2011 World Materials Summit

Panel Discussion Report

Smart Grid/Storage Panel XXXX

2011 World Materials Summit

Overall Objective of Panel

- Describe the current state of the technology
- Identify a long-term vision or goal (e.g. to achieve by 2030)
- Prioritize major research and technological needs and opportunities in support of that vision
- Suggest how research developments will lead to progress toward that vision
- Suggest where international cooperation is needed to accelerate developments
- Identify impediments, hindrances, and stumbling blocks to international cooperation
- Identify policy, support, outreach, and promotion opportunities
- Determine recommendations/open questions

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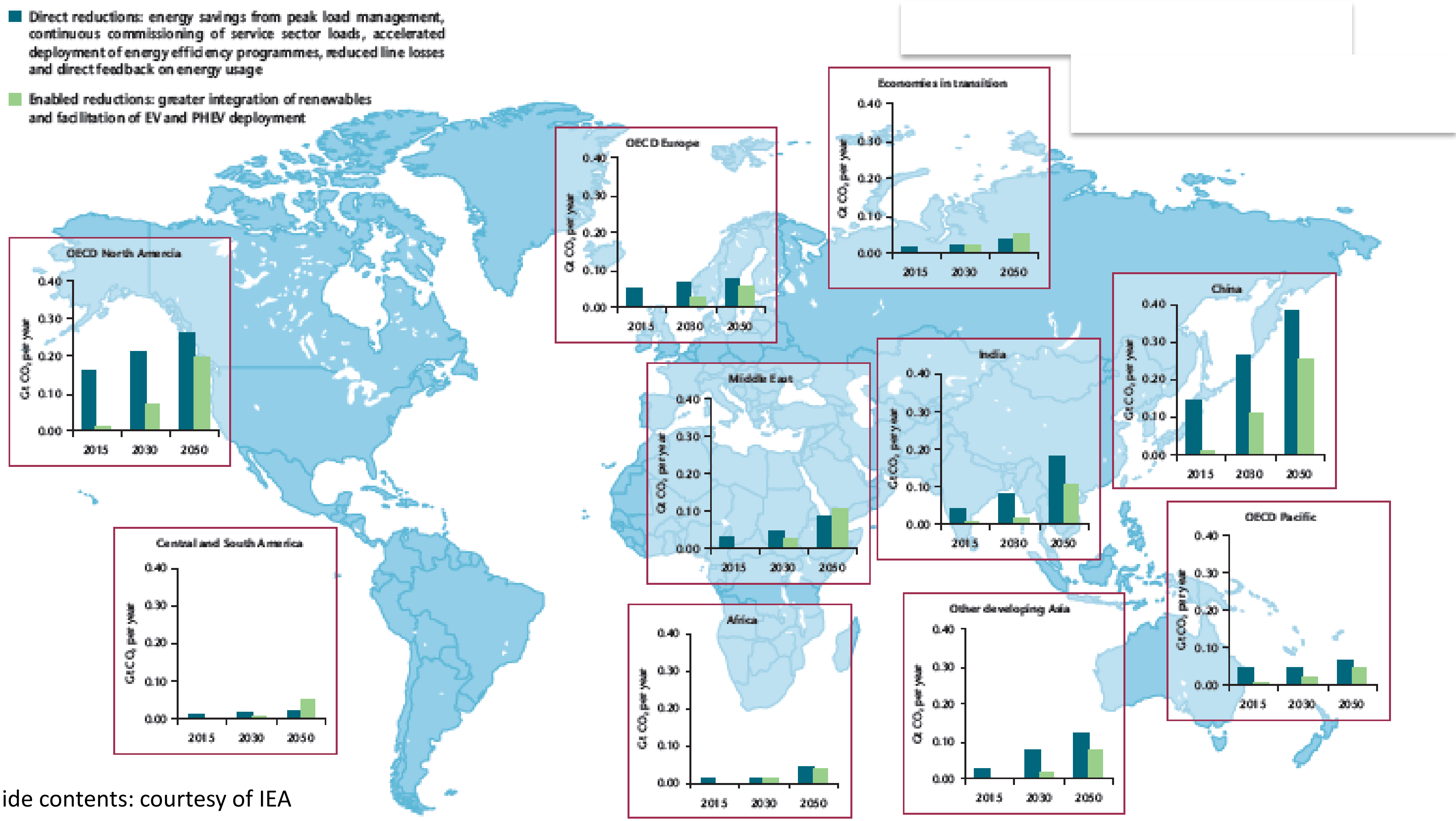
Background

- The smart grid and storage are enabling technologies for both a cleaner and more efficient power grid and cleaner transportation sector. These technologies can be applied internationally to provide more reliable energy in both developed and developing nations.
- Key material challenges include developing new energy storage materials, new methods of transmitting electricity efficiently over long distances, and control systems and smart materials for grid communications and control.

CO2 abatement potential of 0.9-2.2 Gt/year by 2050



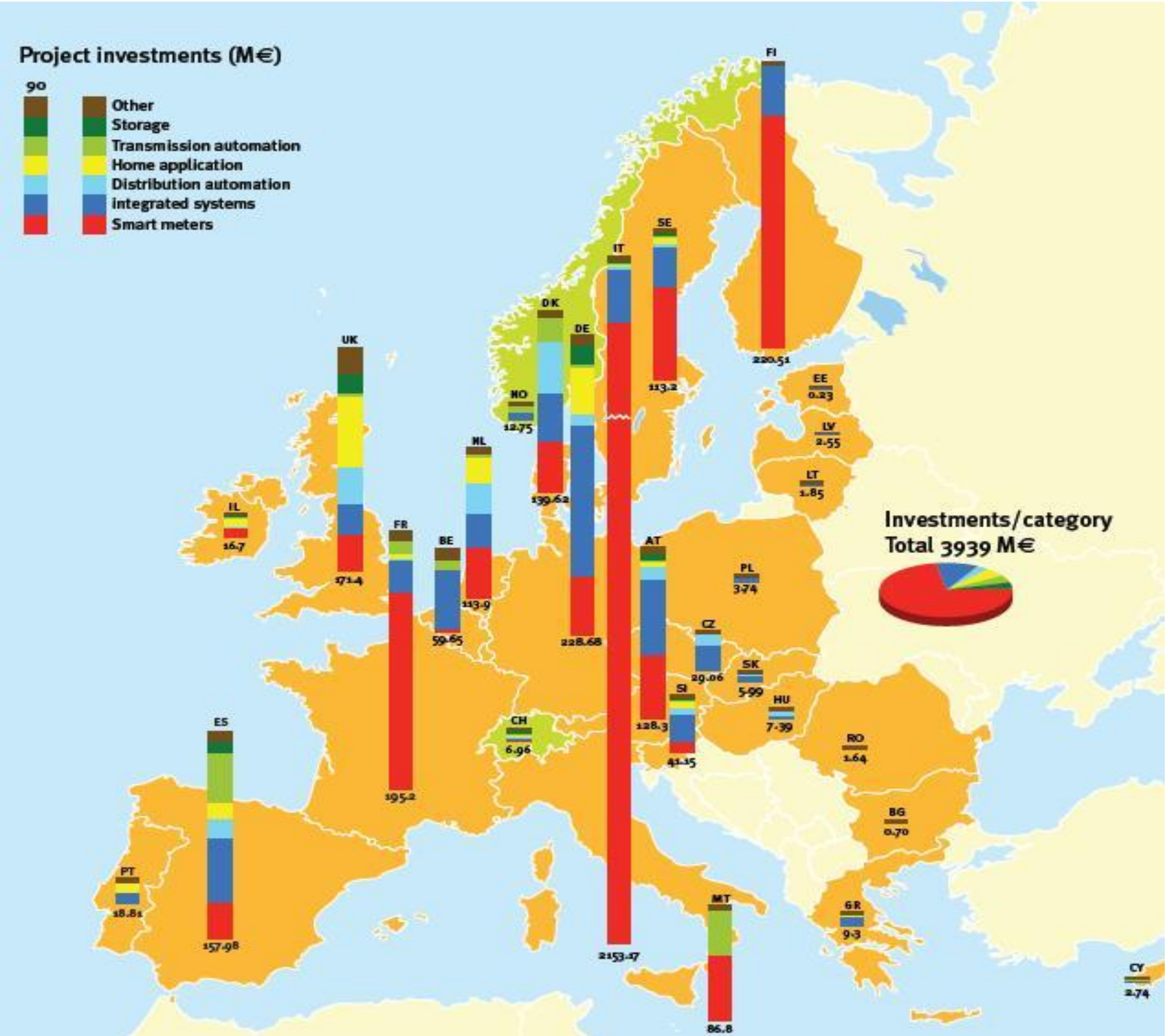
Slide contents: courtesy of IEA

Smart Grids have the potential to reduce global CO_2 emissions by over 2 gigatonnes per year by 2050

Current state of the technology (Bird's eye view)

Description and scope of the technology

- viable technologies are already available for smart grid sensors, communications and control
- amorphous core and nano-crystalline energy saving materials will have a large role to play
- in the case of storage the costs are high and deployment is low; compressed air is the most cost -effective for bulk energy storage but has site-specificity challenges; pumped-hydro storage is the most mature; flywheels can be viable for short-term storage
- most other technologies are longer term prospects

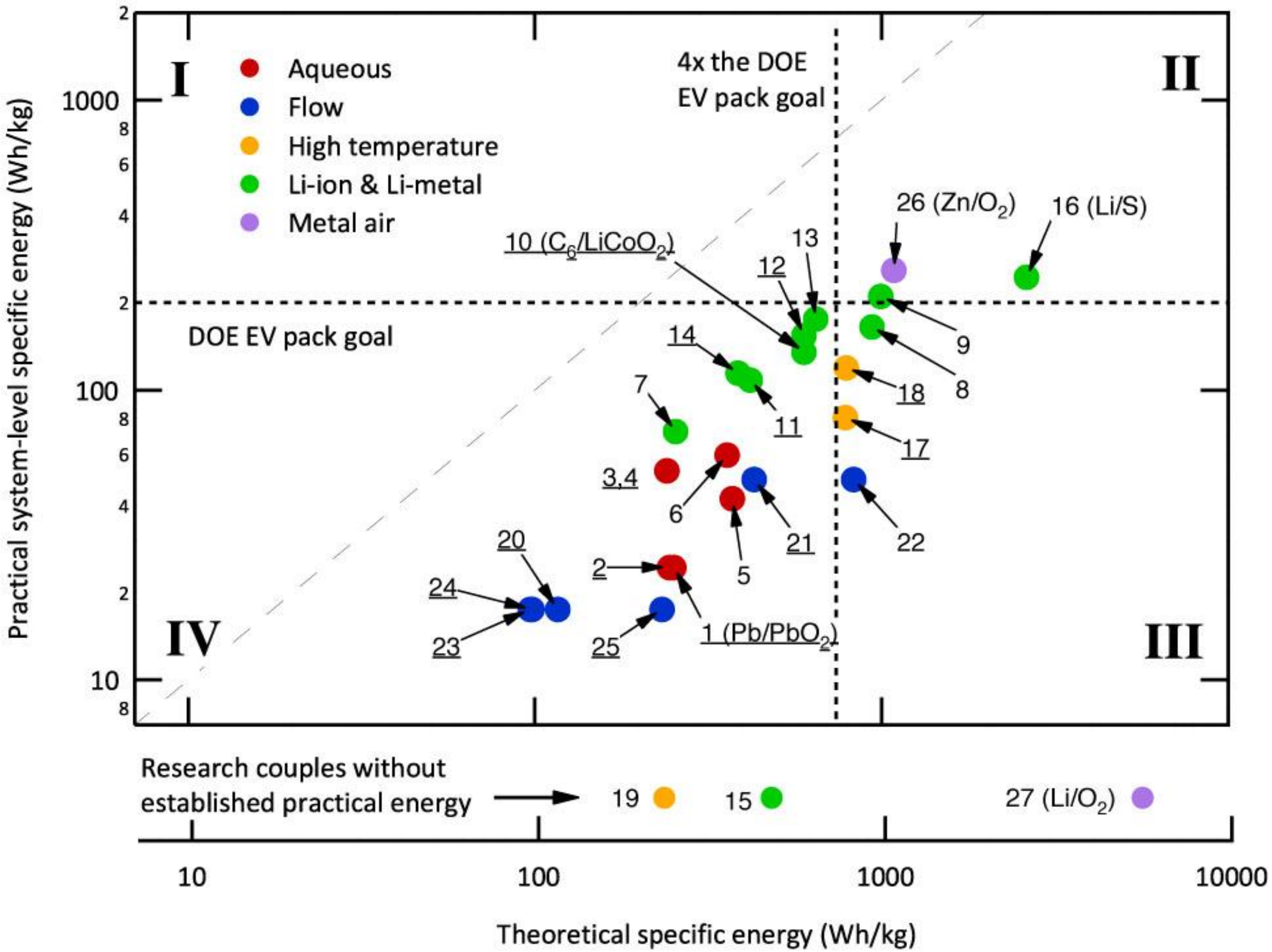


SG investment is happening now: e.g. €4bn in EU

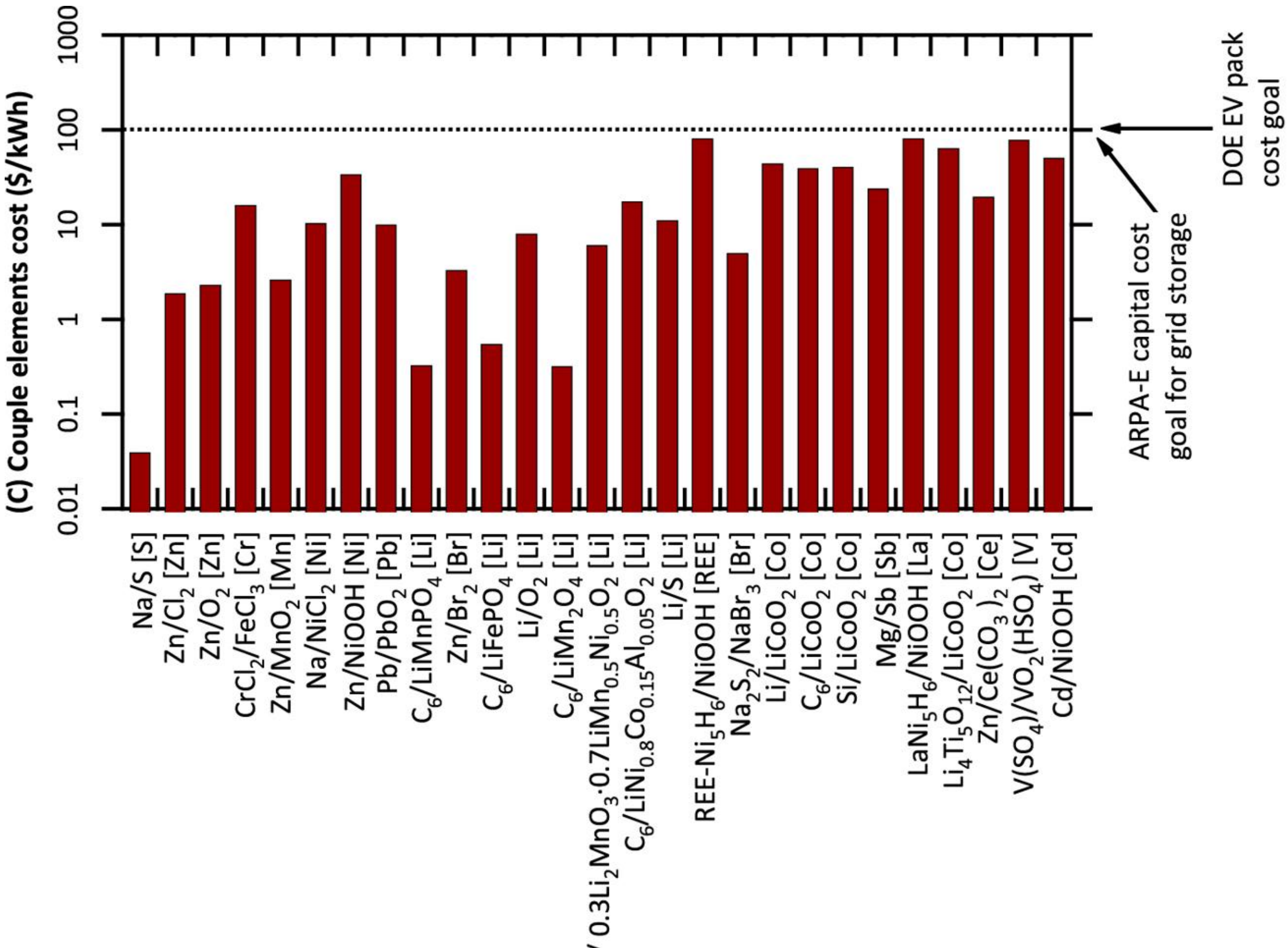
Current directions and rates of change of the technology

- For storage: low learning rates for compressed air and pumped storage; moderate for batteries; medium for thermal storage
- For transmission there's a trend towards: DC cables, super high voltage transmission, ground cables, carbon fibre reinforced cores in overhead cables;
- longer term cable materials research needs include: high temp super conductors; smart materials to mitigate natural risks; heat and flame resistant polymer materials
- EV and hybrids are of growing importance because of the link with rechargeable stations and off-peak charging to levelise loads
- Other major elements and their related materials foci include: power electronics, smart meters, intelligent networks at the end-user site level and end-use interfaces

Batteries *Schmatteries*



Batteries Schmatteries



Current state of the technology (Bird's eye view)

Current "best," i.e. most promising and best-developed options

- For storage: compressed air is cheapest for large scale site issues permitting; pumped hydro most developed but site constrained; batteries and fuel production (hydrogen) have high research development opportunities for material science; fly wheels have a role for short term storage
- For transmission cables: trend towards DC and super high voltage transmission; also ground cables; carbon fibre reinforced core for overhead cables; longer term research needs include: high temp super conductors; smart materials to mitigate natural risks; heat and flame resistant polymer materials
- RE sources are key element in smart grid; fuel cells for distributed generation

Strengths and weaknesses in the science and technology (core competencies and gaps)

- There are a significant number of technology assessments of both the smart grid and energy storage that can be used (IEEE, APS, CRS, Sandia others – these are U.S. centric, so international perspective would be useful.
- There is an important gap in the matching of material science technologies with market applications

Long-term vision or goal (toward 2030)

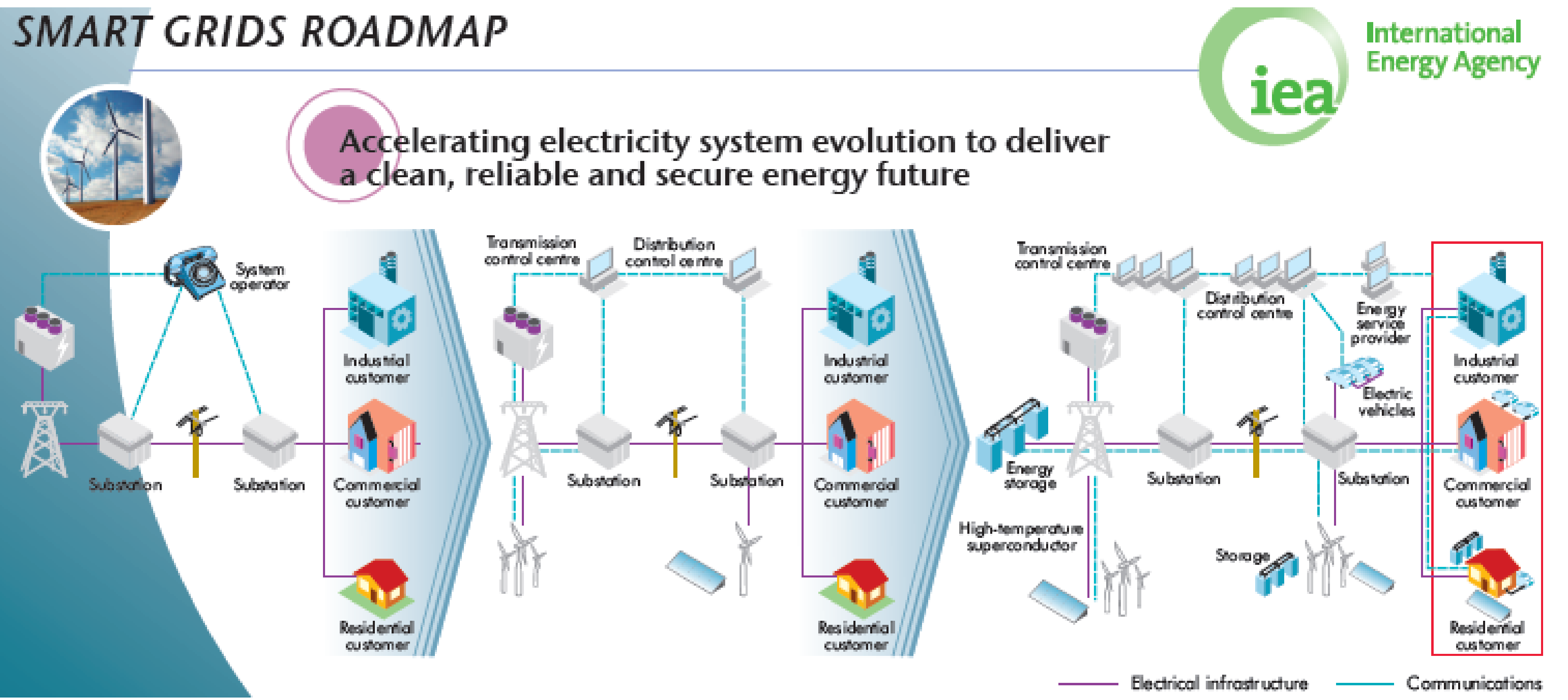
Relevant existing roadmaps and their time horizons

- Regional: EU-DESERTEC, DOE, Chinese plan etc
- International: Clean Energy Ministerial -International Smart Grid Action Network;

Need for new or modified roadmaps –

- the need is for progressive development of the existing road maps
- Its realistic that some of the regional smart-grid road maps could be deployed within the 2025-50 timeframe; worldwide development will be longer term
- Many micro-challenges exist within these and these are where material science has a role. e.g. in the US there are ARPA-E goals for $100/kWh for system storage, and other policy goals for smart grid infrastructure and storage deployment)

Many SG road-maps exist



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US DOE storage technology road-map

FIGURE 1: PRIORITIZED ACTIVITIES TO ADVANCE ENERGY STORAGE TECHNOLOGIES

	NEAR TERM (< 5 years)	MID TERM (5–10 years)	LONG TERM (10–20 years)
ADVANCED LEAD-ACID AND LEAD-CARBON BATTERIES	Conduct DOE-funded validation tests of system lifetime, ramp rates, etc. Develop high-power/energy carbon electrode for lead-carbon battery	Understand poor materials utilization through diagnostics and modeling	
LITHIUM-ION BATTERIES		Develop models for ion transport through solids (inorganic solids, polymers) Conduct experiments to develop a quantitative understanding of catastrophic cell failure and degradation Design and fabricate novel electrode architectures to include electrolyte access to redox active material and short ion and electron diffusion paths (e.g., non-planar geometries) Develop a highly conductive, inorganic, solid-state conductor for solid-state Li-ion batteries	Develop new intercalation compounds with low cycling strain and fatigue; aim for 10,000 cycles at 80% depth of discharge
SODIUM-BASED BATTERIES	Develop robust planar electrolytes to reduce stack size and resistance Implement pilot-scale testing of battery systems to develop performance parameters for grid applications	Decrease operating temperature, preferably to ambient temperature	Develop a true sodium-air battery that provides the highest value in almost any category of performance Use surface-science techniques to identify species on sodium-ion anodes and cathodes

	NEAR TERM (< 5 years)	MID TERM (5–10 years)	LONG TERM (10–20 years)
FLOW BATTERIES	Establish a center for stack design and manufacturing methods, including joint and seal design Develop low-cost, formable, chemically and thermally tolerant resins for piping, stacks, and tanks Develop an inline, real-time sensor that can detect impurities in electrolyte composition for various flow battery chemistries Create a computational fluidics center at a national laboratory or university Identify low-cost hydrogen suppression materials (anti-catalysts) and redox catalysts for negative electrodes	Improve membranes to enable minimum crossover, lower system cost, increased stability, and reduced resistance Improve mass transport via a tailored catalyst layer and flow field configurations to increase operating current density and reduce system cost per kilowatt	Develop non-aqueous flow battery systems with wider cell operating voltages to improve efficiency
POWER TECHNOLOGIES	Develop a 1-megawatt flywheel motor capable of vacuum operation and superconduction Develop high-power/energy carbon electrode for electrochemical capacitors	Optimize materials utilization through diagnostics and modeling Develop hubless flywheel rotor with four times higher energy	
EMERGING TECHNOLOGIES		Improve thermal management in endothermic electrolysis reactions and exothermic fuel cell reactions in regenerative fuel cells	Develop new catalysts for metal-air batteries with low overpotentials for oxygen reduction in order to make systems more efficient, cost-effective, and bifunctional Explore the untapped potential of multivalent chemistries Develop air electrodes for metal-air batteries with high electrochemical activity and lower polarization and resistance
CROSSCUTTING ACTIVITIES	Combine technologies for synergy Conduct DOE-funded demonstrations of all energy storage technologies Specify cycle and life tests for stationary power applications	Take an integrated approach to degradation by combining microstructure/chemistry observations with mechanistic modeling (both degradation and electrochemical models) and accelerated testing	

Major research and technological needs and opportunities in support of vision

Current limitations to achieving goals

- Storage energy densities are too low for mobile applications and prices are too high
- For smart-grid the primary barriers are policy, market and organisational in nature; technology limitations are secondary

Ways to overcome/bypass such limitations

- Governmental and industrial partnerships; common visions; new business models

Main challenges

- – Material science community is not sufficiently involved in the discussions about SG development

Connection of research developments to achieving vision/goals

- How will materials science developments close technological gaps?
- Several technology issues are *fundamentally* materials issues (storage, transmission)
- How will end results affect societal development, resource use, emissions, waste, security?
- Key point is smart grid is not an end to itself but enables certain technologies (DG, RE, etc. Storage does not produce energy, indeed it is a net consumer)

Major research and technological needs and opportunities in support of vision

- Limitations include technology, but also communication, education and outreach regarding the benefits and importance of a smarter grid
- Existing assessments will help however –
  - Storage represents a disparate set of technologies so a uniform technology assessment and prioritization is somewhat challenging

Opportunities for international cooperation to accelerate developments in this field

- WHY & WHERE are there international cooperation needs
  - Tools
  - Scale
  - Critical players
  - Benefits to these technologies {whole > Σ(parts)}

- Mechanisms to stimulate cooperation
  - Who/what (type, specialty, size) should be involved
  - How people/organizations should be involved?
  - Funding
  - How to involve less developed and developing countries/regions and emerging economies

Opportunities for international cooperation to accelerate developments in this field

- Well developed international organizations on smart grid
- Less on grid storage. Tend to be technology centric by discipline
- Some international organizations/conferences (EESAT, ESA)

Impediments/hindrances/stumbling blocks to international cooperation

- Major factors that slow progress in this field
- Possible means to minimize/eliminate them
- Potential cost to the field/technologies if there is no international collaboration

Concluding/summary slide

Recommendations

- Material Science community needs to follow and aim to be present at the discussions on SG development to ensure that its role is understood and to better plan its input