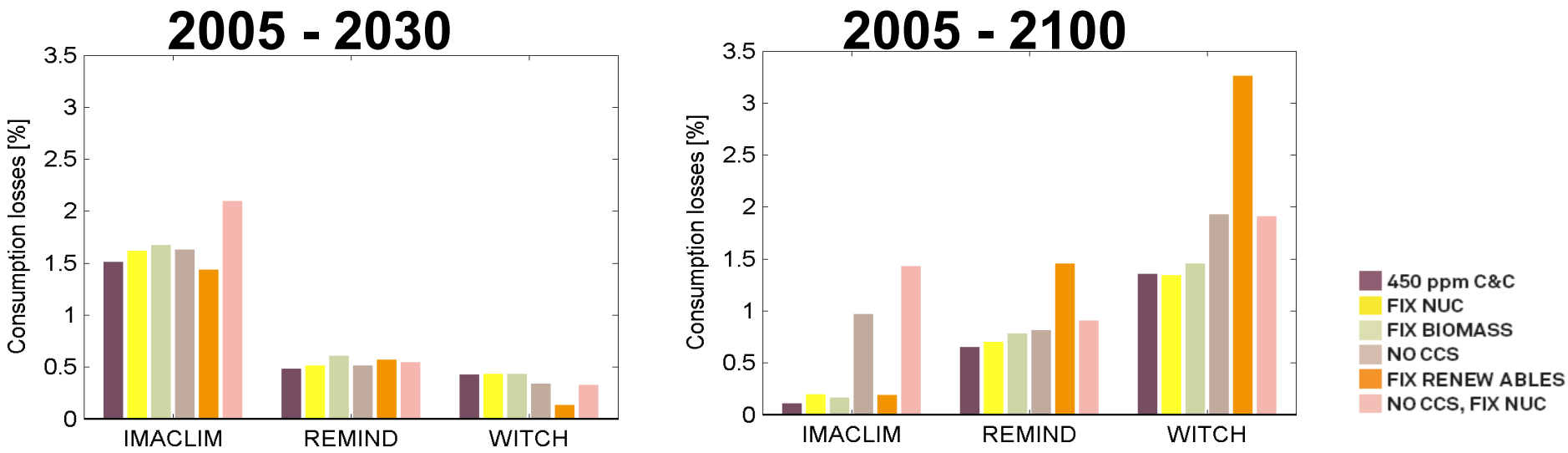
# R&D investments are needed, but on what technology??

Cat always lands on her feet.

# RECIPE: Technologies: Option Values



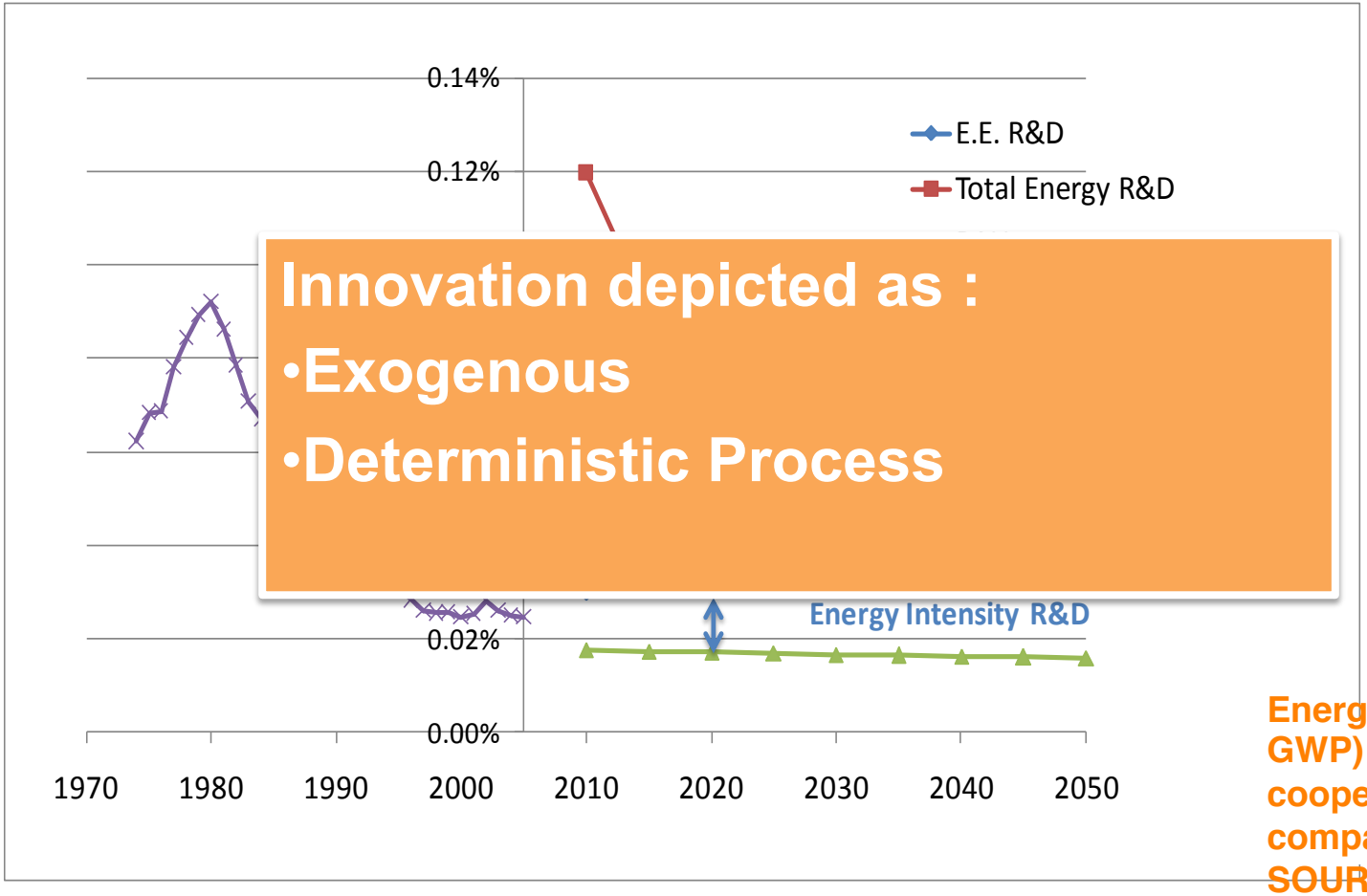

Renewables and CCS have the highest option values, nuclear and biomass play less important roles

Renewables pay off in the long run due to learning effects

Energy efficiency becomes more important if some technologies are not available

Broad technology portfolio minimizes risks

# Optimal Energy R&D investments to stabilize climate




**Innovation depicted as :**

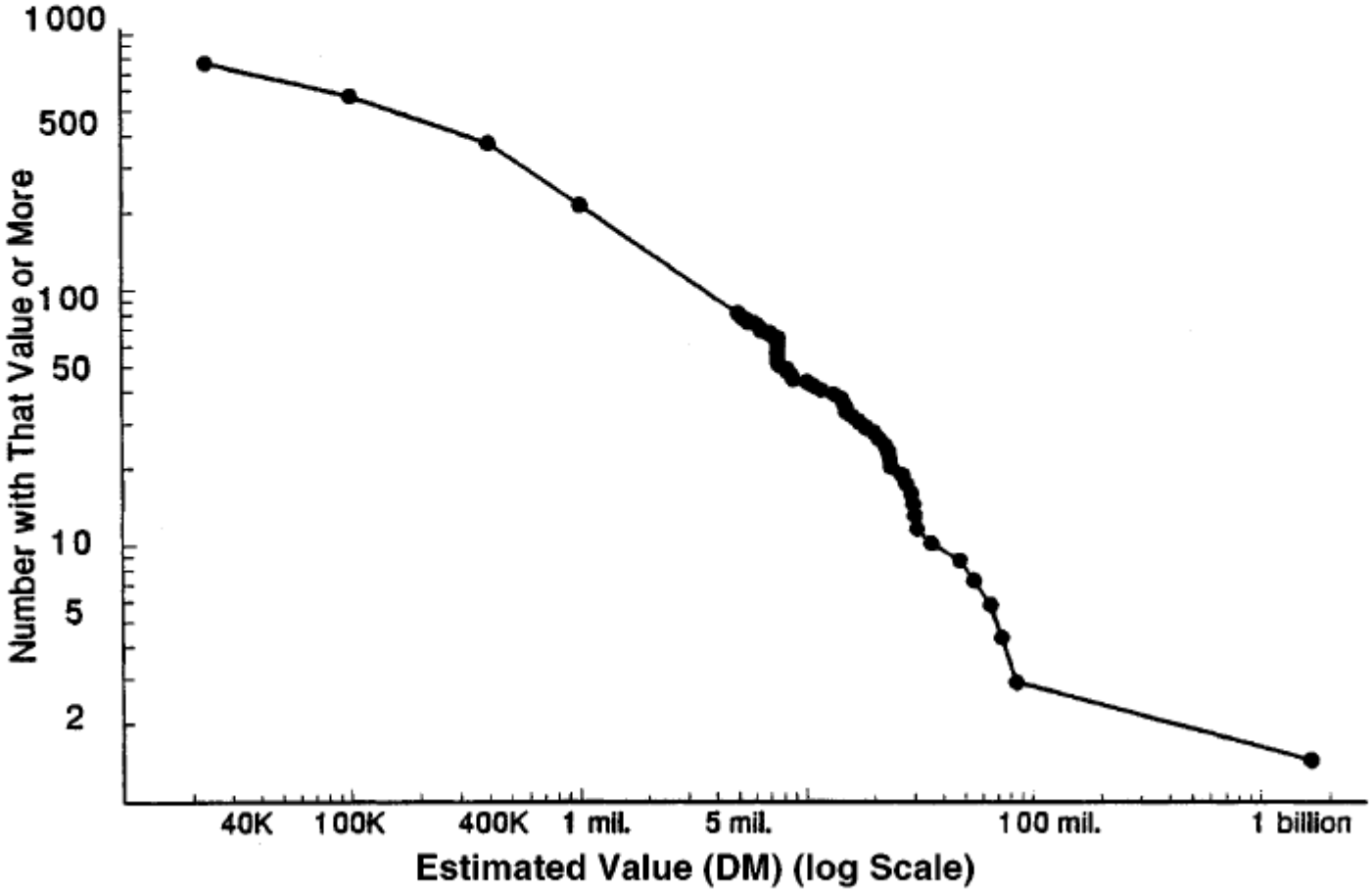
- **Exogenous**
- **Deterministic Process**

**Energy R&D investments (as shares of GWP) in the baseline and in climate cooperation scenario (450 ppm CO2), compared with historical figures. SOURCE: WITCH model**

# Using Expert Judgments

- R&D Effectiveness and deep uncertainty

# Plot of German renewed patent values on Pareto coordinates




**Uncertainty and the size distribution of rewards from innovation**
**F. M. Scherer, Dietmar Harhoff and Jörg Kukies**
**Evo.lutionary Economics Vol 10**

# Using Expert Judgments

- R&D Effectiveness and deep uncertainty
- Analysis of Patent data: R&D programs are often not riproducibile.


*"Thank God! A panel of experts!"*

# Using Expert Judgments

- R&D Effectiveness and deep uncertainty
- Analysis of Patent data /R&D programs are often non riproducible.
- CONS: Experts Biases (Tversky, Kahneman), representativeness, anchoring, availability, affect
- PRO: Intuition: recognition of patterns stored in memory (Herbert Simon)
- Compromise: Elicitation Protocols

# Protocol

Introductory assessment

↓

Selection of the elicitation components

↓

Elicitation process

↓

Analysis procedures

- Selection of the questions areas
- Selection of the experts

- Face-to-face interviews
- Estimates of physical/monetary quantities and of probabilities

- Bias control
- Pilot tests

- Follow up sessions
- Analysis of correlation and bias detection
- Assessment of uncertainty
- Use of data/aggregation

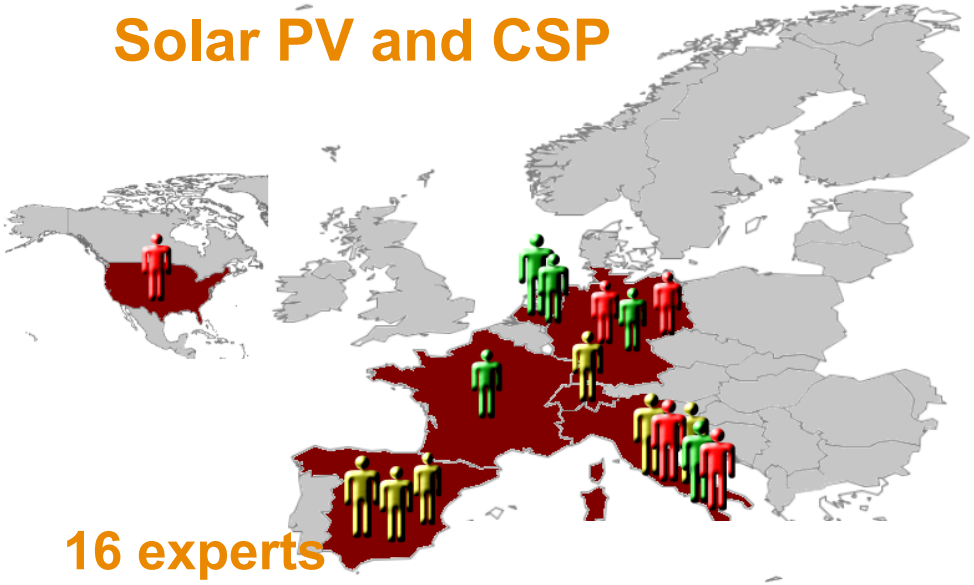
(2) Morgan and Henrion, 1990; O'Hagan et al., 2006; Meyer and Booker, 1991; Clemen and Reilly, 2001; Keeney and von Winterfeldt, 1991; Phillips, 1999; Walls and Quigley, 2001.

# Technologies Surveyed so Far

- Biofuels for transportation
- Storage for transportation (EDV)
- Solar technologies (PV and CSP)
- Nuclear (with Harvard)
- Bioenergy
- CCS (with University of Massachusetts)

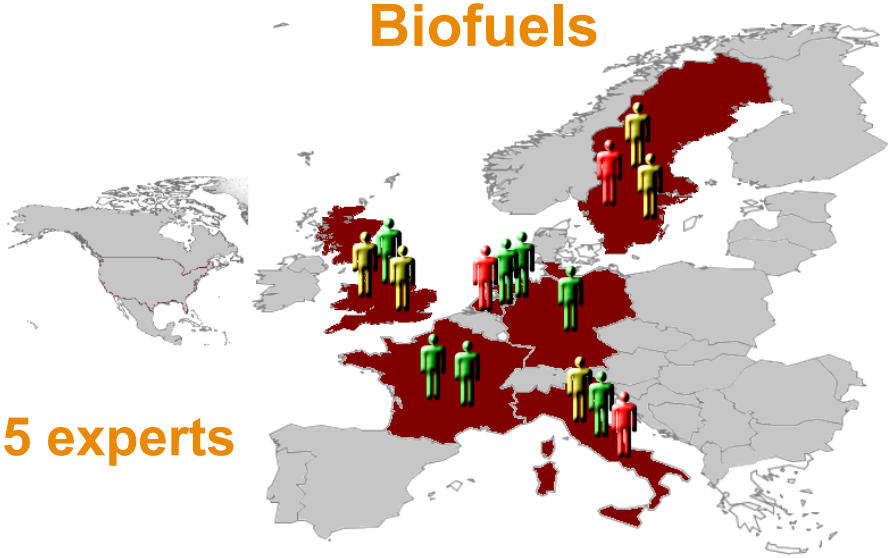
# Example of Panel Composition

## Solar PV and CSP

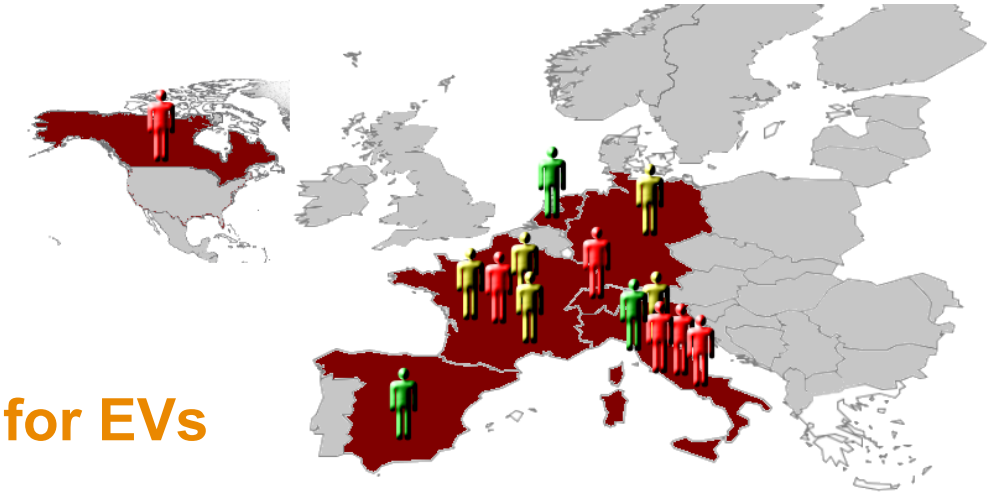


16 experts

## Biofuels



15 experts



Institution

Academy

Private sector

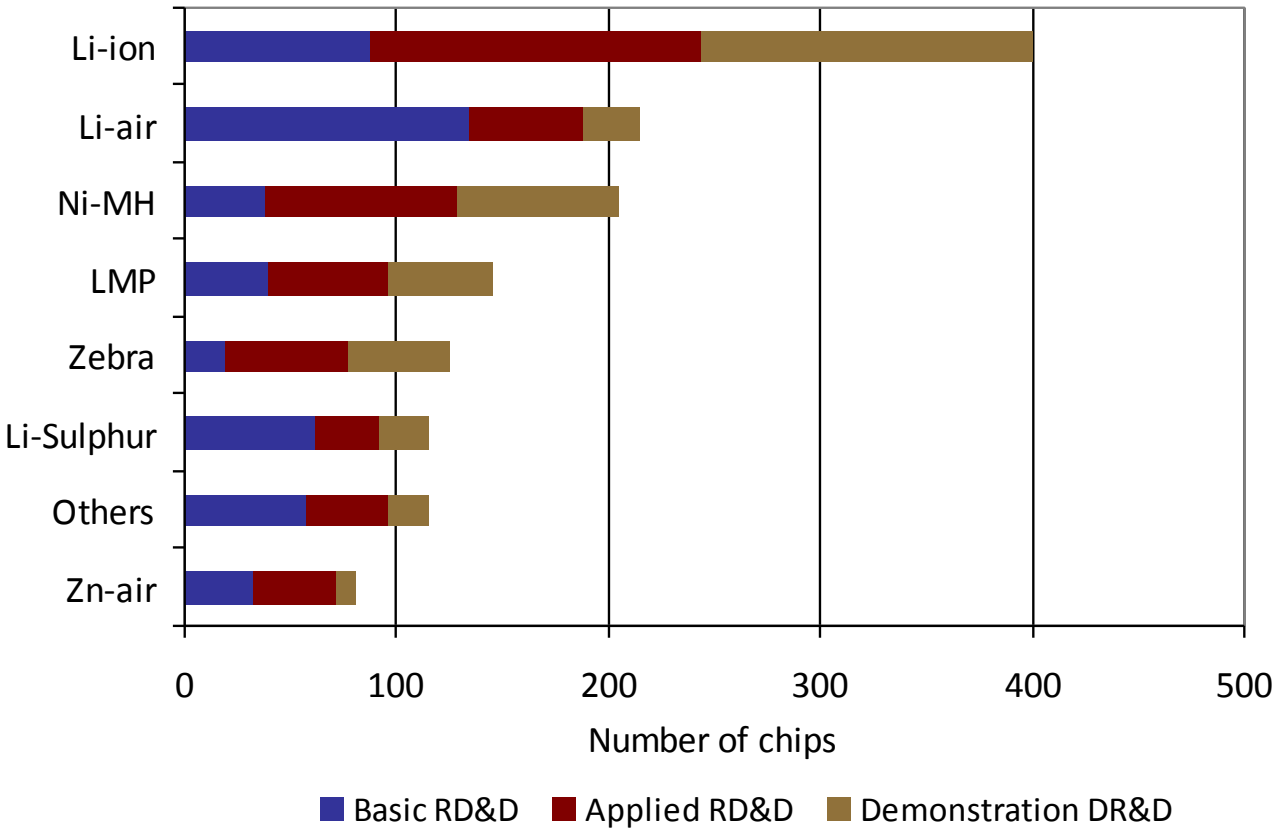
## Batteries for EVs

15 experts

# What do we survey?

- How much and what type of R&D
- What is the cost of the technology going to be in 2030 (under specified circumstances and different levels of R&D expenditures)
- How fast is the diffusion going to be? Are there going to be upper limits?

# An example : Batteries for EDV

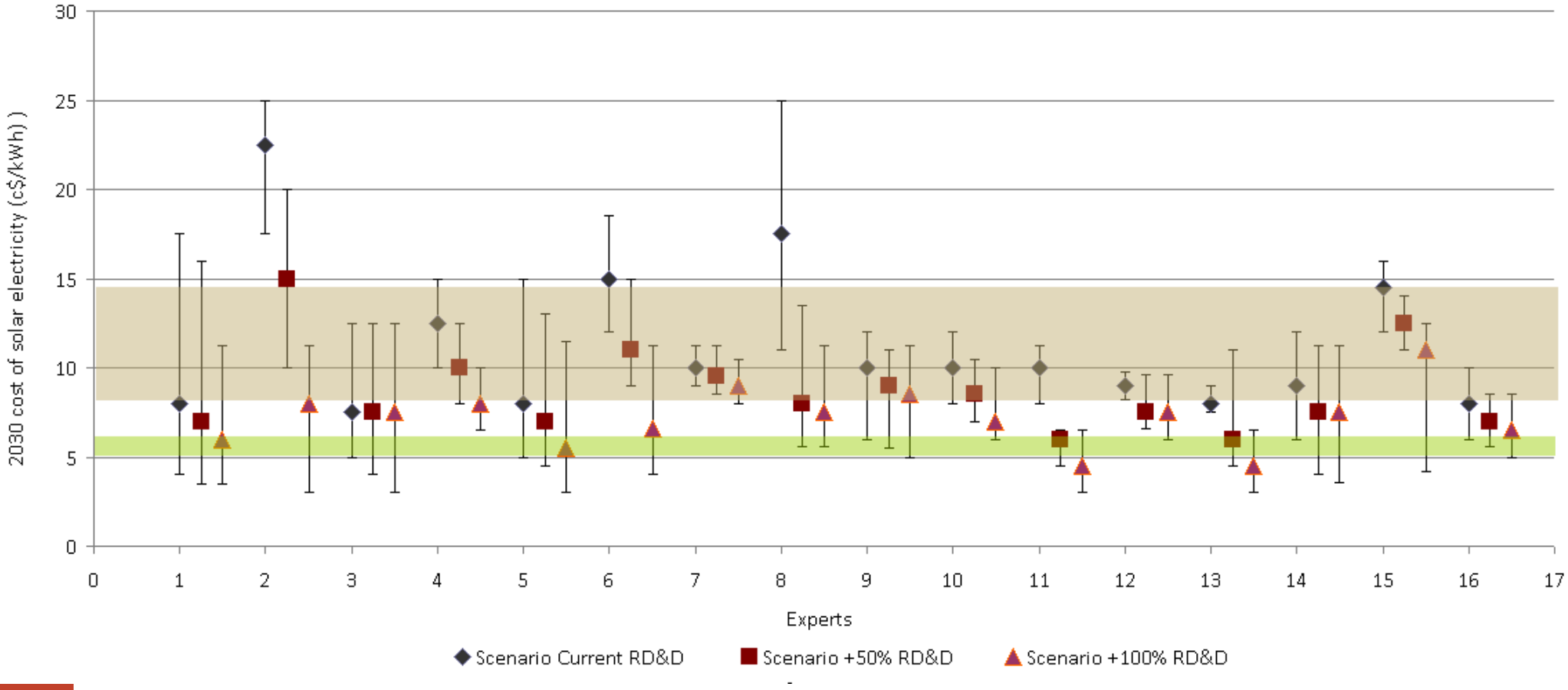



***Sum of the RD&D allocated by all experts among different technologies and budget breakdown among basic, applied and demonstration RD&D.***

# What do we survey?

- How much and what type of R&D
- What is the cost of the technology going to be in 2030 (under specified circumstances and different levels of R&D expenditures)
- How fast is the diffusion going to be? Are there going to be upper limits?

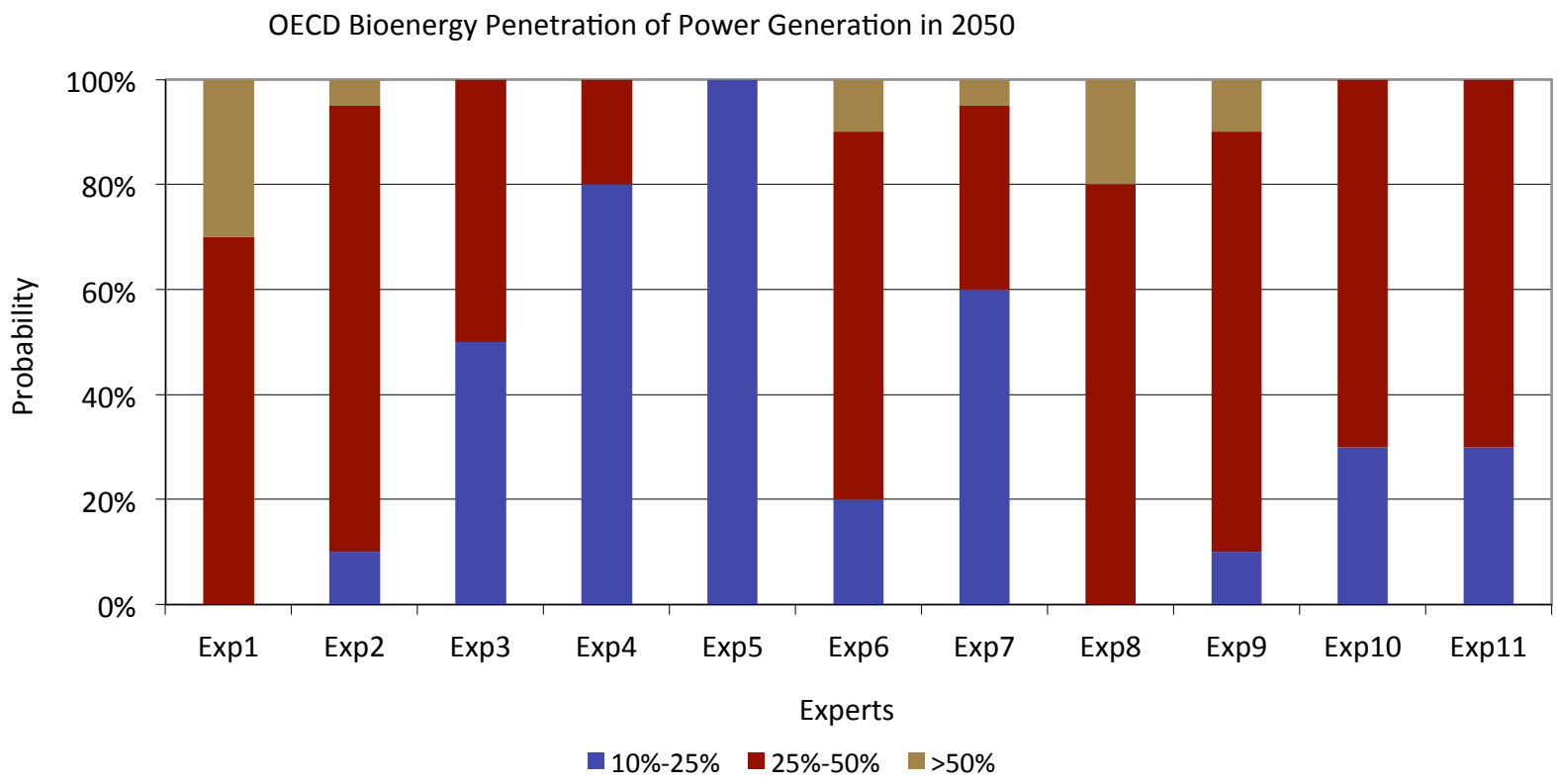
# Solar Technologies (2030 Cost conditional on R&D budgets



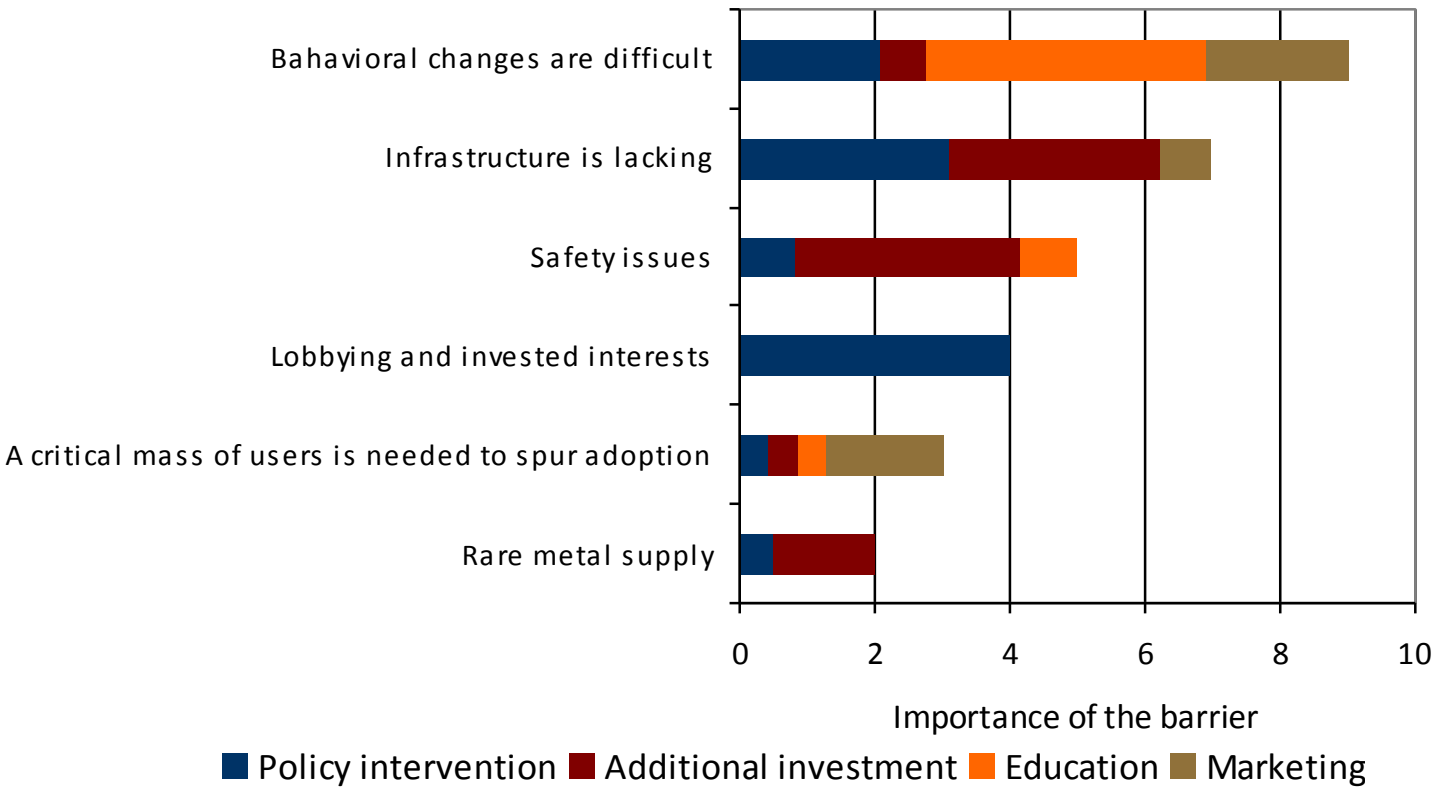
# What do we survey?

- How much and what type of R&D
- What is the cost of the technology going to be in 2030 (under specified circumstances and different levels of R&D expenditures)
- How fast is the diffusion going to be? Are there going to be upper limits? What are the key factors?

# Example: Bioenergy Power



# Example: Batteries for EDV




***Factors which could represent non-technical barriers to the diffusion of EDVs and potential solutions to overcome the barriers. The importance of the barrier is given by the number of experts who indicated the barriers with maximum importance.***

# What is the optimal energy RD&D portfolio?

**Coupling :**

- **Better empirical understanding of the innovation process**
- **Information on probabilities of breakthroughs and diffusion scenarios**

**we can model the problem of the optimal RD&D portfolio in a coherent and complete fashion;**

**provide input to other Integrated Assessment Models.**

**More info on :**

**www.icarus-project.org**

# Thanks

The research leading to these results has received funding from the European Research Council under the *European Community's* Seventh Framework Programme (FP7/2007-2013) / ERC *grant agreement* n° 240895 – project ICARUS "Innovation for Climate Change Mitigation: a Study of energy R&D, its Uncertain Effectiveness and Spillovers".