New Insulation Materials – Is Nanotechnology the Solution?

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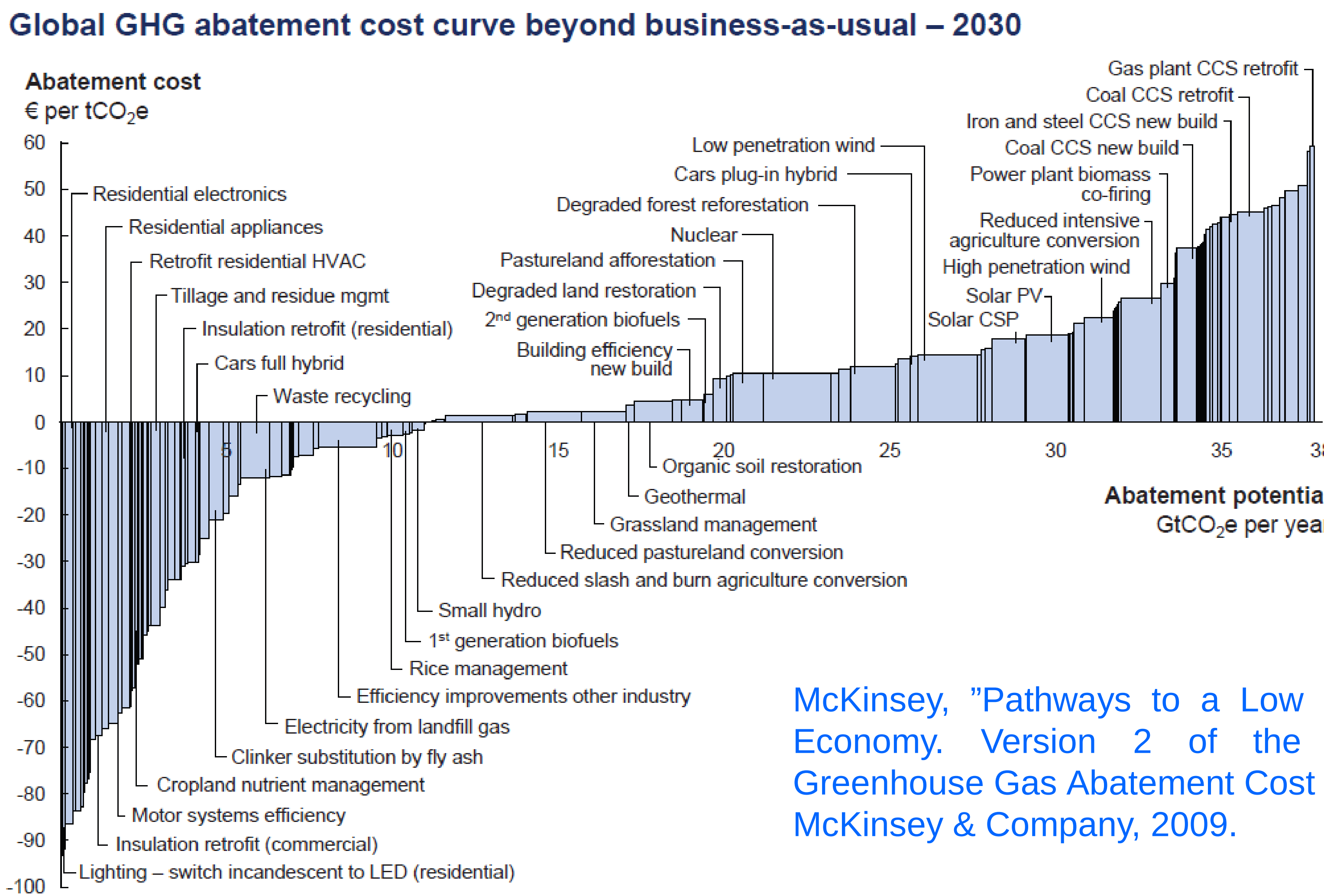
NTNU, SINTEF Building and Infrastructure, and SINTEF Materials and Chemistry

Outline

- Background
  - Why focus on thermal insulation materials?
  - Current thermal insulations materials
  - State-of-the-art materials
- Why Nanotechnology?
  - Theoretical possibilities
- Nano Insulation Materials – ZEB Development Results

Why Thermal Insulation Materials?



McKinsey, "Pathways to a Low Carbon Economy. Version 2 of the Global Greenhouse Gas Abatement Cost Curve", McKinsey & Company, 2009.

Note: The curve presents an estimate of the maximum potential of all technical GHG abatement measures below €60 per tCO_2e if each lever was pursued aggressively. It is not a forecast of what role different abatement measures and technologies will play.
Source: Global GHG Abatement Cost Curve v2.0

Traditional Thermal Insulation of Today

- What is Out There?

- Mineral Wool
  - Glass wool (fibre glass)
  - Rock wool
  - 30-40 mW/(mK)
- Expanded Polystyrene (EPS)
  - 30-40 mW/(mK)
- Extruded Polystyrene (XPS)
  - 30-40 mW/(mK)
- Cellulose
  - 40-50 mW/(mK)
- Cork
  - 40-50 mW/(mK)
- Polyurethane (PUR)
  - Toxic gases (e.g. HCN) released during fire
  - 20-30 mW/(mK)

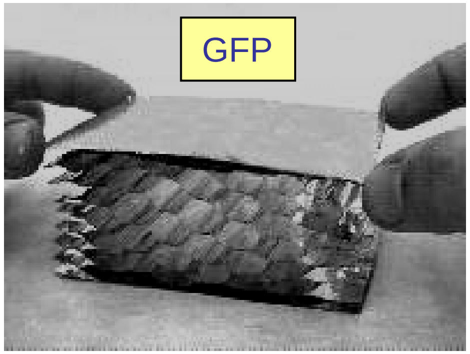
State-of-the-Art Thermal Insulation of Today

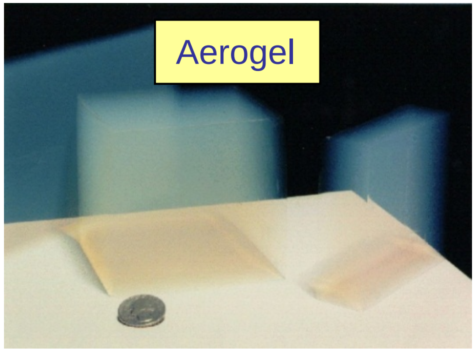
- What is Out There?

- Vacuum Insulation Panels (VIP)
  "An evacuated foil-encapsulated open porous material as a high performance thermal insulating material"
  - Core (silica, open porous, vacuum)
  - Foil (envelope)
  - 4 - 8 - 20 mW/(mK)

- Gas-Filled Panels (GFP)
  - 40 mW/(mK)

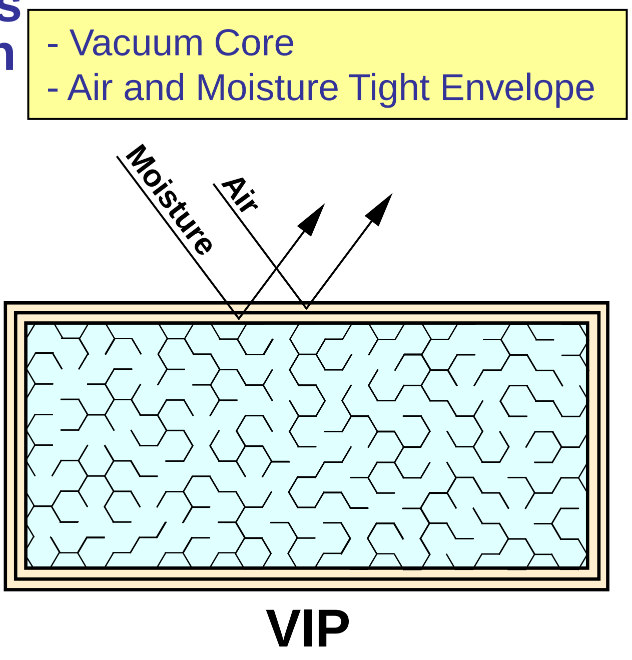
- Aerogels
  - 13 mW/(mK)





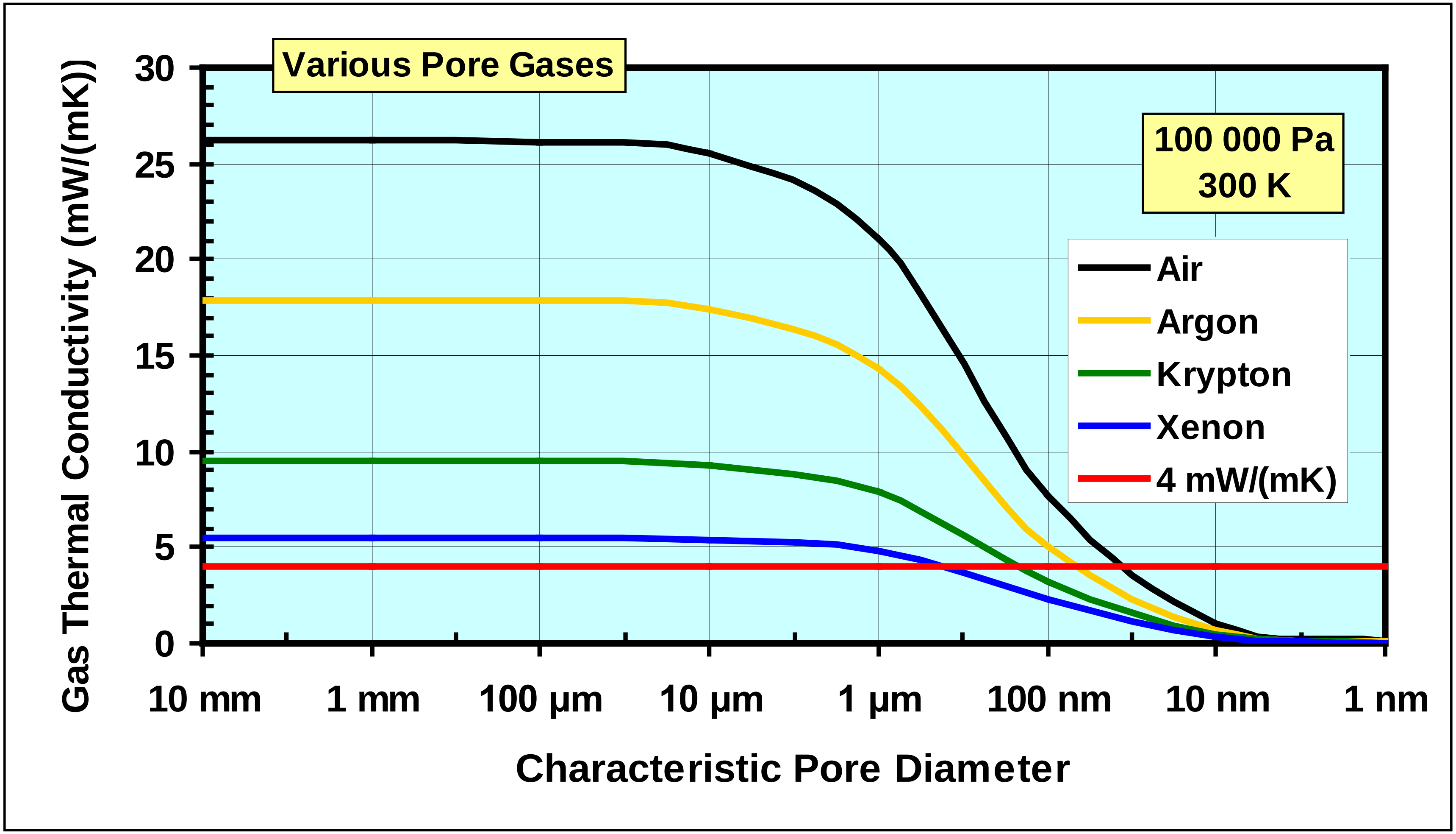
Major Disadvantages of VIPs

- Thermal bridges at panel edges
- Expensive at the moment, but calculations show that VIPs may be cost-effective even today
- Ageing effects - Air and moisture penetration
  - 4 mW/(mK) fresh
  - 8 mW/(mK) 25 years
  - 20 mW/(mK) perforated
- Vulnerable towards penetration, e.g nails
  - 20 mW/(mK)
- Can not be cut or adapted at building site
- Possible improvements?



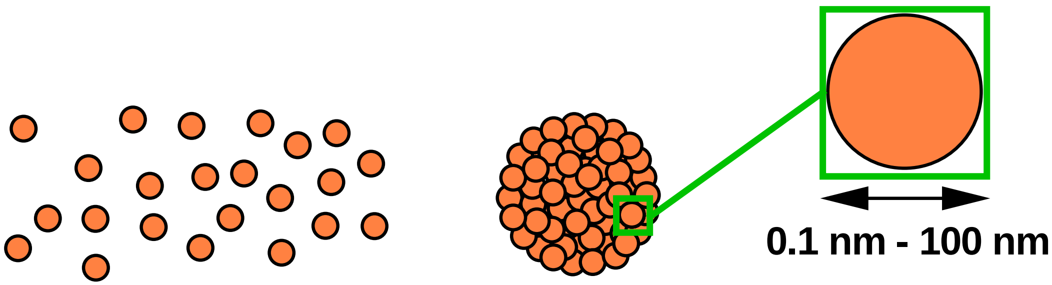
Gas Thermal Conductivity

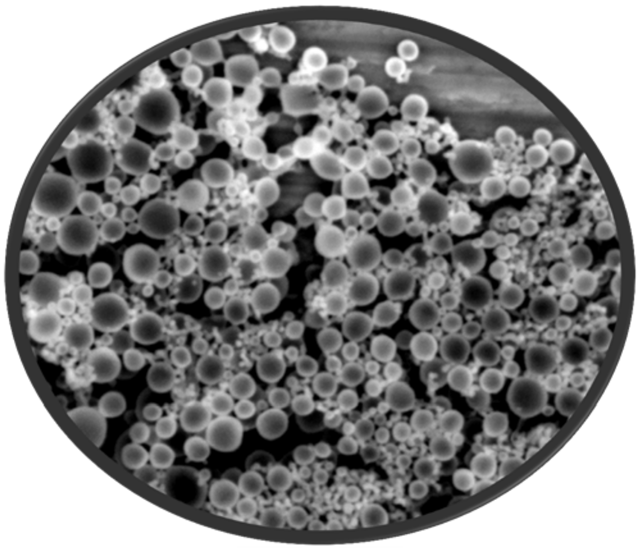
Conductivity vs. Pore Diameter



Nano Technology

Nanotechnology:
Technology for controlling matter of dimensions between 0.1 nm - 100 nm.



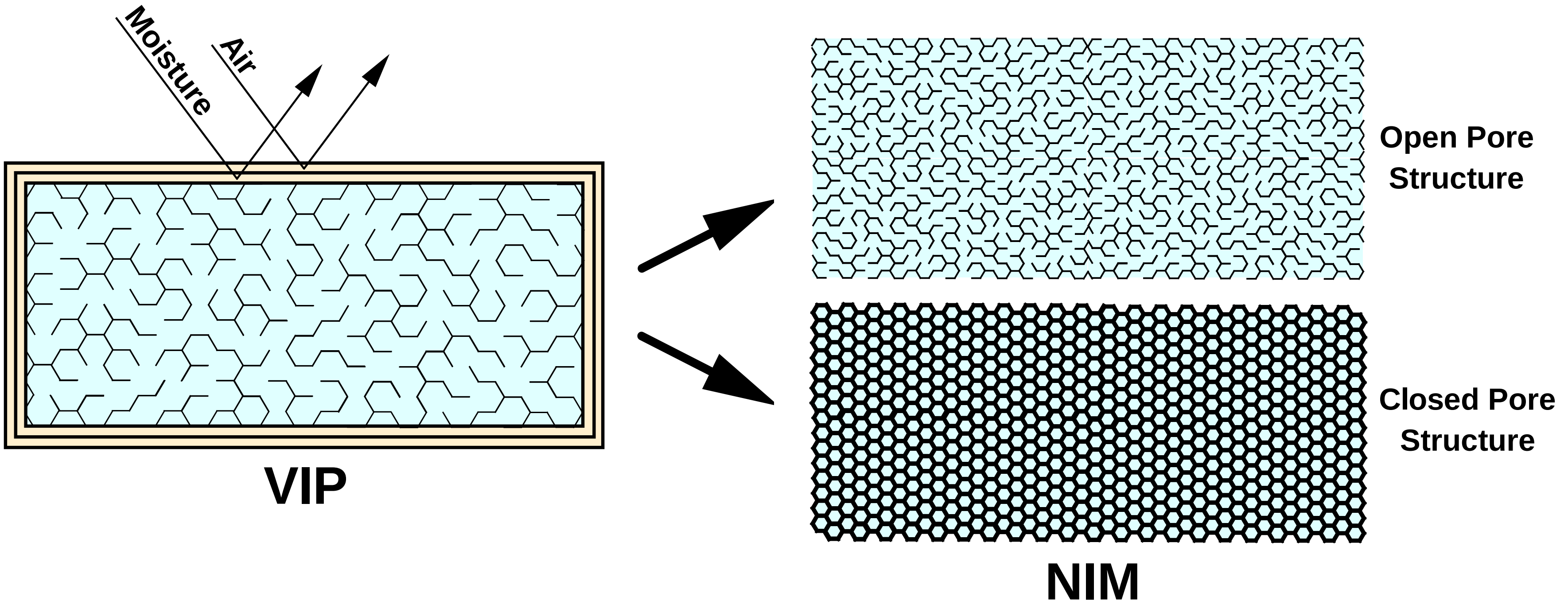


For comparison:

- **Solar radiation: 300 nm - 3000 nm**
- **Atomic diameters:** Hydrogen: 0.16 nm; Carbon: 0.18 nm; Gold: 0.36 nm
- **Molecular length:** Stearic Acid: 2.48 nm ($C_{17}H_{35}COOH$)

Nanotechnology:
Technology for controlling matter at an atomic and molecular scale.

Nano Insulation Materials (NIMs)

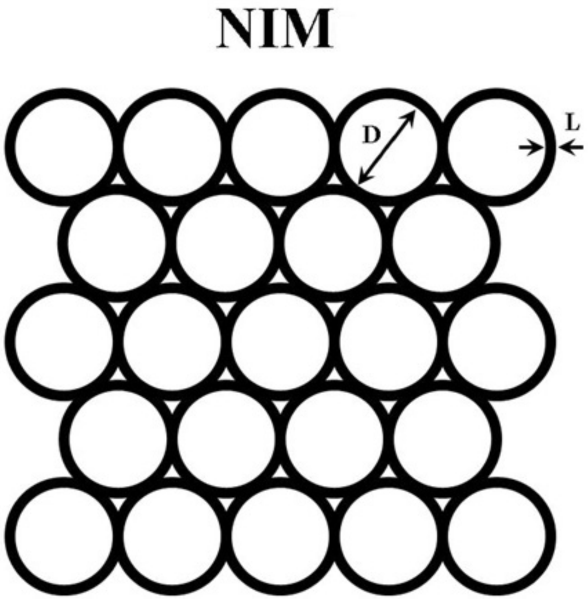


NIM - A basically homogeneous material with a closed or open small nano pore structure preferably with an overall thermal conductivity of less than 4 mW/(mK) in the pristine condition.

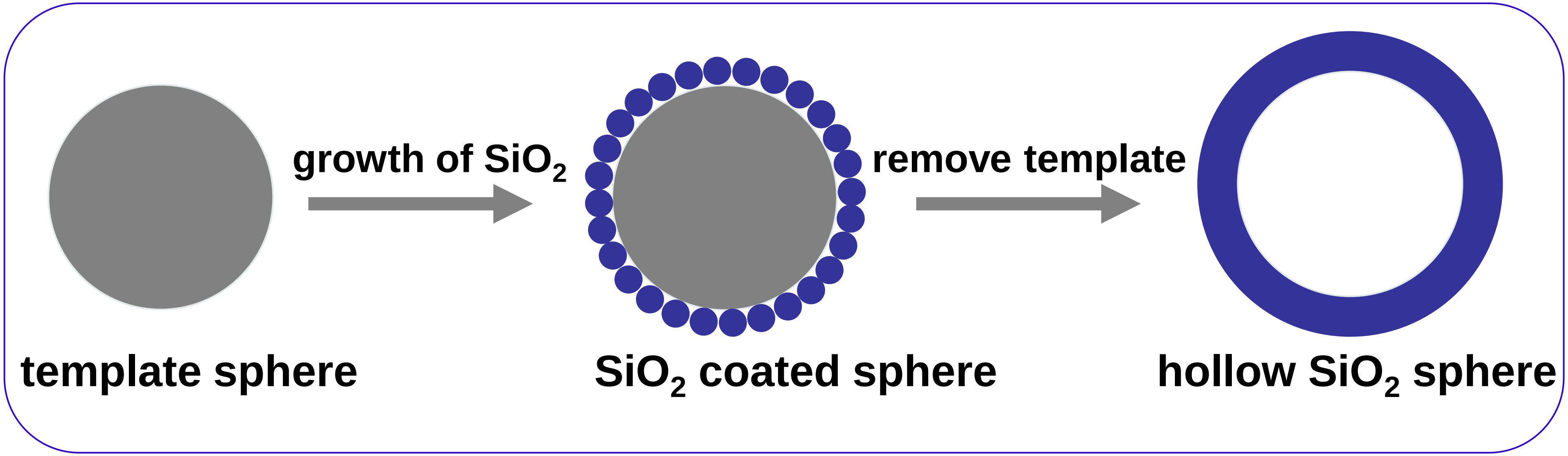
Synthesis of NIMs

The thermal properties of the material can be controlled by varying several parameters, e.g.:

- **The diameter of the pores (D)**
- **The thickness of the silica shell (L)**
- **The roughness of the silica shell**
- **Shell material (can be other than silica)++**



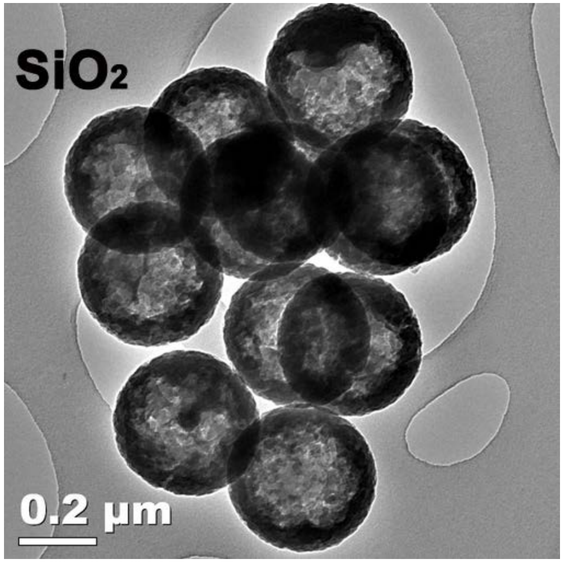
Hollow Silica Nanospheres: *How*

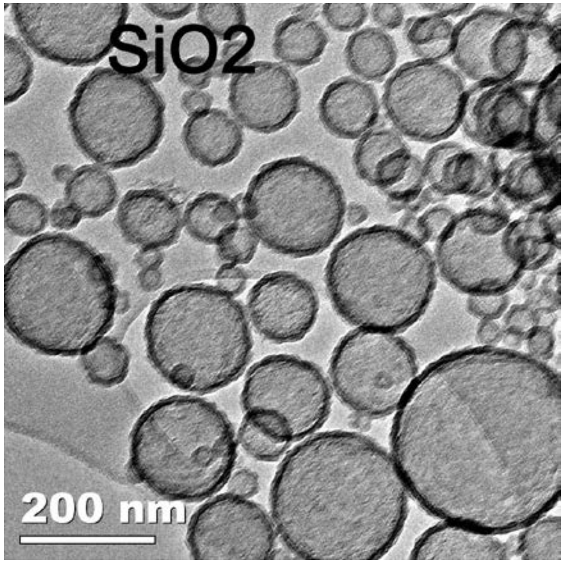


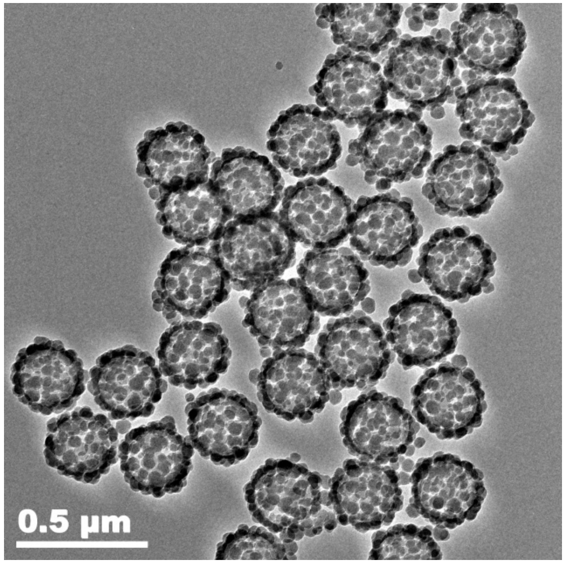
Two additional parameters

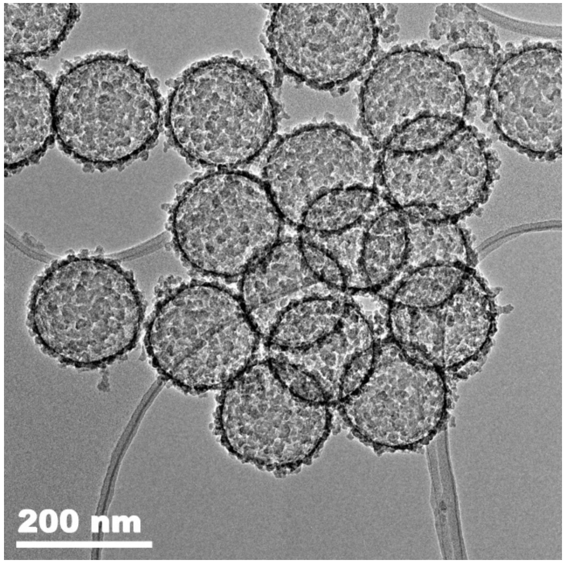
- *Template materials*: easy synthesis, less environmental hazard, recyclable
- *Removal of template*: environmental friendly process

Synthesized Hollow Silica Nanospheres









Hollow SiO_2 Nanosphere NIMs: *Thermal Conductivity*

	Outer diameter (nm)	Layer thickness (nm)	Thermal conductivity (W/mK)
Solid SiO_2	~ 300	-	0.089
Hollow SiO_2: *dissolution-regrowth*	~ 300	~ 50	0.067
Hollow SiO_2: *PAA template*	~ 50 – 300	~ 10	0.045
Hollow SiO_2: *PS template*	~ 180	~ 15	0.020
Aerogel	-	-	0.015

Is Nano Insulation Materials (NIMs) the Ultimate Insulation Solution?

Maybe, depending on …

- Thermal performance of bulk material
- Scalability – In buildings we need large amounts of material
- Environmental performance – For the materials to be usable (in a large scale) in zero emission buildings, the carbon footprint needs to be comparable to traditional insulation materials

And last but not least

- Cost

Thank you for your attention!