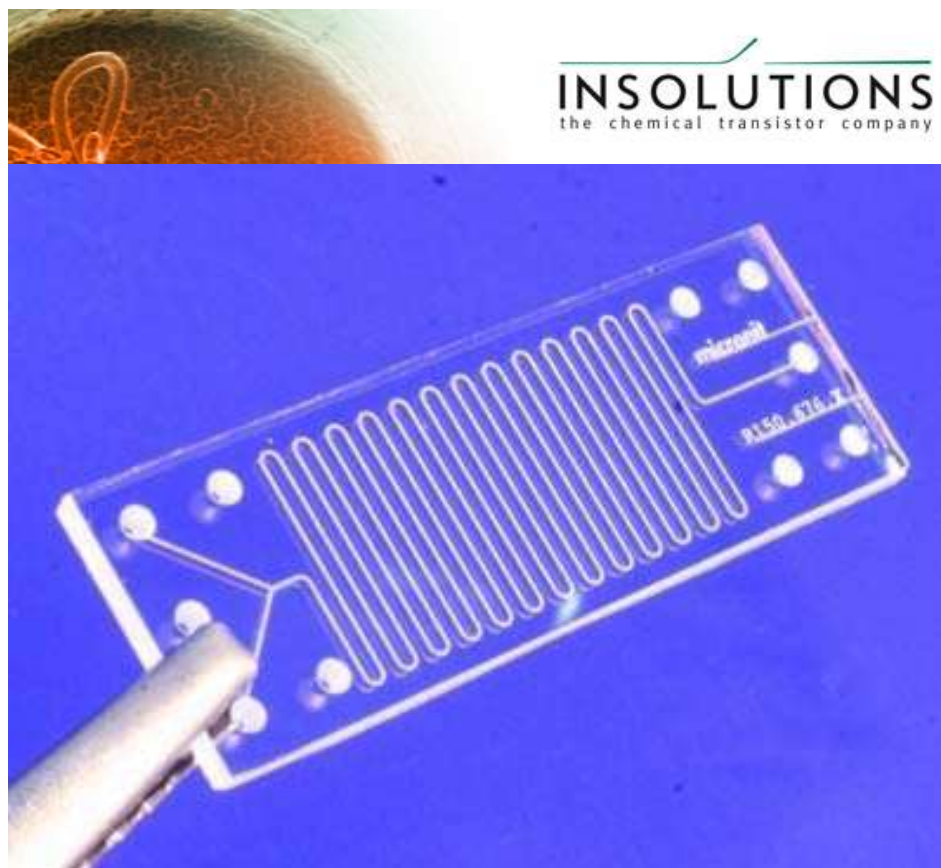
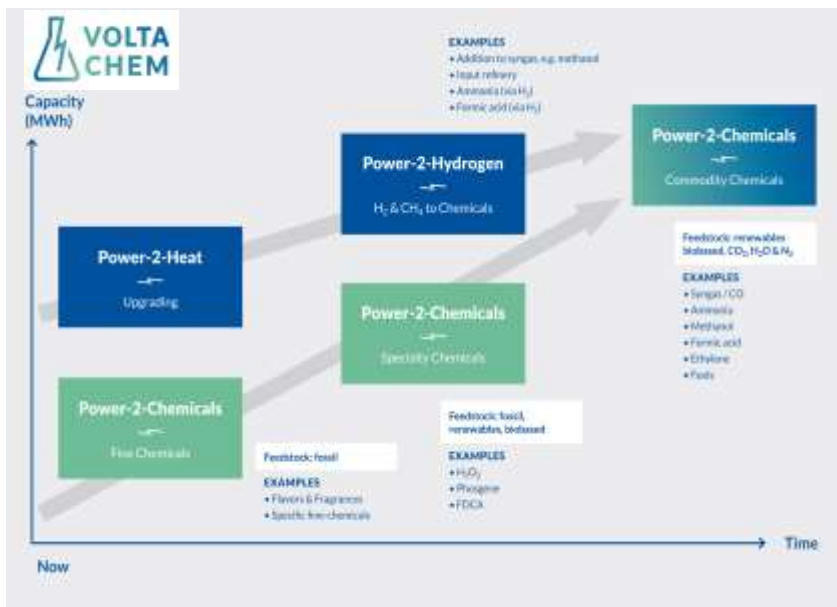
Paving the way for virtual power plants



Source: Lux Research

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

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 heat 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.

Waste heat to electricity: the inverse CHP



Heat source:
Customer supply

Periphery (flue gas, pipes, valves, heat rejection system, etc):
Supplied by Triogen as part of the system

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



LUX TAKE



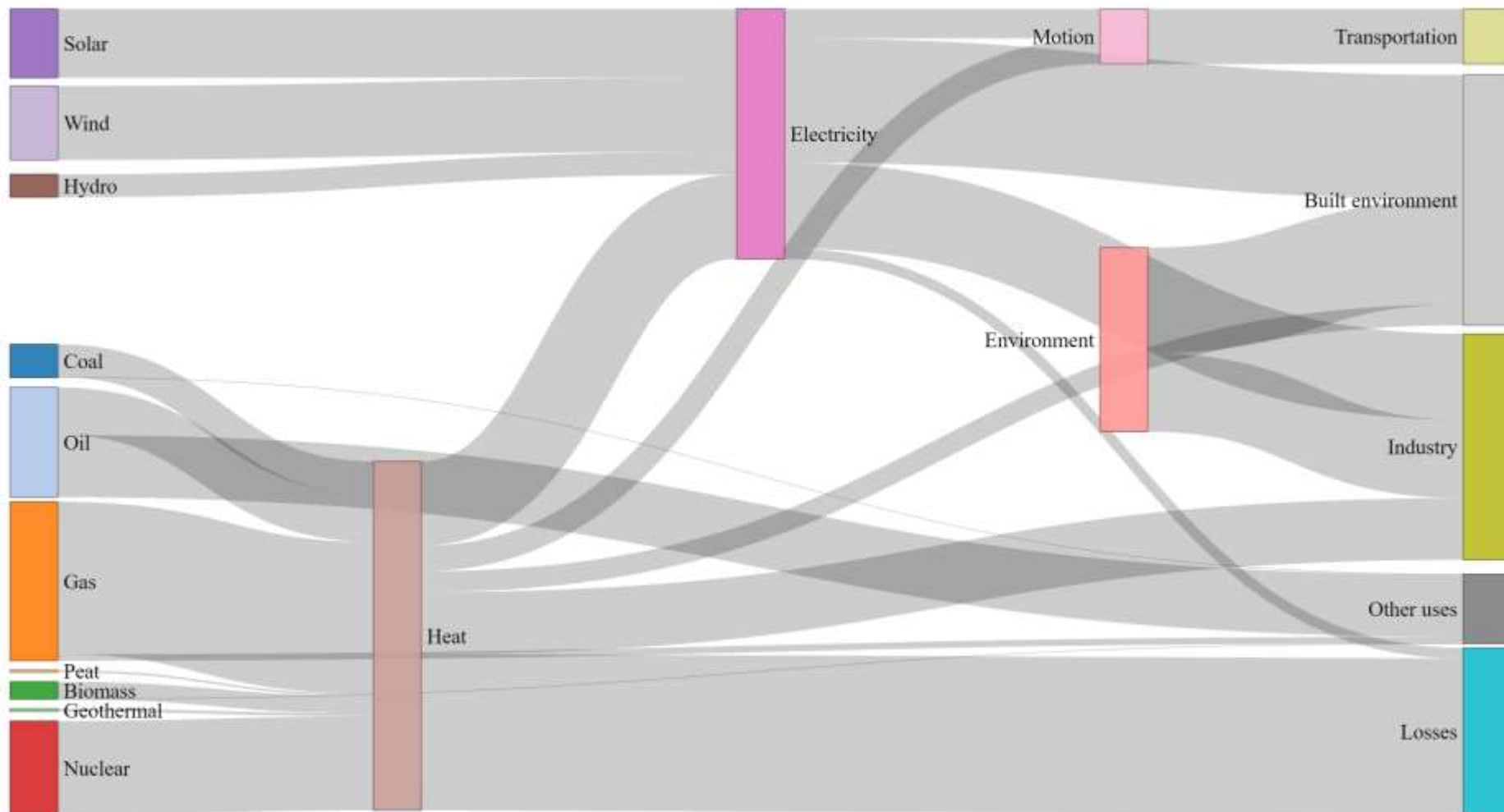
STAGE OF DEVELOPMENT



Headquarters:	Netherlands
Founded:	2001
Business Model:	Provides Services; Sells Product
Employees:	25
Cash:	\$1 million
Revenue:	\$6 million 2015 revenue
Website:	www.triogen.nl

Italics indicate Lux Research estimated value

The future use of energy: >80% renewable electricity



In summary

The energy transition is a complex non-linear process

- › Energy storage starts from alternative business cases and is not always electric
- › Regular cheap electricity will help industry electrify, if engineers lose focus on efficiency
- › High temperature heat offers backup capacity
- › Software to utilize battery capacity will mobilize storage
- › Oil refineries and chemical industry in jeopardy

Finally:

Technology is showing and paving the way
Government policy sets the pace

Thank you

