A Lower Carbon – Higher Energy Future: A Few Grand Challenges to Shell

Jose Bravo
Shell Chief Scientist, Thermodynamics and Separations

MAIN DRIVERS FOR CHANGE

- Climate Change

- Higher Energy System

- Other Factors:
  - New Resources – changing markets locally
    - Shale Gas/Oil
    - New Areas
  - New Technologies to Produce, Store and distribute Renewable Energy

THE NEW ENERGY FUTURE BY 2050

RISING ENERGY DEMAND, SUPPLY PRESSURE, CLIMATE CHANGE

9 BILLION people, **75%** living in cities

(**2 BILLION** more than today)

2 BILLION vehicles

(**800 MILLION** at the moment)

Many **MILLIONS** of people will rise out of energy poverty; with higher living standards energy use rises

Energy demand could **DOUBLE** from its level in 2000… while CO_2 emissions must be half today's to avoid serious climate change

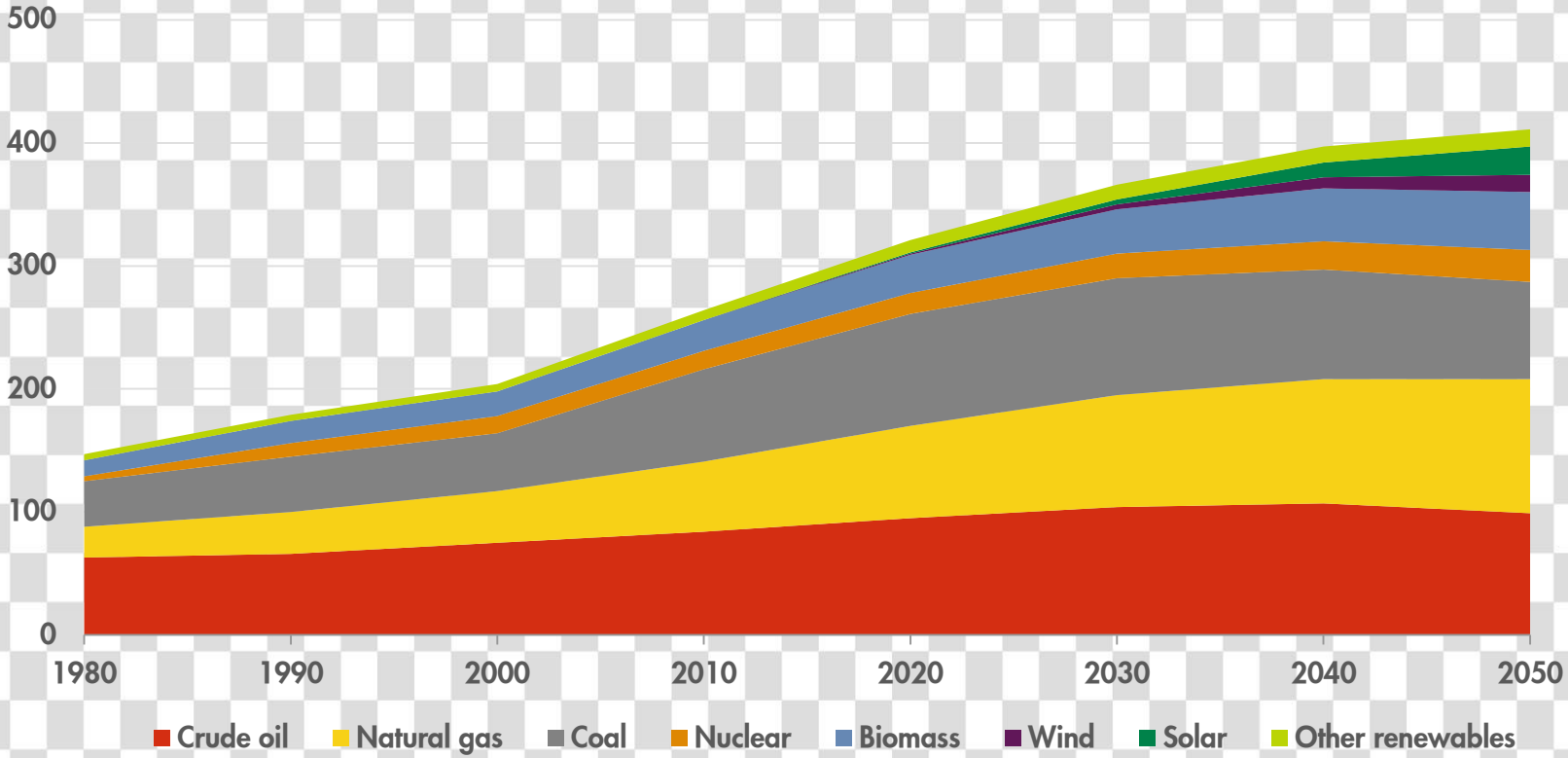
Need to become twice as efficient, using **HALF** the energy to produce each dollar of wealth

3 times more energy from renewable sources

THE ENERGY CHALLENGE

PROJECTED GLOBAL ENERGY DEMAND TO 2050

million barrels of oil equivalent a day



Source: Shell analysis, February 2014

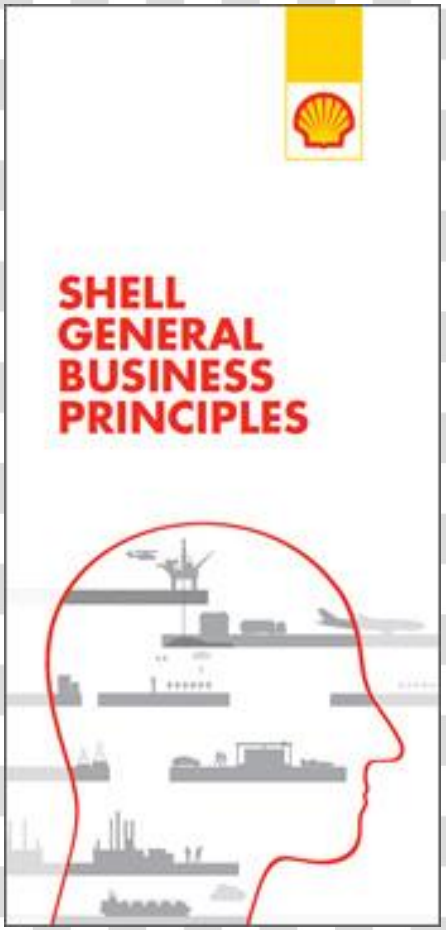
OUR COMMITMENT TO SUSTAINABLE DEVELOPMENT

We include our commitment to contribute to sustainable development in our Business Principles:

"**Long-term** profitability is essential…"

"…**balancing** short and long-term interests…"

"… **integrating** economic, environmental and social considerations into business decision-making…"



"… reduce the **environmental** impact of our operations, products and services…"

"… be good neighbours… manage the **social impacts** of our activities… enhance benefits to local communities…"

"… regular dialogue and **engagement** with our stakeholders is essential…"

MOUNTAINS & OCEANS – OVERVIEW

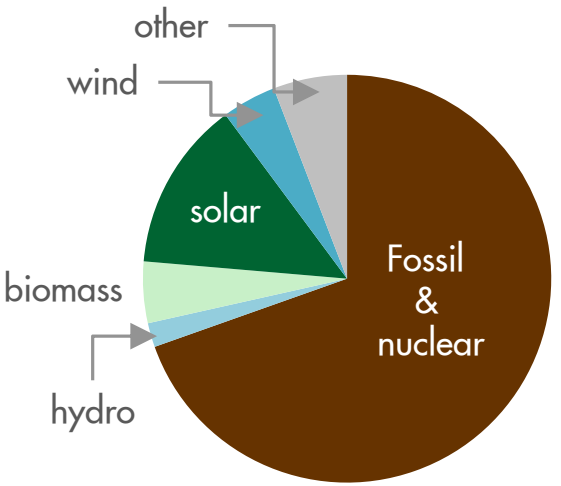
MOUNTAINS

- **Power remains concentrated in economic and political elites/governments**
- **Top Down policy making in**
  - Renewables
  - Hydrogen
  - Gas with CCS as a low carbon alternative to Coal

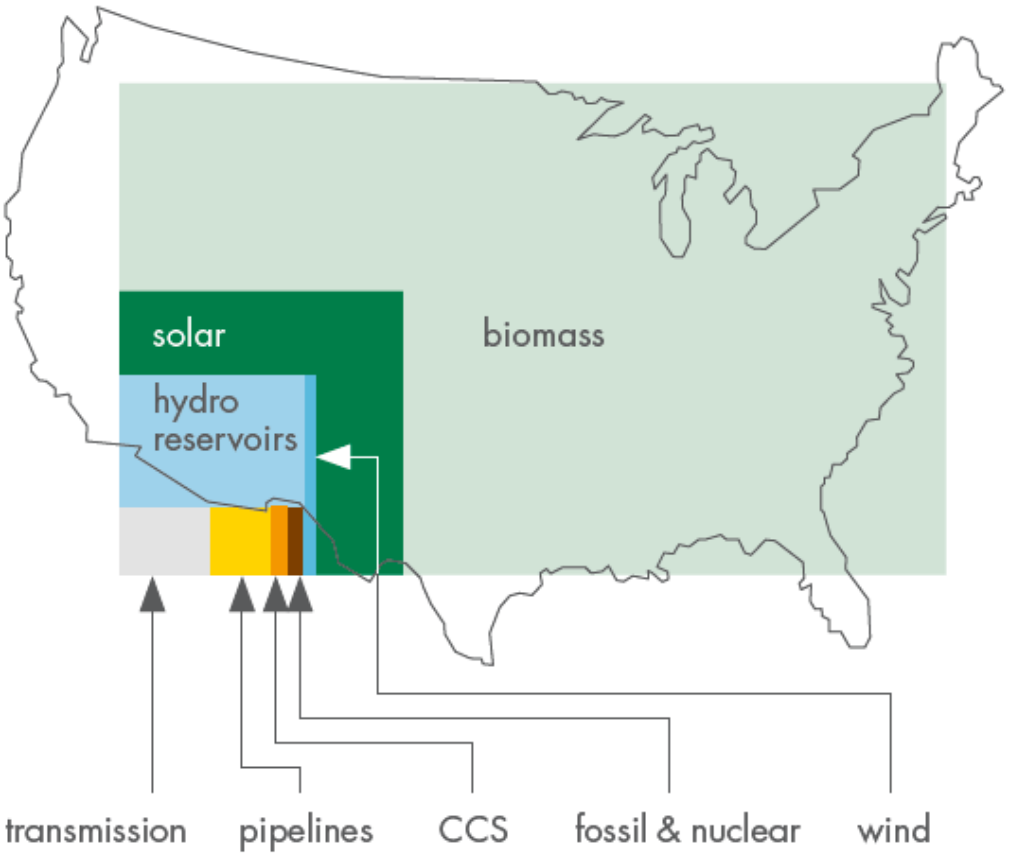
OCEANS

- **Power devolves away from governments and elites**
  - Spurs (local) innovation and economic growth
- **Less consensus building:**
  - Transition from Coal to Gas will be slower
  - Slow adoption to Efficient energy usages measures and CCS

ENERGY RESOURCES: FOOT PRINTS MATTER!

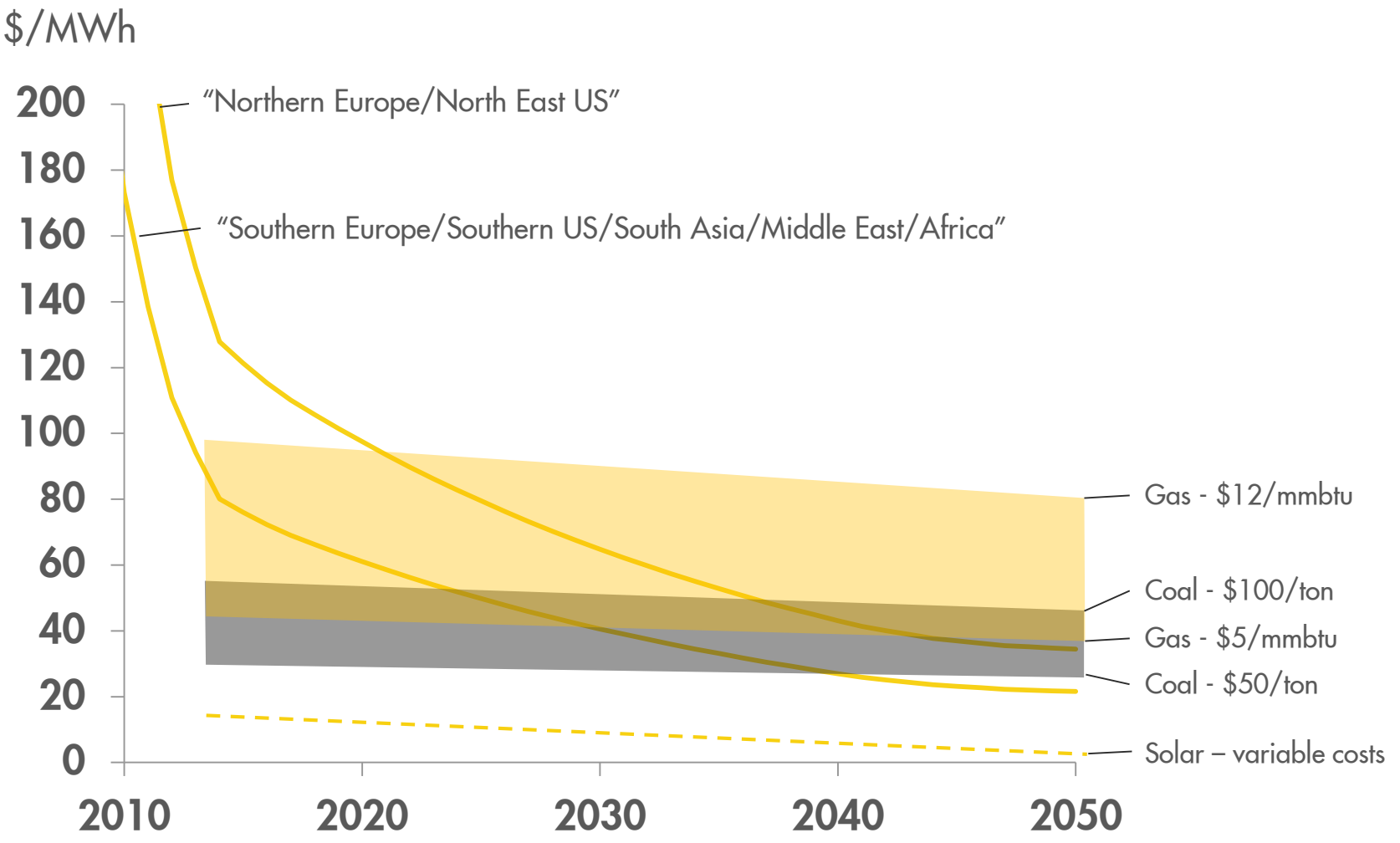


Total Primary Energy
970 EJ

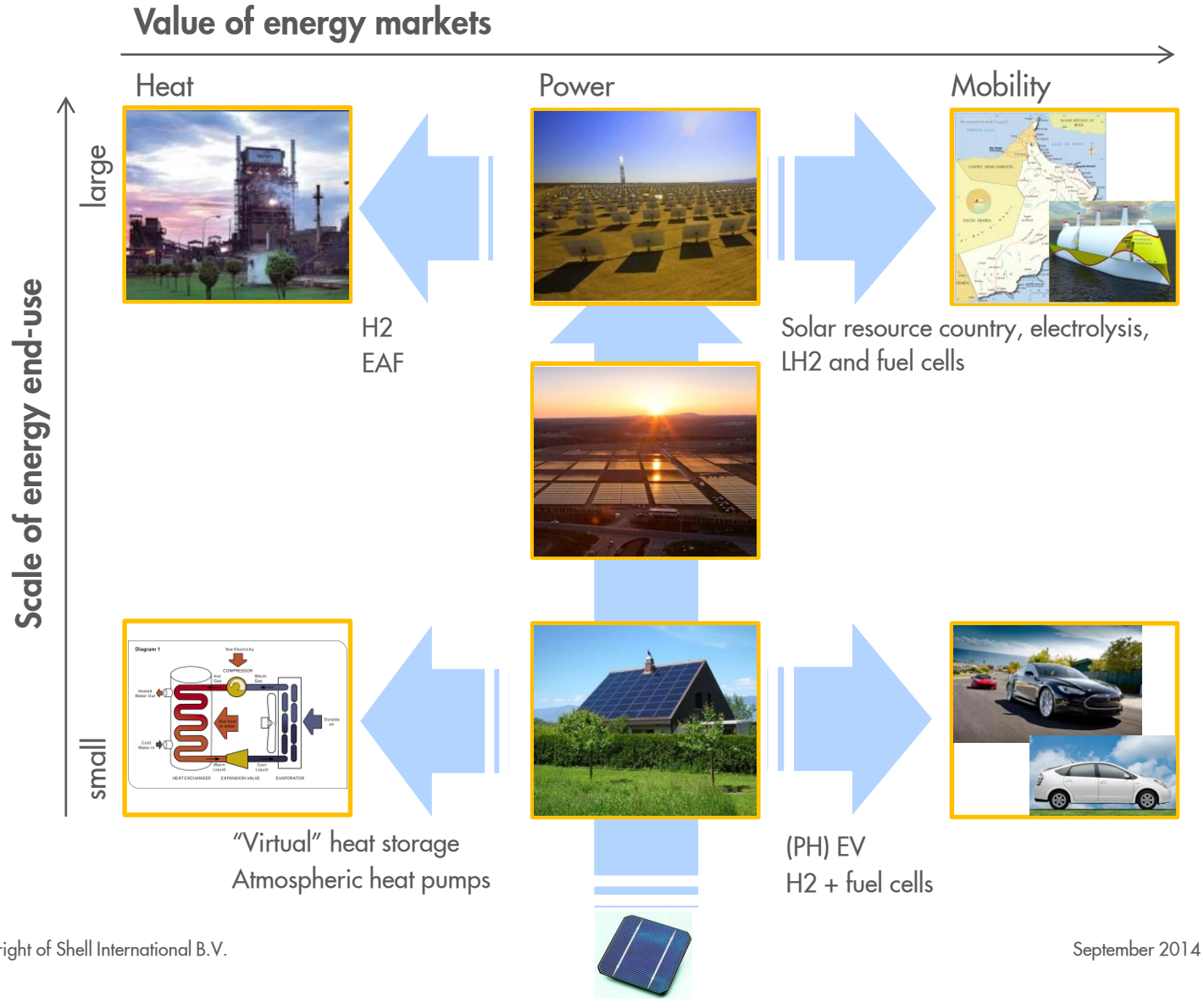


‘GREEN ELECTRONS’ – THE FUTURE ENERGY BACKBONE?

Example - costs of Solar PV versus fuel costs existing thermal generation



FUTURE ENERGY – NEW SYSTEM CONNECTIONS

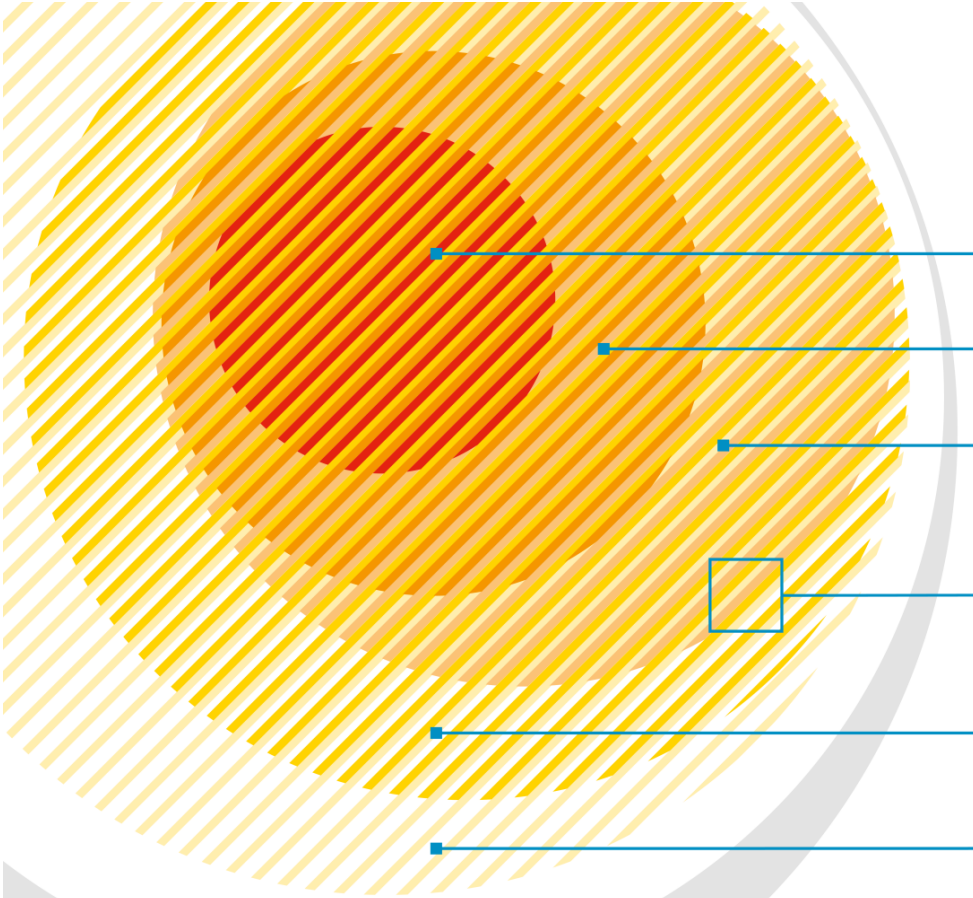


A FORMIDABLE CHALLENGE…

- **Shift to a low carbon energy system**
  - Sustainable, affordable while meeting increasing demand,
  - Must make significant changes for global warming < 2 Deg

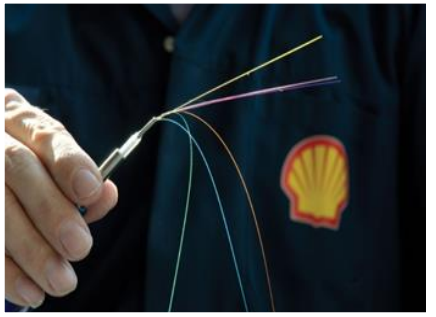
- **Response: Shell's core business shifts to Natural Gas:**
  - Abundant and available
  - Can substitute for coal
  - Mitigates intermittency of other (renewables)
  - Enables development of hydrogen fuels
- Challenges: Efficiency, Affordability (operations, assets), CCS

GRAND CHALLENGES: SEVEN AREAS



1. Hydrocarbon Discovery
2. Hydrocarbon Extraction
3. Hydrocarbon Processing
4. Data Management Utilisation and Automation
5. Availability of Assets and Operations
6. Product Engineering and Development
7. Sustainability

OVERARCHING THEMES



Monitoring, Sensing, and Data Management

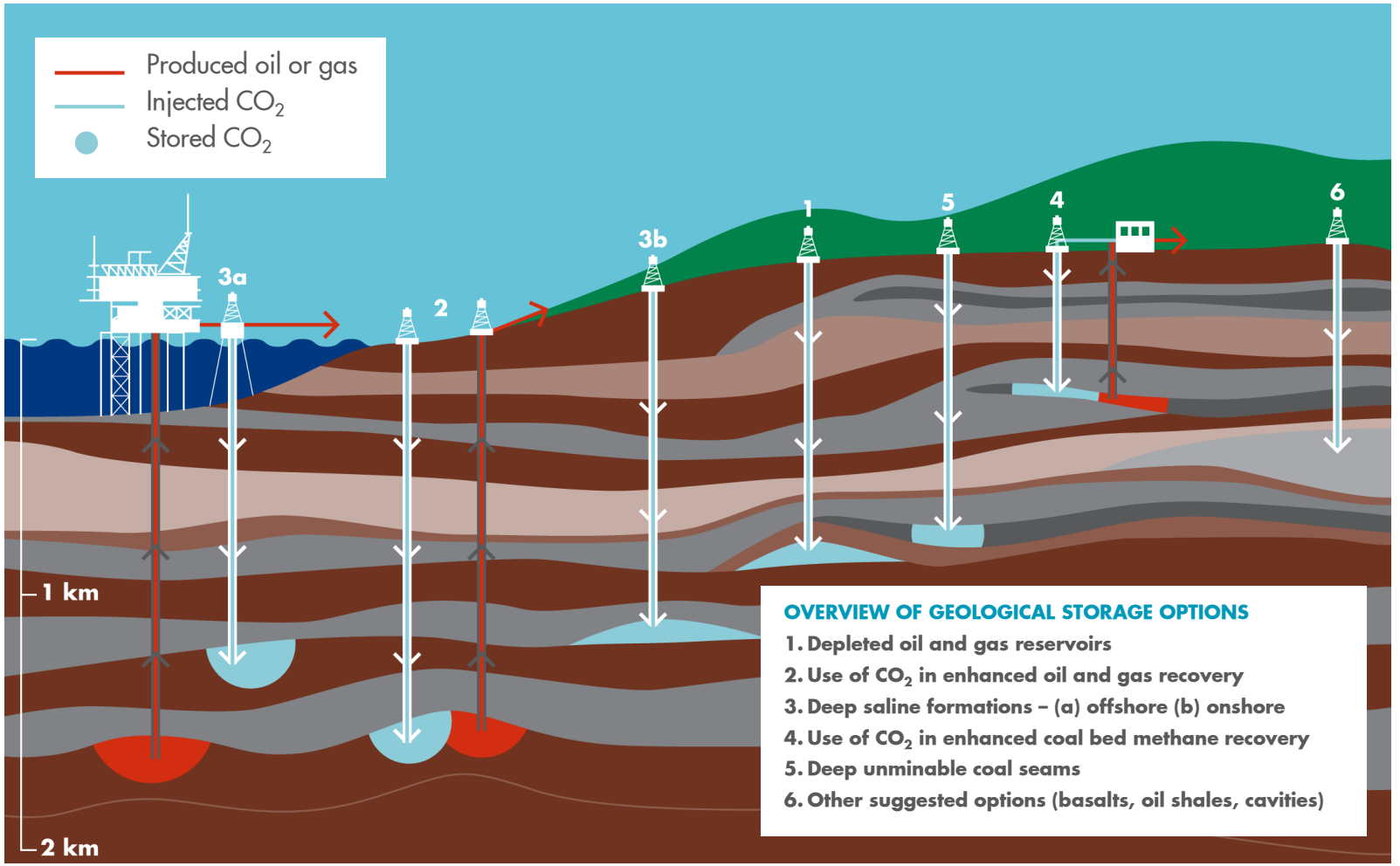
Sustainability

Talent for R&D and Engineering

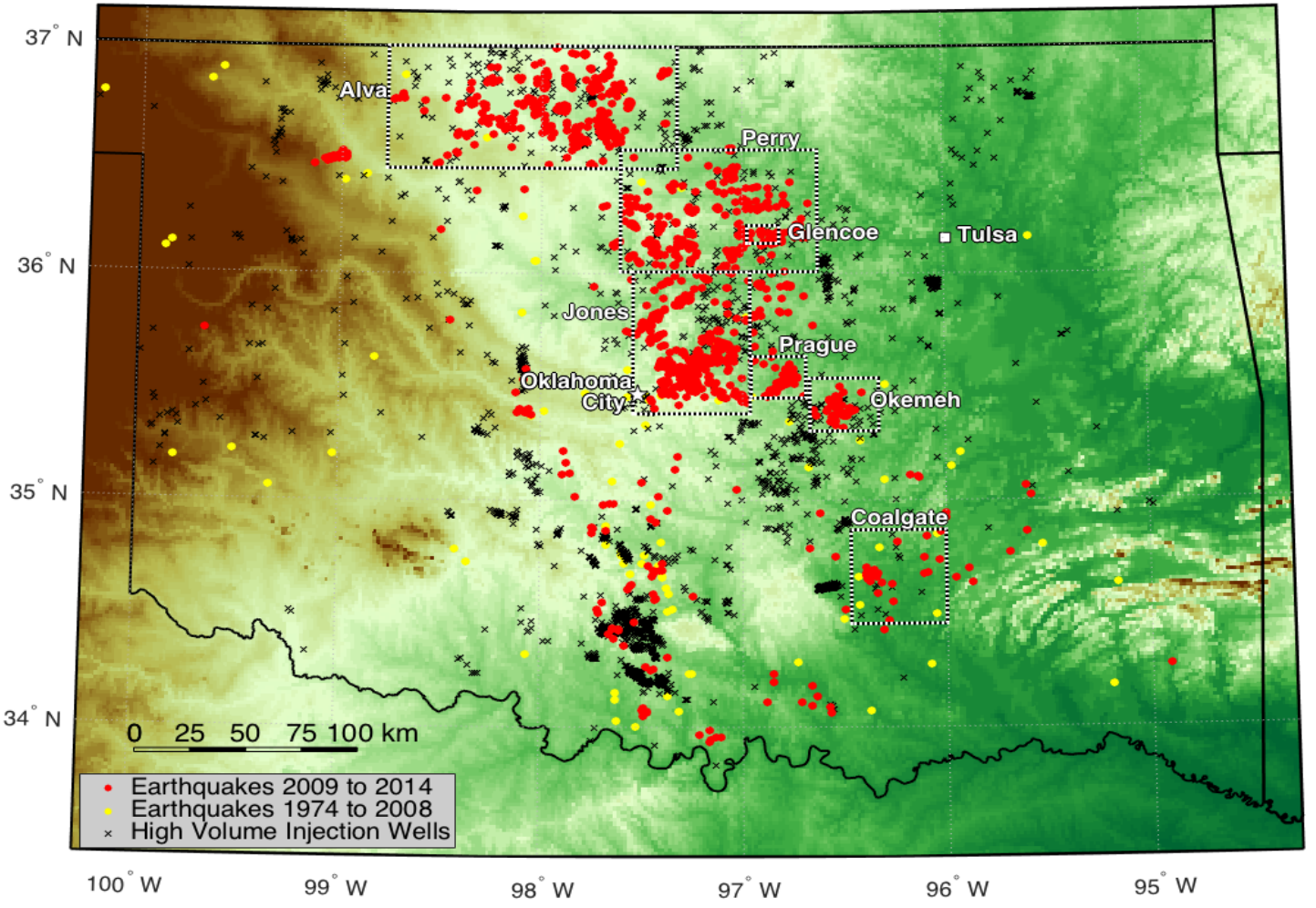
HYDROCARBON DISCOVERY: OVERVIEW

- **Need:**
  - Reliable Resource Characterization and Understanding Subsurface uncertainty
    - Hydrocarbon, Water resource potential and management
  - Monitoring: Integrate subsurface dynamics and environmental impact of operations
- **How:**
  - Exploit low cost, more versatile and more accurate sensor systems integrating surface and subsurface information
  - Knowledge/Data Management through internet platforms: eg. "Google Earth for the Subsurface"

RESERVOIR MONITORING AND CO_2 MANAGEMENT



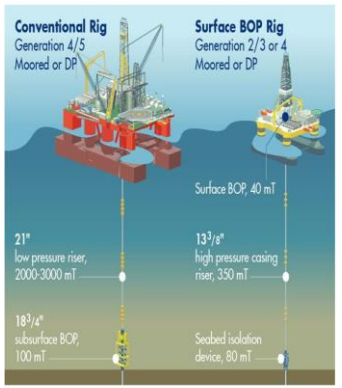
WASTE WATER INJECTION INJECTION RELATED TREMORS?

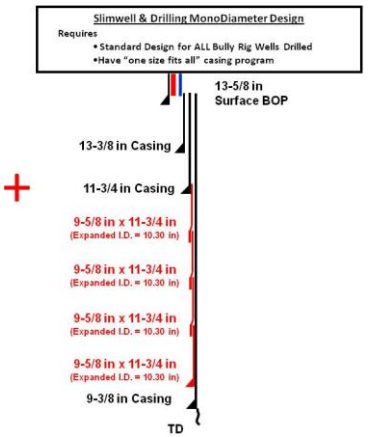


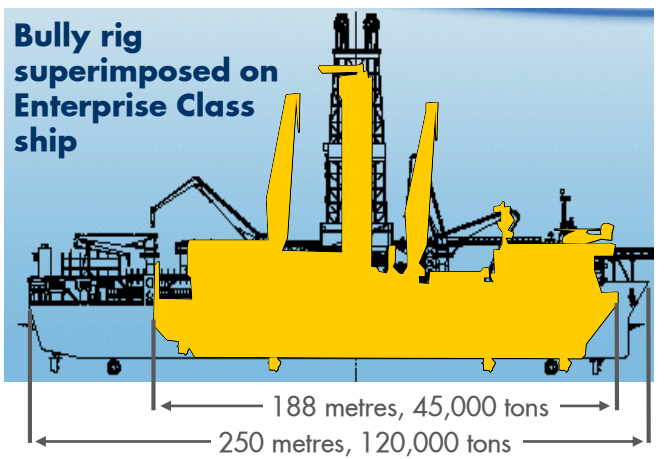
Zoback, Walsh 2014 - submitted Proc Nat.Acad Sci

MAXIMIZING RESERVOIR CONTACT – DEEP AND WIDE

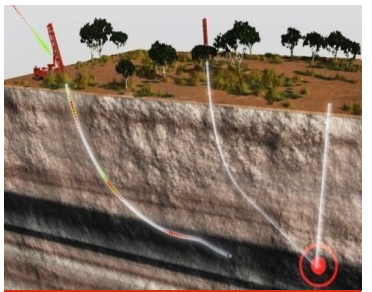
Ultra Deepwater Wells



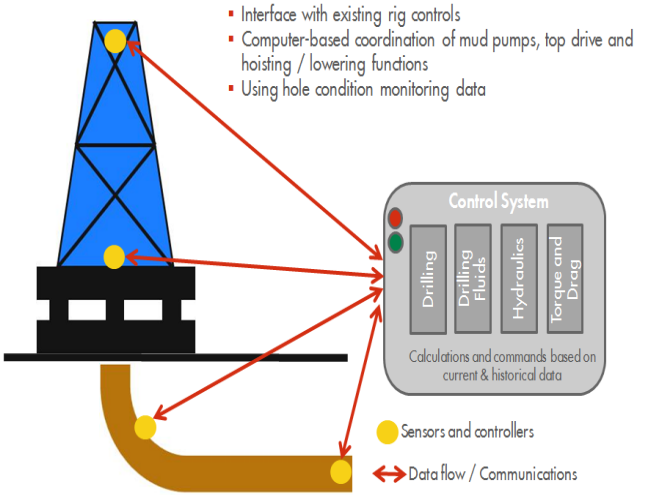




Onshore Shale-Gas Wells



"Manufacture" the wells by automated, truck-mounted rigs



Automate the drilling rig AND Control the rig from central location

WHAT is the *New* WELL MANUFATURING?

- Reversed conveyer belt: machinery moving along the well sites drilling and completing wells
- Specialised, highly automated truck-mounted rigs
- Hub-structure, allowing centralised production of key logistics, such as drilling fluids - 'Mud', tubes and pipes, for several well sites at a time
- **Autonomous drilling and trajectory control with supervisory control and data acquisition system (SCADAdrill)**

HYDROCARBON PROCESSING: OVERVIEW

- Spearhead environmentally acceptable technology – especially in heavy oil
- Develop options to monetize carbon in hydrocarbon reserves, ie carbon materials.
- Develop "molecules for electricity" generation and storage
- Continue focus on technology that brings natural gas to market
- Exploit (contaminated) gas from distributed sources as an advantaged feedstock
- Develop technologies that provide robust competitive feedstock flexibility

Key Challenges Chemistry & Catalysis

Natural Gas

- Making C-C bonds from CH4
  - No full conversion routes (except C-products)
  - Limited yield valuable products requires expensive separation & recycles
- CH4 activation: no alternative yet for synthesis gas

(Extra) Heavy Oil

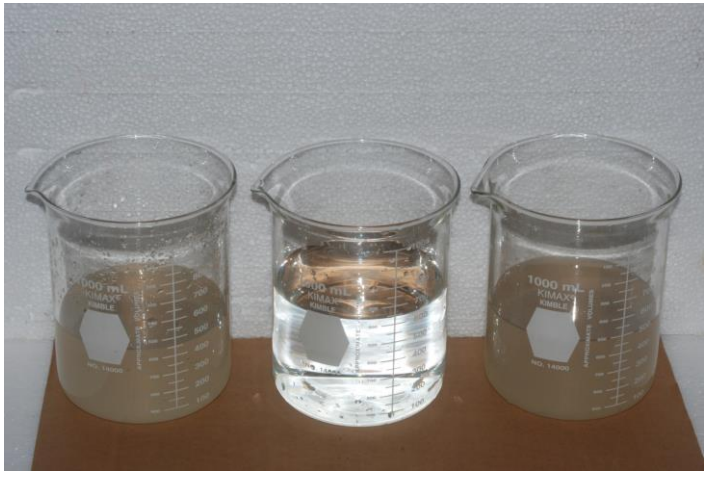
- Limited understanding molecules and molecular interactions
  - Thermodynamics (solubility) & Kinetics (reactivity)
  - Limited chemistries for reduction of molecular weight initiated by radicals (heat): coking or hydrocracking

CURRENT PROCESS USES WATER TO LIBERATE BITUMEN

- Surface Mining Operation of Ore
- Followed by extraction using Water
- Large amounts of water in contact with ore
- Water Recycle Fundamental for success
- Need to recover solids for land reclamation
- Many Separations Challenges

MONETIZE HEAVY OIL RESERVES

- Reduce use, reuse and recover water
  - Improved processes
  - Water and Tailings treating technologies
- Lower CO2 and energy footprint
- Decarbonize heavy oil into performance materials
- Upgrade asphaltenes
  - Fuels
  - Chemicals
  - Performance Materials



SUPPLY MOLECULES FOR ELECTRICITY

- Natural gas supply, transport, delivery technologies that simplify supply chain (FLNG for example)
- Alternative Energy Carriers Such as Hydrogen
  - Lead technologies that manufacture and deliver hydrogen to consumers (decarbonization of hydrocarbon sources)
- Supply for Electricity Storage
  - Can electricity be stored in molecules? And can Shell manufacture and supply these as natural gas and hydrogen?

➢ **In the long run this seems at odds with Future Energy Program?**

➢ What are priorities in the Technology Program

➢ **How does this relate to the Heavy Oil/ Bitumen Option?**

PROCESS TECHNOLOGIES FOR NEW PRODUCTS

- Our existing assets will continue to deliver more product specification and new products demanded by the consumer
- Process Technologies for superior lubricants
  - GTL provides lead but lower cost alternatives at smaller scale are differentiators
- Fuels and lubes with bio elements incorporated
  - Co-processing or blending of bio streams. Technologies probably available in the market
- Hydrogen
  - Manufacture technologies from the market but delivery technologies my be a proprietary advantage

INTEGRITY & RELIABILITY OF ASSETS/OPERATIONS: OVERVIEW

- Accelerate the integration of remote monitoring sensors with predictive models
- Enable data-driven decision making at operations through aggressive deployment
- Instrument assets with modern smart technology
- Deploy robotic and automated technologies for repetitive or hazardous tasks
- Persistently drive cost reduction behaviors
- Improve availability at an acceptable cost

SMART ASSETS VISION

Safe Reliable Assets

Fast Secure Global Data Access

Global real time decision support platform for Upstream and Downstream

Validation, Analytics, Reference Models

Faster, Better Decisions

Synergy between businesses

Prioritization with Business

DATA, AUTOMATION & INTEGRATION: OVERVIEW

- Examine how mining existing large datasets can answer key business questions – Big Data Analytics
- Integrate data streams in all decision-making workflows for improved business insight
- Make monitoring data publicly available to demonstrate prudent operatorship and base plans and actions on same datasets

ANALYTICS CREATES INFORMATION FROM (BIG) DATA

Competitive Advantage

TYPE	ANALYTICAL MATURITY	WHICH QUESTION?	OIL & GAS EXAMPLES
Prescriptive	**Optimization**	"What's the best that can happen?"	Prescribed production set points and maintenance plan for statistically optimal case
Predictive	**Predictive Modeling**	"What will happen next?"	Scenario models show the relative impact of different production/maintenance options
Simulation	**Forecasting/ extrapolation**	"What if these trends continue?"	Analytics show revenue and cost impact of maintaining current performance
Diagnostic	**Statistical analysis**	"Why is this happening?"	Data mining uncovers statistical relationships that are impacting production performance
Descriptive	**Alerts**	"What actions are needed?"	Automatic warnings trigger managerial awareness based on presumed correlations
	Query/drill down	"What exactly is the problem?"	Multiple custom reports highlight variables that could be impacting production performance
	Ad hoc reports	"How many, how often, where?"	Custom report helps to understand the extent of the production problem
	Standard Reports	"What happened?"	Standard report describes production performance anomalies over the last 1-7 days

Derive insight, make better decisions

PRODUCT ENGINEERING & DEVELOPMENT: OVERVIEW

- Continue developing and supplying competitive low or zero GHG emission fuels
- Better understand threat of emission-reducing technologies, particularly fuels and lubes.
- Consider how growth in personal information technology plays role in mobility
- Maintain awareness of renewable hydrogen technology
- Strengthen engine industry partnerships to see potential for smog-emission free engines

THE CHALLENGES FOR FUTURE MOBILITY

Access to Energy/Fuels

Which energy sources will meet the growing demand for mobility?

Total Cost of Ownership

Which fuel/vehicle combination will allow mobility to remain affordable ?

World Population Growth & Urbanisation

How will mobility & infrastructure concepts change mobility in megacities?

Reduction of GHG & Local & Noise Emissions

Fuel/vehicle options for lowest amount of GHG and local emissions

New Technology Options

Vehicle Autonomous Drive, Continuous Connectivity, Safety Features *(Night vision, active braking, distance control, advanced stability control…)*

New Mobility Policy

Taxes /Incentives to manage Mobility & Local Entry Restrictions (Cities)

Changing Consumer Values & Social Acceptance

New consumer values – "Mobility on Demand". Which factors drive social acceptance & resulting uptake of new fuel/powertrain solutions?

SUSTAINABILITY

SUSTAINABILITY: OVERVIEW

- Champion strategy and commit resources that reflect gravity of low-carbon and water-constrained future
- Reduce operational footprints in gas production, gas to chemicals, gas to fuels and direct gas utilisation
- Lead the development of sustainable technologies for heavy oil, EOR and unconventionals
- Identify and pursue key technical expertise and competencies to address future energy and chemicals businesses
- Create sustainability global centre of excellence capable of full life-cycle and stakeholder impact assessment

Our Biggest Challenge

We need to attract bright young people

need to educate the public

inspire potential scientists