Smart Grids

A Perspective on Market Readiness

Global Data Points

Workshop 12 March 2008

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What do SmartGrids mean for:

Governments

- A policy deliver mechanism for greene energy
- Actions to enhance supply security

Regulators

- Need to have assurance of the need case
- Mechanisms to ensure efficient investment

Companies

- Concrete actions: what and by when
- What are the opportunities; what are the risks

Customers

- Having choice, quality, and security
- Enabling involvement and a positive stateme

A Common Vision but different Value Propositions

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EU Technology Platform: SmartGrids

The SDD
Strategic
Deployment
Document

- **SmartGrids: ensuring tomorrow's electricity networks will be fit for purpose, across Europe**
- **The Technology Platform brings together key stakeholders**
- **Vision document & Strategic Research Agenda published**
- **The current task is the Strategic Deployment Document**
- **Framework-7 funding:** €2.3bn over 7 years for energy research) and includes SmartGrids

Download the new SmartGrids video!

eyond EU – some Utility SmartGrid actions

Utility of the Future - Duke Energy

gridSMART – American Electric Power

Intelligrid – CEMIG (Brazil)

Blueprint for the Future – Pepco Holdings, Inc.

Circuit of the Future – Southern California Edison, Kansas City Power & Light Co.

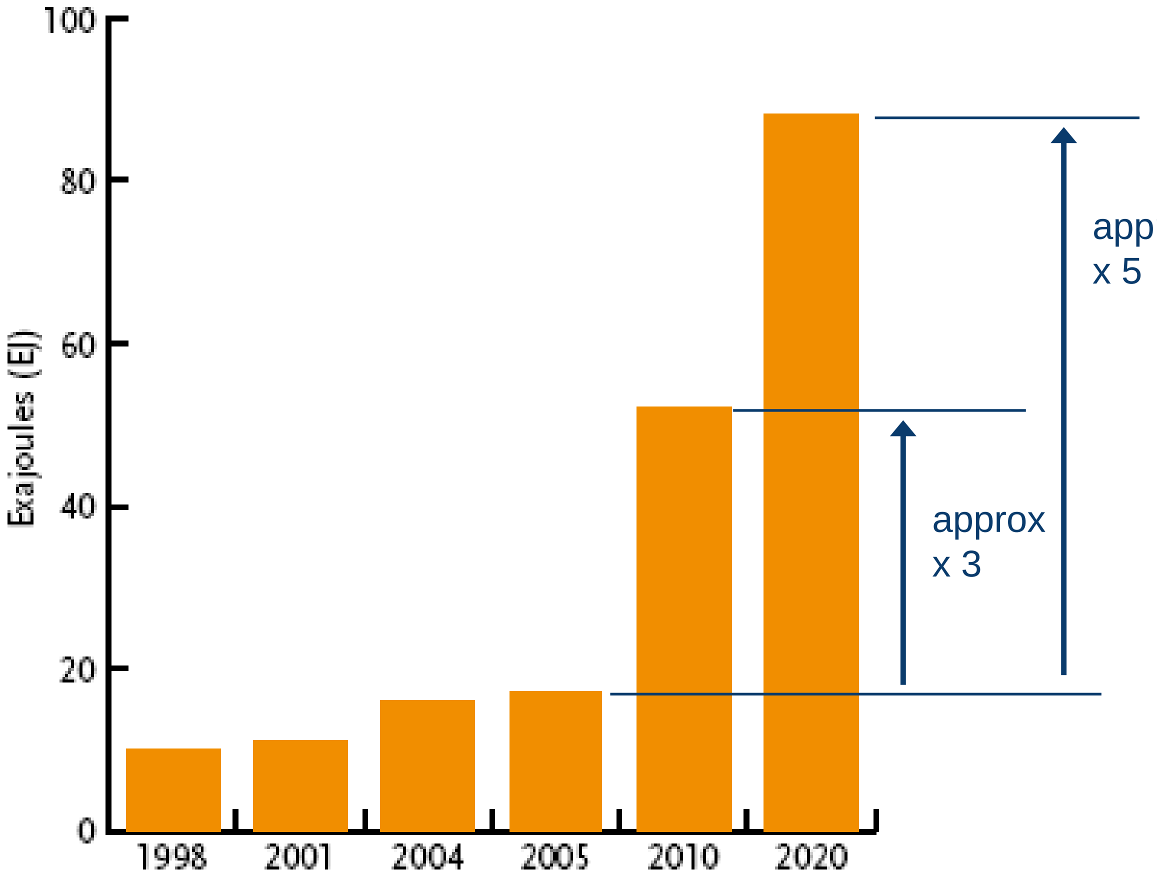
Intelligent Utility Grid - CenterPoint Energy

Power the Future – WE Energies

- How can initial investments in AMI o Smart Metering be leveraged into a broader Smart Grid architecture?
- Which technologies are ready for investment now? Which ones shoul be deferred?
- What is the right regulatory recover scheme (short and long-term)?
- How will consumers accept and inte with these applications?
- How will incremental CapEx requirements be integrated into exis grid resource plans?
- What rate and service offerings are needed to maximize consumer participation?
- How well will standards drive innovation, while maintaining securi and reliability?

There are several other programs not listed, including Oncor, Progress Energy, FPL and others

Coming to a network near you?



Projections for Global Renewable Energy 2010 & 2020

Note: Projections of modern renewables (including small hydro, excluding large) based on 11.5 percent growth per year, over the period 2001-2005.

Sources: UNDP, UNDESA, and WEC, 2000 and 2004; REN21, 2006; And IEA, 2006

The Key Drivers

> Supply Security > Reasonable Cost > Sustainability >

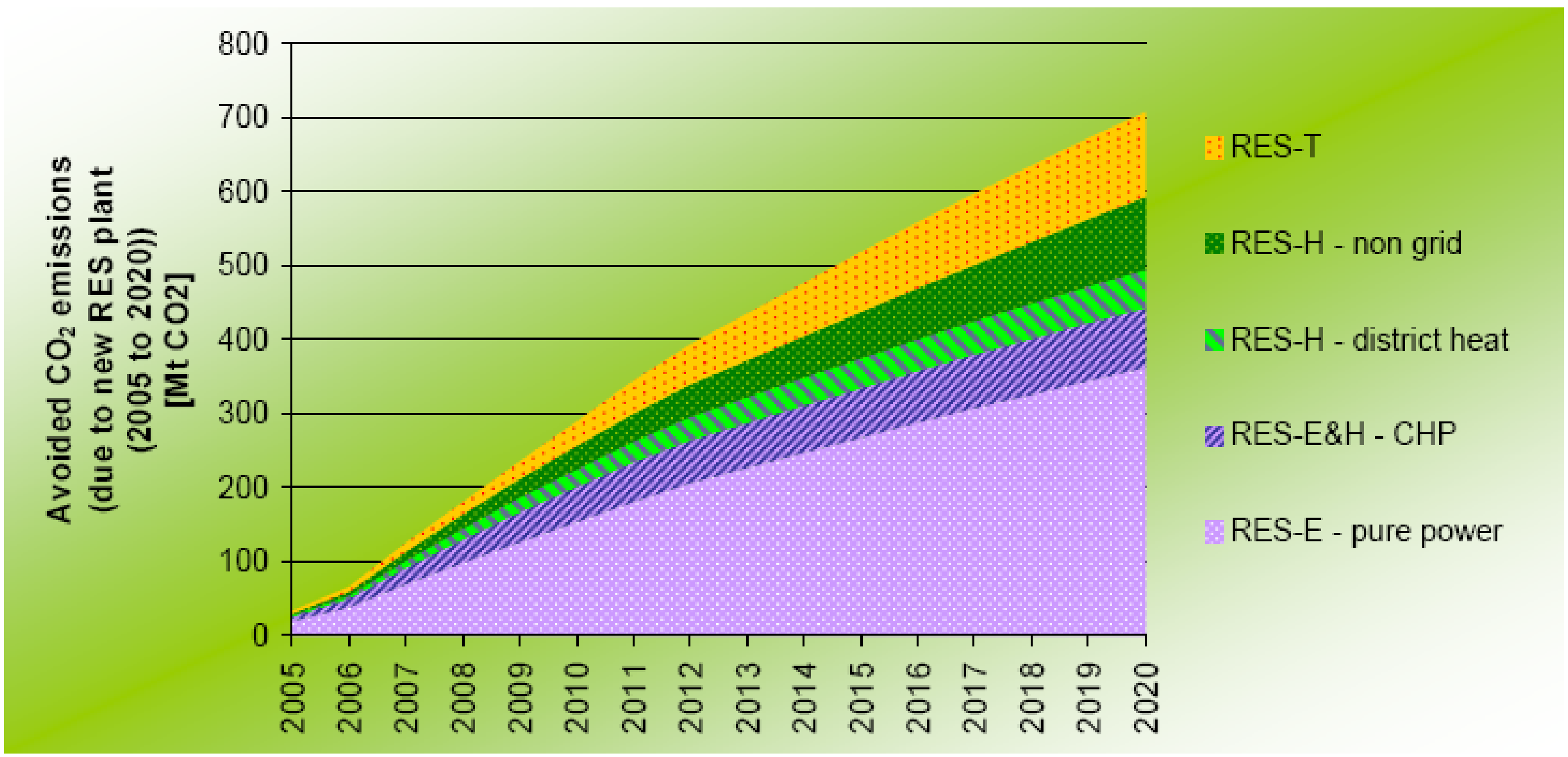
- **Sustainability: less carbon and less waste, greater efficiency**
- **Impact of neighbours: security of sources, loop flows, incidents**
- **Less dependence on traditional ‘economy of scale’**
- **Mini, micro and community-scale advantages now identified**

- **Significant New Residential Construction Offering PV as Option**
- **Consumer side Energy Storage a Logical Adjunct to PV**
- **Leads to Grid Interconnection Issues and Higher “Potential Peak” Loading Conditions**
- **Grid Reliablity (SAIDI) Will Have to Approach 6 Sigma to Maintain Consumer “Relevance”**

EU targets 2020: 3x20

- 20% reduction CO_2 emission
- 20% renewable sources
- 20% energy saving

CO_2 Emissions Avoided due to New RES Deployment up to 2020 in EU-25



The Key Stakeholders

'those with a shared interest in success'

- T&D network companies
- Their shareholders
- End customers
- Governments
- Regulators
- Manufacturers
- Academia
- Research institutions
- Consultants & Specialists

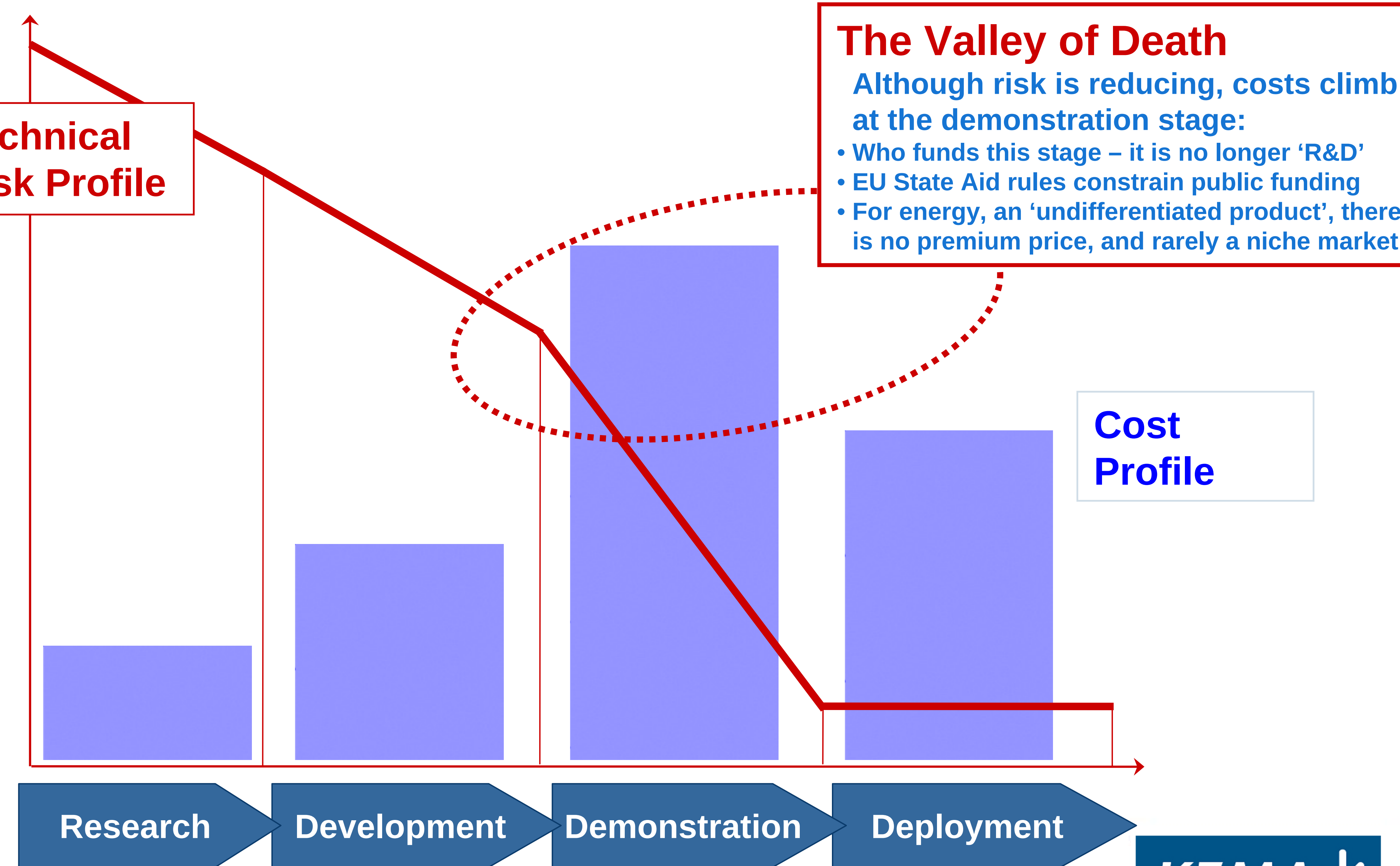
Also:

- Finance providers
- Insurers
- Company staff
- 'the public'
- others….?

New Entrants

- Retailers (Home depot)
- Local Heating/Plumbing
- Home Builders

nnovation Chain risks



Case Study:The UK Situation

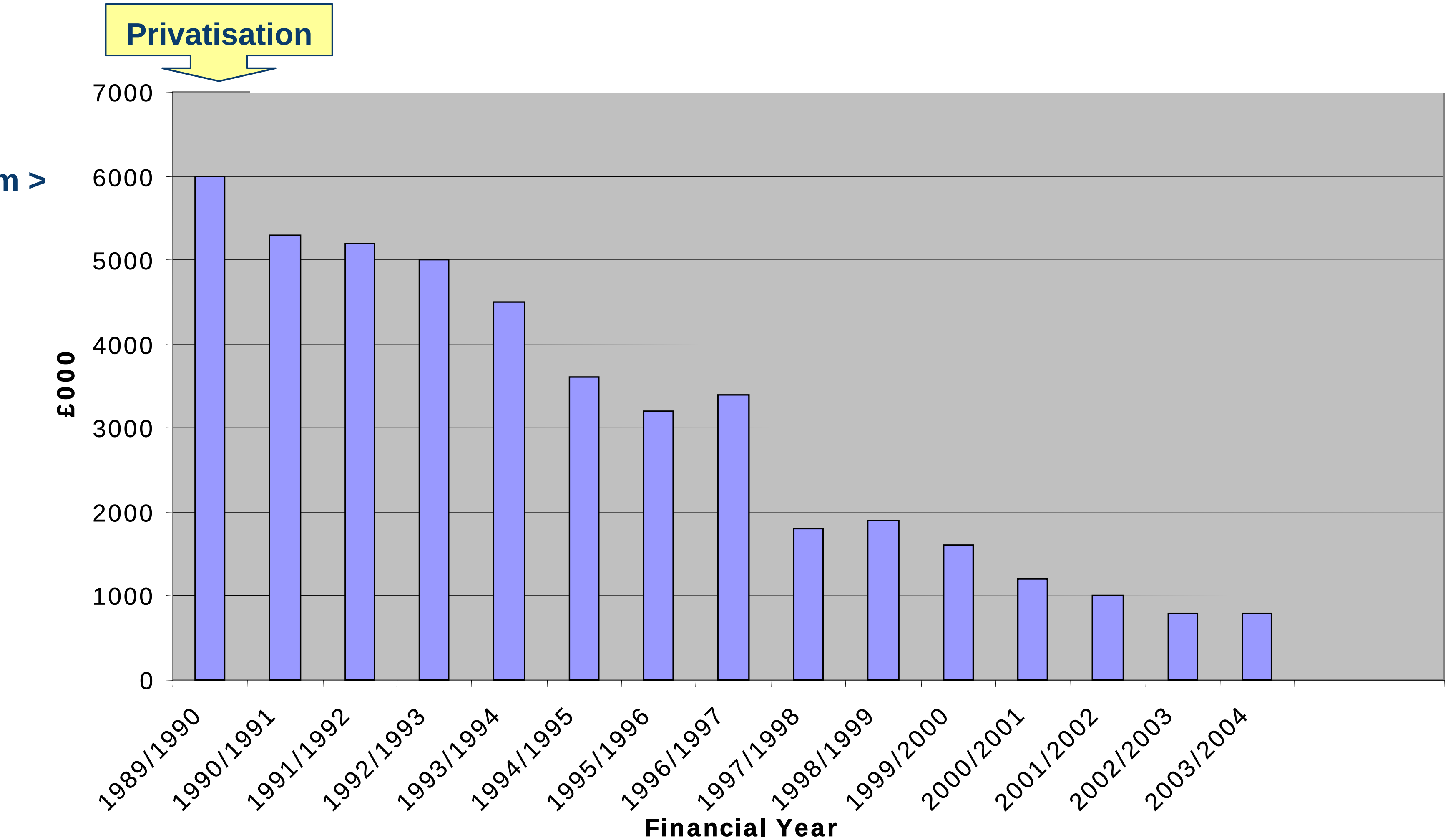
Ofgem, the regulator, identified in 2004 that:

- **investment levels would be beyond recent experience**
- **there are diverse new challenges for networks**
- **the issues are Europe-wide and international**
- **Innovation was not encouraged by the RPI-X framewo**

- **Why is a Regulator interested in innovation?**
  - Ofgem’s primary duty is to customers, both today and in the future
  - it seeks to promote effective and efficient investment, and
  - recognises that engineering innovation has a role where it adds value

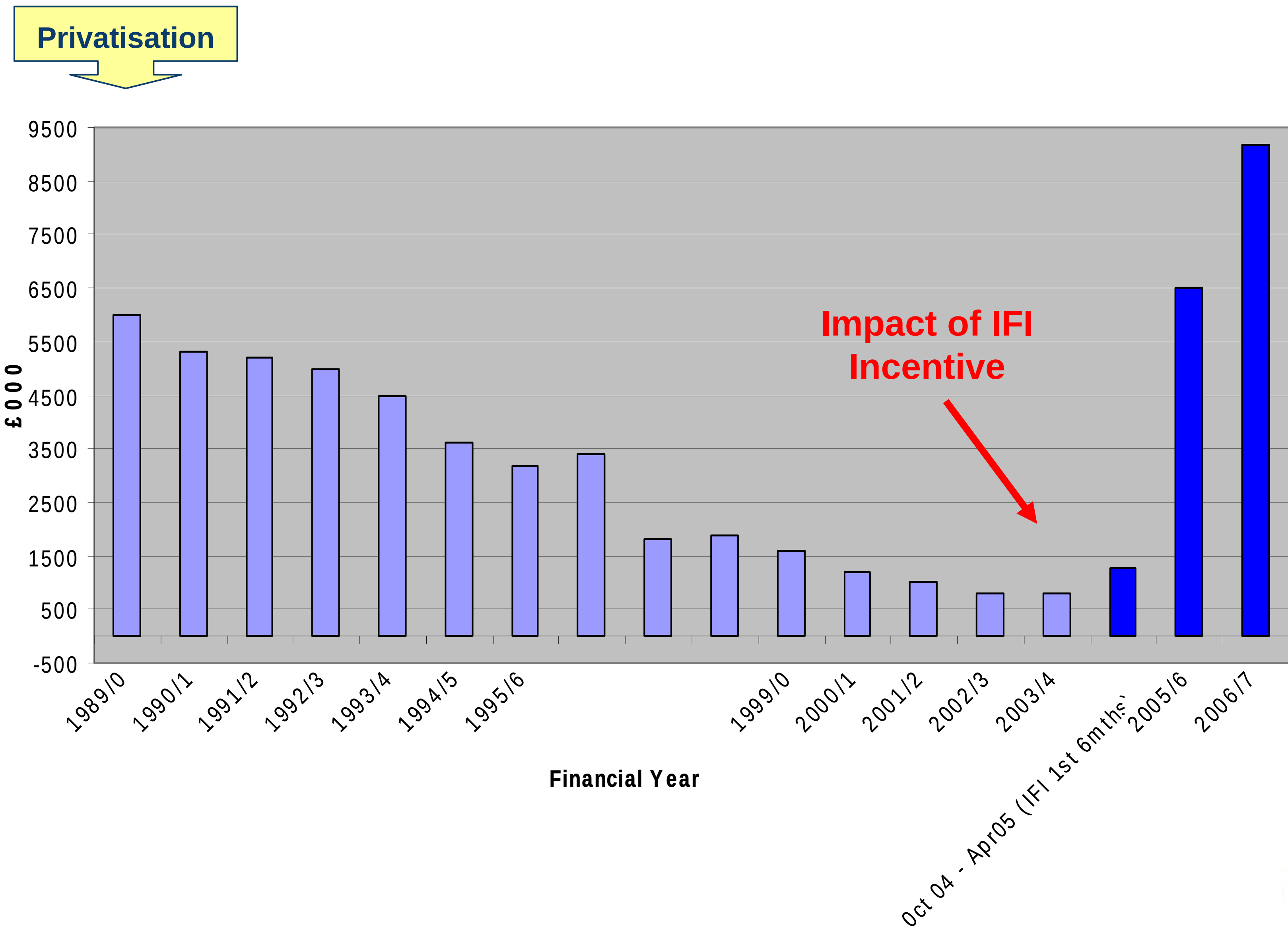
UK Distribution Company R&D

Trend since 1990



UK Distribution Company R&D trend

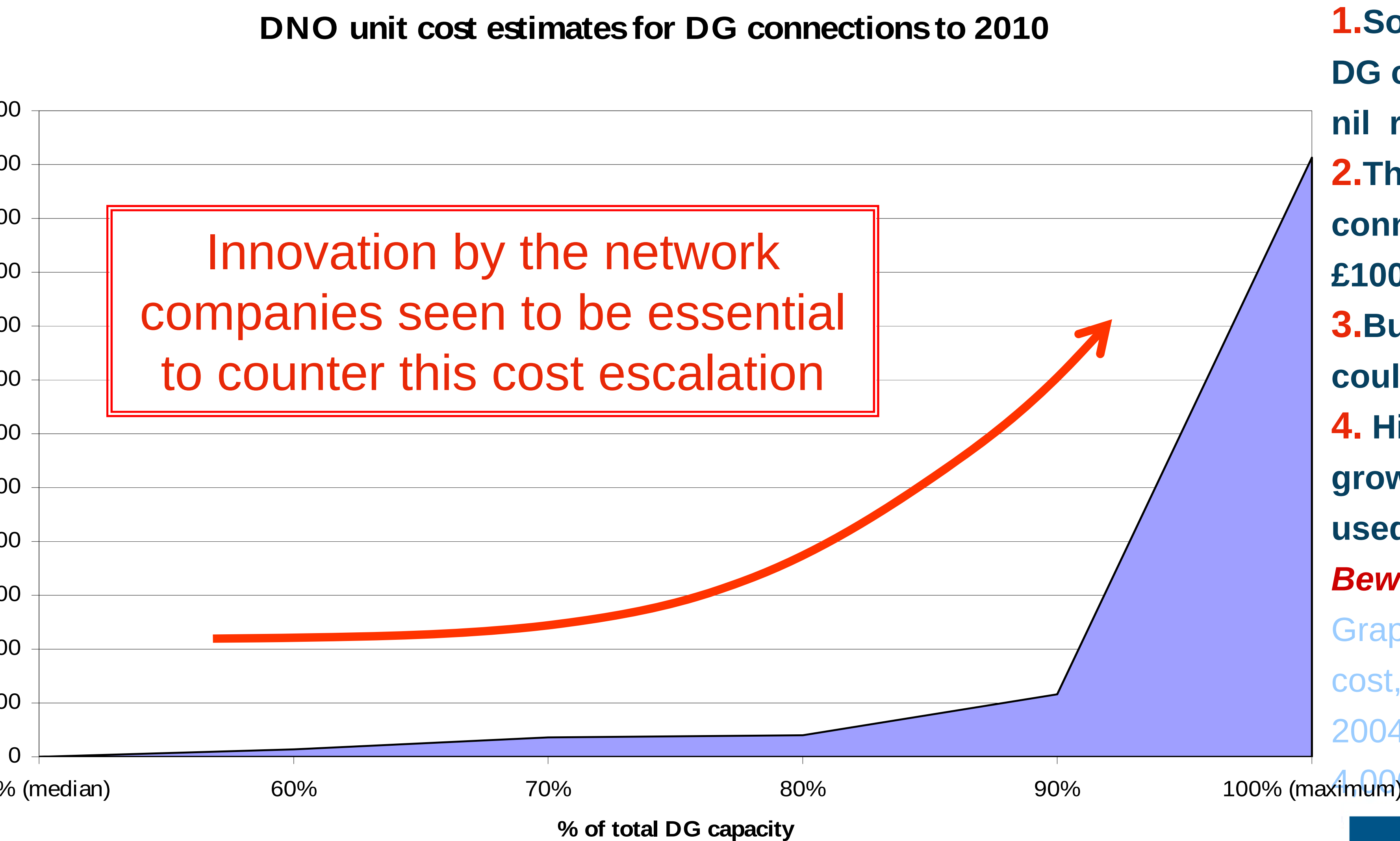
Impact of new incentives



- c.180 projects
- Projects are initiated by the companies
- Ofgem does not 'approve' each project
- Only one company is spending to its cap
- Av. intensity is 0.27%
- Forecast benefits total €70m (NPV)

* Data from 1989/1990 to 2003/2004 is the collaborative spending on R&D amongst the DNOs through a single provider.
* Data from Oct 2004 - April 2005 and the last financial year (2005/2006) shows reported total IFI spend.

GB Distributed Generation Connection Costs
beware the sting in the tail!



NOTE

1. **Some 50% of proje DG can be connectec nil reinforcement co**

2. **There is 40% that c connected at less tha £100/kW**

3. **But there is 10% th could cost up to £100**

4. **High cost element grow as spare capac used up beyond 2010**

Beware the "high cos

Graph is ranked by orc cost, not timing of proj 2004 data. Projects tot 4,000MW of DG

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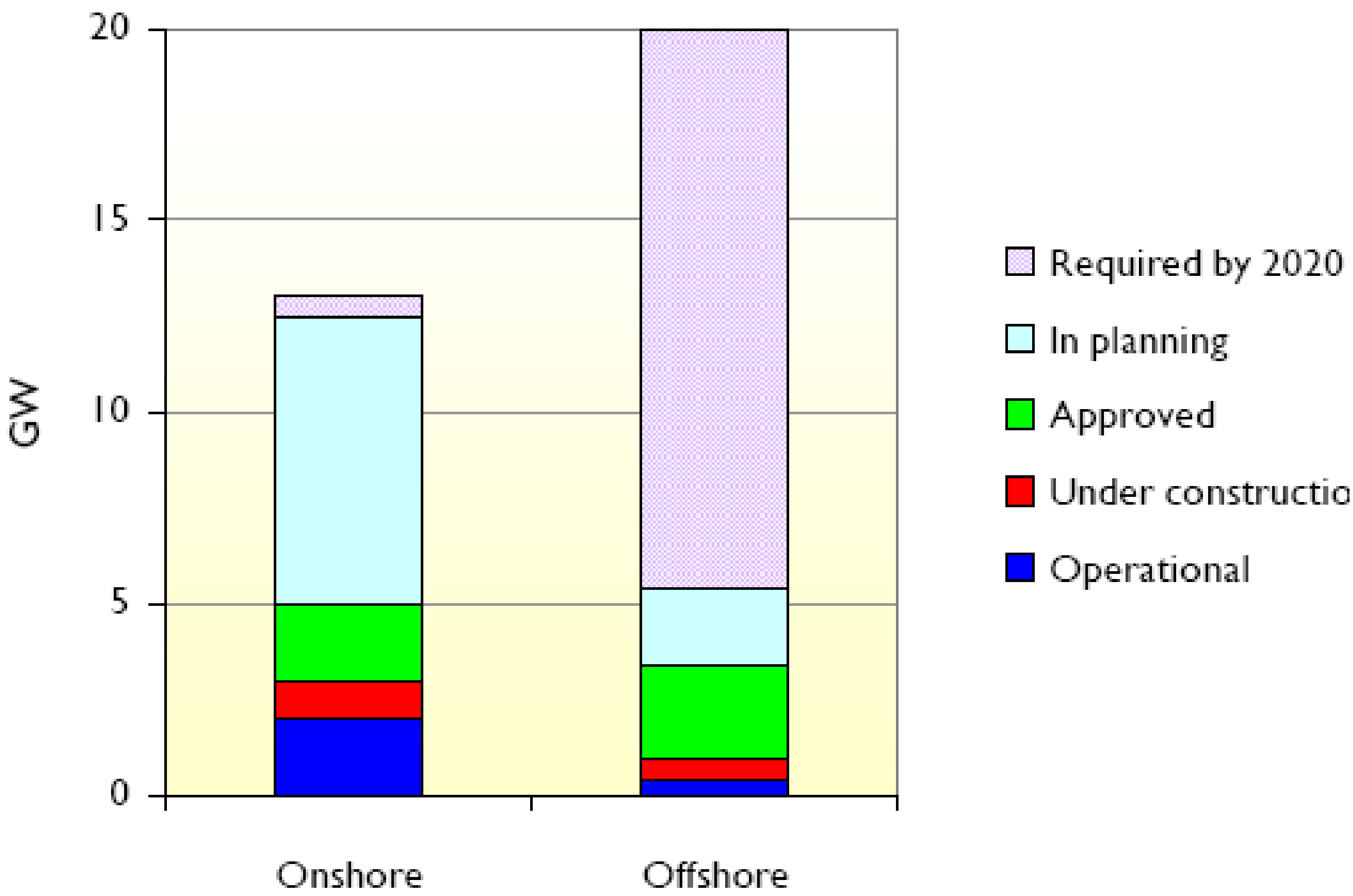
The Scale of the Challenges

UK Wind capacity Required by 2020 BWEA Jan 08



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Smart Grids: practical application

SMALL USERS			DISTRIBUTION		TRANSMISSION		LARGE USERS	
DEMAND	**METERING**	**GEN.**	**Network Assets**	**Network Operations**	**Network Assets**	**Network Operations**	**GEN.**	**STORAGE**
➢Responsive demand control of white goods, aircon, heating.	➢Smart Meters, basic functionality ➢Demand displays	➢ROCOF etc ac interfaces ➢Convertor dc interfaces ➢Micro-generation with export capability	➢Condition Monitoring real time ➢Fault prediction ➢New network voltage control for DER feeders	➢Dynamic plant ratings	➢Condition Monitoring real time ➢Flow control devices	➢Dynamic ratings ➢WAM	➢Off-shore substations ➢Grid-friendly intermittent gen controls	➢MW scale battery devices
➢Energy efficiency innovations	➢Interactive customers ➢Smart Meters, advanced functionality	➢Community level Micro-generation management	➢Flow control devices ➢Fault Level Limiters ➢Active distribution networks ➢Distribution power electronics	➢Quality of supply enhancement ➢Waveform enhancement ➢Storage for peak smoothing and investment deferral ➢DMS to EMS	➢Fault Level Limiters ➢Off-shore connections ➢Off-shore substations ➢Investment decision tools ➢Carbon-costed asset management	➢Storage for balancing and other ancillary services ➢Pan-EU emergency co-ordination ➢New protection principles	➢Generation management for constrained networks ➢Ancillary services from renewable sources	➢MW scale flow cell devices
➢Virtual Power Plant electric vehicles for storage	➢Distributed ICT and Settlement systems ➢Smart Meters, full gateway	➢VPP Virtual Power Plant for mini and micro generation	➢Fully Active D networks ➢Modelling tools ➢Stability control	➢Self-healing grids ➢Islanded operation capability ➢G to T through flows	➢Off-shore grids and interconnection ➢Integration of H2 transmission	➢Self-healing grids ➢Balancing Services from aggregated DER ➢Pan-EU inter-operability	➢Integration of Commercial Energy Management Systems	➢GW scale marine storage

Level 1 Technology is Available Now	**Level 2** Technology is Near to Market	**Level 3** Research & Development is needed

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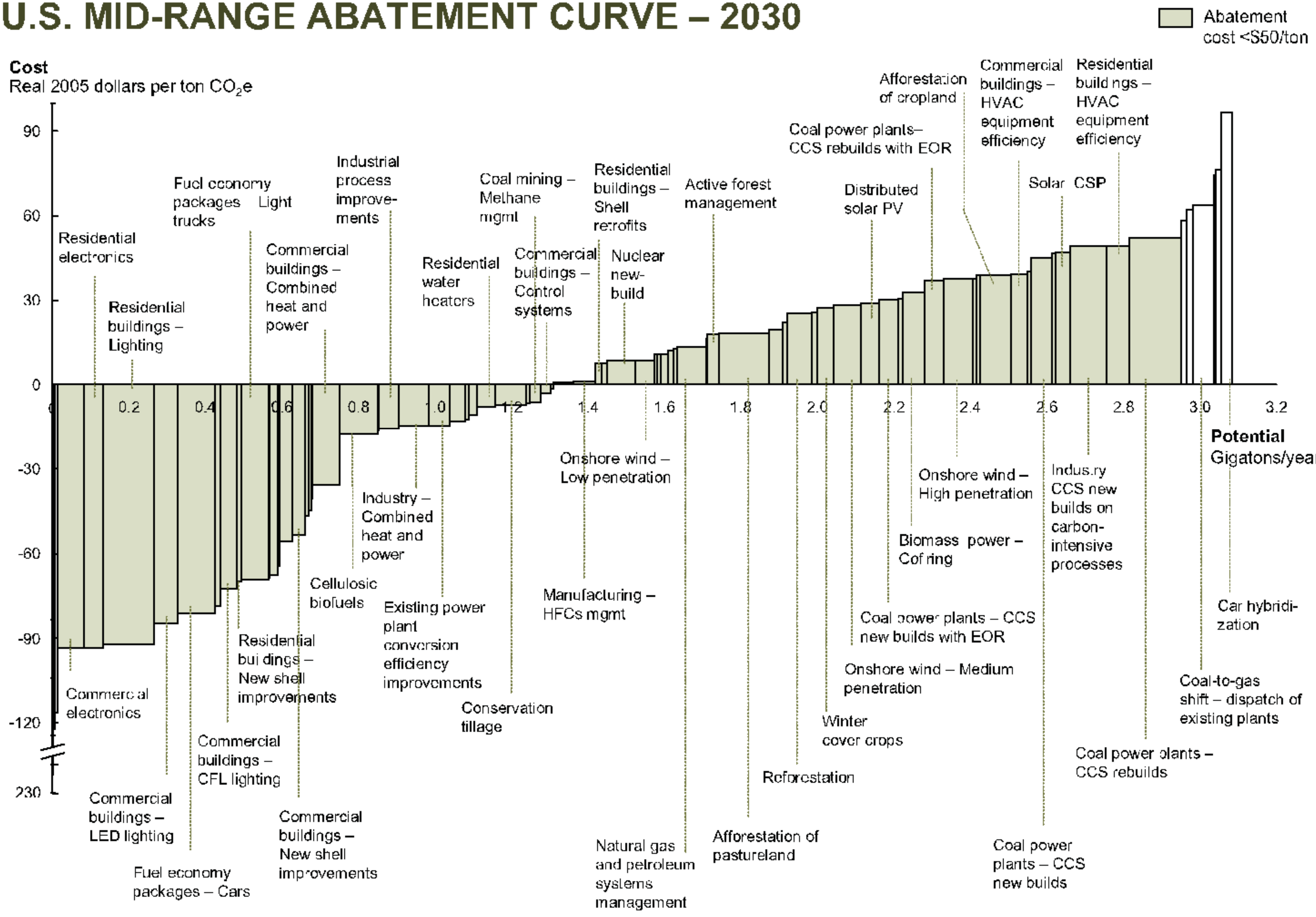
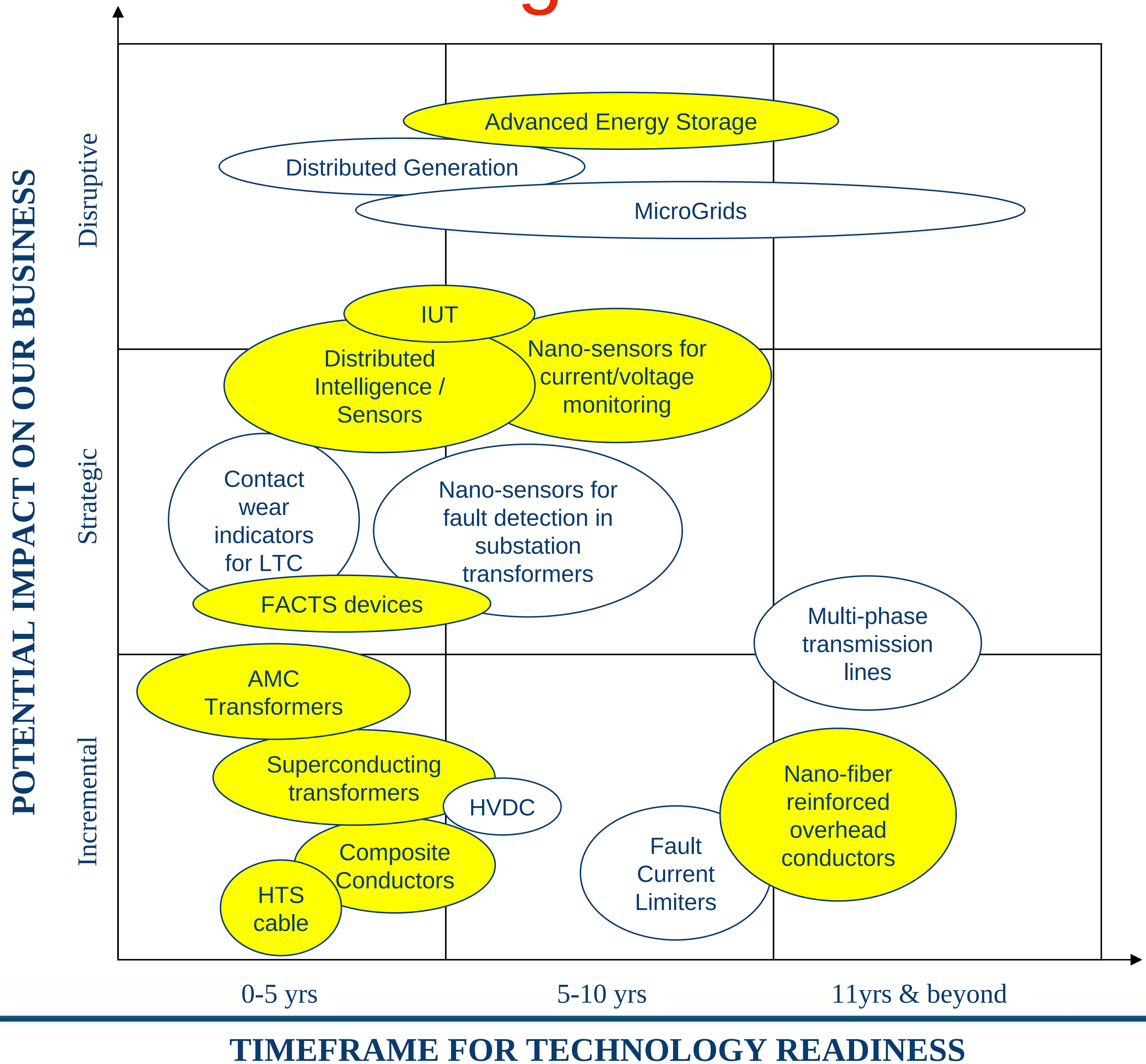
Exhibit B

U.S. MID-RANGE ABATEMENT CURVE – 2030



T&D Technologies



= Could help to reduce system losses

NOTE: *This chart only reflects timing around technical readiness and does not reflect timing around overcoming economic hurdles.*

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Example Of A Strategic Technology: Sensors

Description

Links to Utility of the Future concept

The hardware component of Distributed Intelligence (the two other components are Communication & Software)

Application

Power conductor sag sensors can determine sag, tension and line capacity

Transformer coil temperature sensors can determine transformer capacity and predict failure

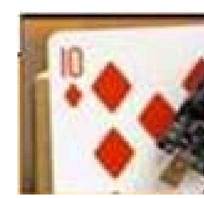
Underground cable sensors can detect hazardous situations to support preventative maintenance

Other low cost physical sensors can be used to measure voltage, current and phase angle in power systems; pump & motor vibration in generating stations; vehicle/personnel detection for security, etc.

Current Status

Dust Networks has deployed “motes”, miniature sensors/radios, for Department of Defense as well as industrial applications.

It is possible that nano-sensors could be adapted for this application and deployed within 5-10yrs.



WHAT WOULD YOU MEASURE IF IT WAS FREE TO DO SO?
HOW CAN THAT INFORMATION BE TURNED INTO VALUE?

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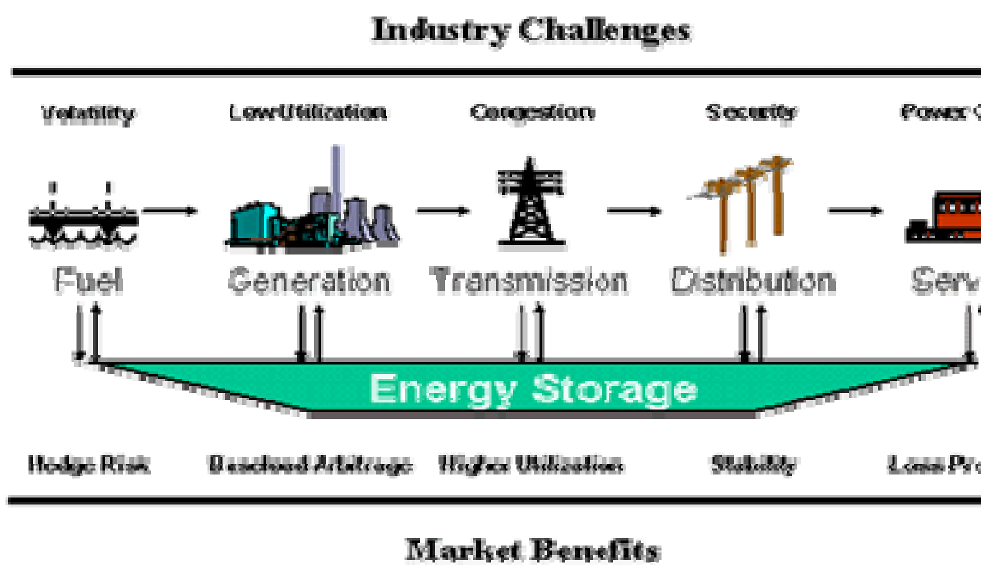
Example Of A Disruptive Technology: Storage

Description

- Superconducting Magnetic Energy Storage
- SuperVAR
- Nano-structured electrodes for batteries
- Super efficient flywheels
- Carbon Nano Tube reinforced flywheels
- Ultra-capacitors (Electrochemical capacitors)



Application

- Dynamically injecting/absorbing reactive power
- Premium-quality power products for customers
- Defer more capital-intensive infrastructure investment
- Enhance system efficiency
- Act as spinning reserve
- Reduce grid congestion.

Current Status

- Energy storage provides only about 2.5% of total electricity capacity in the US – nearly all of it from pumped-hydro installations used for load shifting (150 facilities in 19 states totaling 22GW).
- Driving down cost is still major the challenge and focus of current research efforts.
- Nano-technology developments could significantly enhance energy storage capacity & battery life for EVs and portable electronics.

Technologies For Addressing System Losses

chnology	Application	Current Status
mposite conductors: igh strength composite-core replaces steel in existing steel-reinforced or pported aluminum conductors to enable hter, stronger lines with higher capacity	•Operates at higher temps without significant line sag and with lower losses. •Transports 2 to 3 times as much power over the same ROW without tower modifications.	•Aluminum composite-core conductors, terminations, and suspensions have be developed by 3M and demonstrated in field by some US and European utilities
nofiber reinforced overhead nductors: croscropic fibers – lighter and less uminous than other composites, can be ed to reinforce overhead conductors	•Conductors core will be less than 25% the weight, have higher tensile strength, and have half the thermal expansion •Current improvements are conservatively estimated to be 150-300% •Avoided cost of additional lines, support structures and rights of way.	•The main barriers for deployment of fib reinforced overhead conductors are higher cost per foot than conventional cable and the development of new methods of splicing and handling.
S (High Temperature perconducting) cable: ers much greater power density than nventional copper-based cables and are pable of serving very large power uirements at medium voltage ratings.	•Enables more compact cable installations with 3 to 5 times more capacity than conventional circuits at the same or lower voltage. •Exhibits much lower resistive losses than occurs with conventional copper or aluminum conductors.	•Over the past decade, several HTS cal designs have been developed and demonstrated. •ASC/TVA rolling out first commercial product – said to deliver 150 times the electricity of conventional wire, but is al 2 to 3 times as expensive as copper
CTS (Flexible AC Transmission stems) devices: wer electronic devices that can help to prove control and stability of the nsmission grid by providing reactive wer supply.	•Controls the magnitude and direction of real and reactive power flows •Provides dynamic voltage support •Reacts almost instantaneously to disturbances •Increases transmission capacity (potentially up to 50%) •Improves overall system reliability •Allow for DER to be connected to existing grid without transmission expansion	•Established technology, but industry ha been slow to adopt because of high installation prices. •Also, FACTS devices generally require the support of Wide Area Measuremen Systems (WAMS) which currently only exist in prototype.

Technologies For Addressing System Losses

nology	Application	Current Status
Intelligent Universal Transformers): te of the art power electronic system will replace the single-function bility of conventional transformers with telligent, controllable system that des multiple functions.	•Remote communication capability. •Enhance power quality through sag correction and harmonic filtering •Regulate voltage and power factor, thus reducing losses and increasing throughput •Flexibility to deliver three phase power from a single phase line •Improved Asset Management •Contains no hazardous liquid dielectrics, •Would not have to bypass for BPL •Could facilitate metering at the transformer	•EPRI is currently undertaking field prototype demonstrations for IUTs.
rphous Metal Core Transformers: silicon steel core inside a transformer is ced with amorphous metal which is easily magnetized and demagnetized h results in less than one-third the es	•60 to 70% lower core losses than other transformers in-service and new high efficiency silicon steel core transformers. •low operating temperatures; •size and weight comparable to silicon steel transformers	•Amorphous metal and amorphous c transformers are now available •Originally developed in the 90's – bu adoption slow due to high unit costs •Are now more competitive due to ris costs of silicon steel.
erconducting transformers: copper-based windings in a entional transformer are replaced by wire coils which incur substantially less tance loss, bringing the efficiency rate e transformer closer to its theoretical ntial (100%).	•About 30% reduction in total losses •About 45% lighter weight •About 20% reduction in total cost •Eliminate need for oil cooling, reducing associated fire and environmental hazards. •Twice the overload rating capability for extended periods without insulation damage or loss of lifetime •Unprecedented fault current limiting functionality •Reduced operating impedance improves network voltage regulation.	•An alpha prototype 5/10 MVA HTS transformer has been built by Wauk Electric. This prototype demonstrate the technical and economic feasibilit 30/60 MVA and larger HTS transformers. •Initial HTS transformers are expecte cost 30% higher with ownership cos 10% higher than conventional units.

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Key Challenges Drive Need for Distributed Resources and Micro Grids

Challenges	Key Drivers	Potential Solutions
Increasing cost of new generation / transmission –Cliffside estimates have increased from $2B-$3B	• Tight commodity markets • Lack of skilled labor	• Build larger scale plants • Increase smaller **distributed generation** • Energy Efficiency – through better utilization
Green House Gas Initiatives	• Global Warming Concerns	• Increase **renewable generation** • Increase environmental controls • Increase Energy Efficiency
Increased reliability needs	• Increased congestion due to lack of investment • Higher reliance on technology is changing customer needs for reliability	• **Back up generation** • Dual Feed to Site • Buried Infrastructure
Load Growth that is more variable – (peaked)	• Industrial flight • Demographic Shift • Energy intensity of economy is decreasing	• Increase peaking capacity both large and **small scale**

As utilities continue to build out Smart Grids, they will further enable Micro Grids

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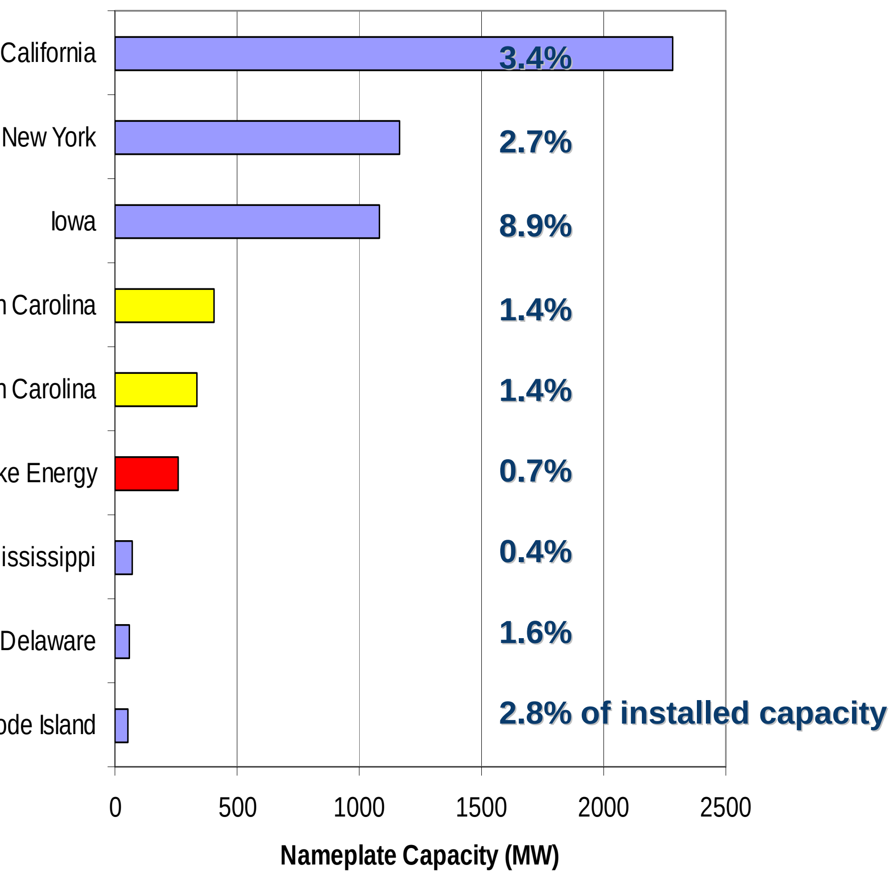
Current Micro Grid Landscape

Nameplate Capacity – Below 10MW



Source: Energy Velocity

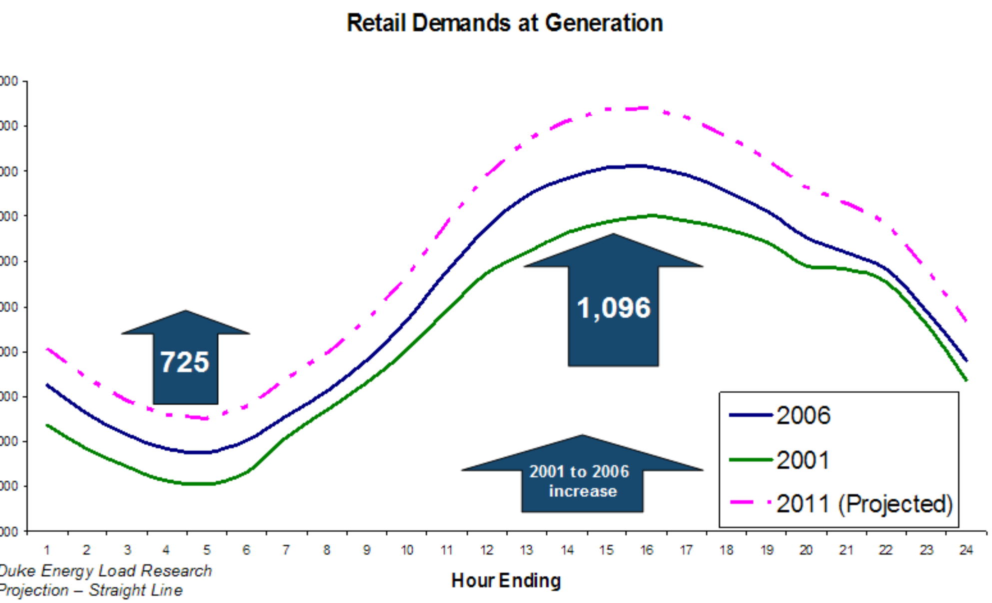
State Incentives for
Distributed Resources / Micro Grid

State	Description
CA	$500 Million in incentives for distributed resources
Ohio	~$1 Million in grants to 26 distribute generation projects
Indiana	Distributed Generation Grant Program (DGGP) offers grants of u to $30,000 or up to 30% of eligible costs
North Carolina	Subsidized Loans with an interest rate of 1 – 3 percent

Vebsite with Incentives by State:
ttp://www.eea-inc.com/rrdb/DGRegProject/Incentives.html

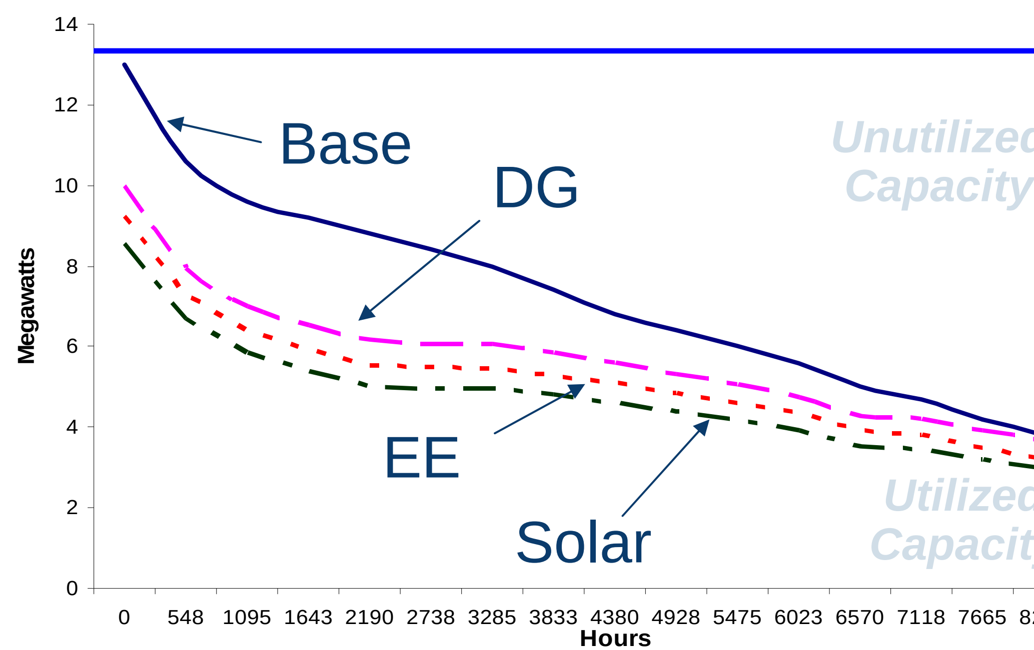
Micro Grids Can Be Used to Shape the Peak and Increase Utilization

Carolinas: Peak Load Growth



- *Increasing Residential Load is resulting in higher peak load*
- *Distributed generation may offer an opportunity for 'peak shaving' at the substation or feeder location*

California Study: Impact on Load Shape of different Energy Initiatives



Source: GTI Distributed and Sustained Energy Center

icro Grids will enable distributed Renewable Generation as Technology Matures

- Potential to reduce CO_2 emissions which are valuable in a Carbon constrained economy
- Contribute to meeting RPS

	Total Installed Cost (2006$'s) *	LCOE ($/MWh)**- Developer Financed, w/o & with PTC	Generation Capacity (GW) 06 Add 2015	NI ($MM)	ROE	Market Maturit y	Pros and Cons Scalable TechMat. Resource Avail.			Rationale
nd Based ind Power	1500 to 1000	90/50	9 20 29	$50+	>12%	Mid	●	◕	◕	Large scale, significant upsic for technologica advance, competitive with PTC
f-shore ind	2300 to 1800	100/60				Low	●	◔	◕	
otovoltaic	9500 to 4500	700/200	1.5 5.5 7	TBD	TBD	Mid	◔	◑	●	Low scale, fragmented and remains uneconomic
o-mass mbustion	2000 to 1900	85/75	10 5.5 15.5	$10+	>10%	Mid to High	◑	●	◑	Small Scale, ve distributed, not competitive
o-mass asification	2400 to 1600	90/80				Low to Mid	◑	◔	◑	
ndfill Gas	1550 to 1400	50/40		$10+	>10%	Low to Mid	◔	◕	◔	
eo-thermal	2400 to 1800	50/40	3 0.8 3.8	TBD	TBD	Mid	○	●	◔	

● High ○ Low

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Micro Grids will be valuable to Customers with Reliability Needs

Description	Load (kw)	Cost Savings	Power Availability	Renewable Generation	Power Quality	Stand By	Peaking
Food - Convenience Stores; Fast Food; Restaurants.	40-50	◔	◔	◔	◔	D	FC
Box Stores	200-400	◒	◔	◔	◔	D	FC/IC
Supermarkets	150-2,000	◕	◕	◔	◔	D/IC	FC/IC
Hospitals	100-6,000	◔	●	◔	◕	IC/D	MT/IC
Hotels	200-2,500	◒	◕	◔	◔	IC/D	MT/IC
Large Office Buildings	400-3,000	◔	◕	◔	◔	IC/D	MT/IC
Universities	1,000-4,000	◒	◒	◕	◕	GT/D	GT/IC/D
Factories	500 and up	◕	●	◒	●	GT/D	GT/IC/D

Key: D Diesel; FC Fuel Cell; IC Internal Combustion Engine; MT Micro Turbine; GT Gas Turbine

● High ○ Low

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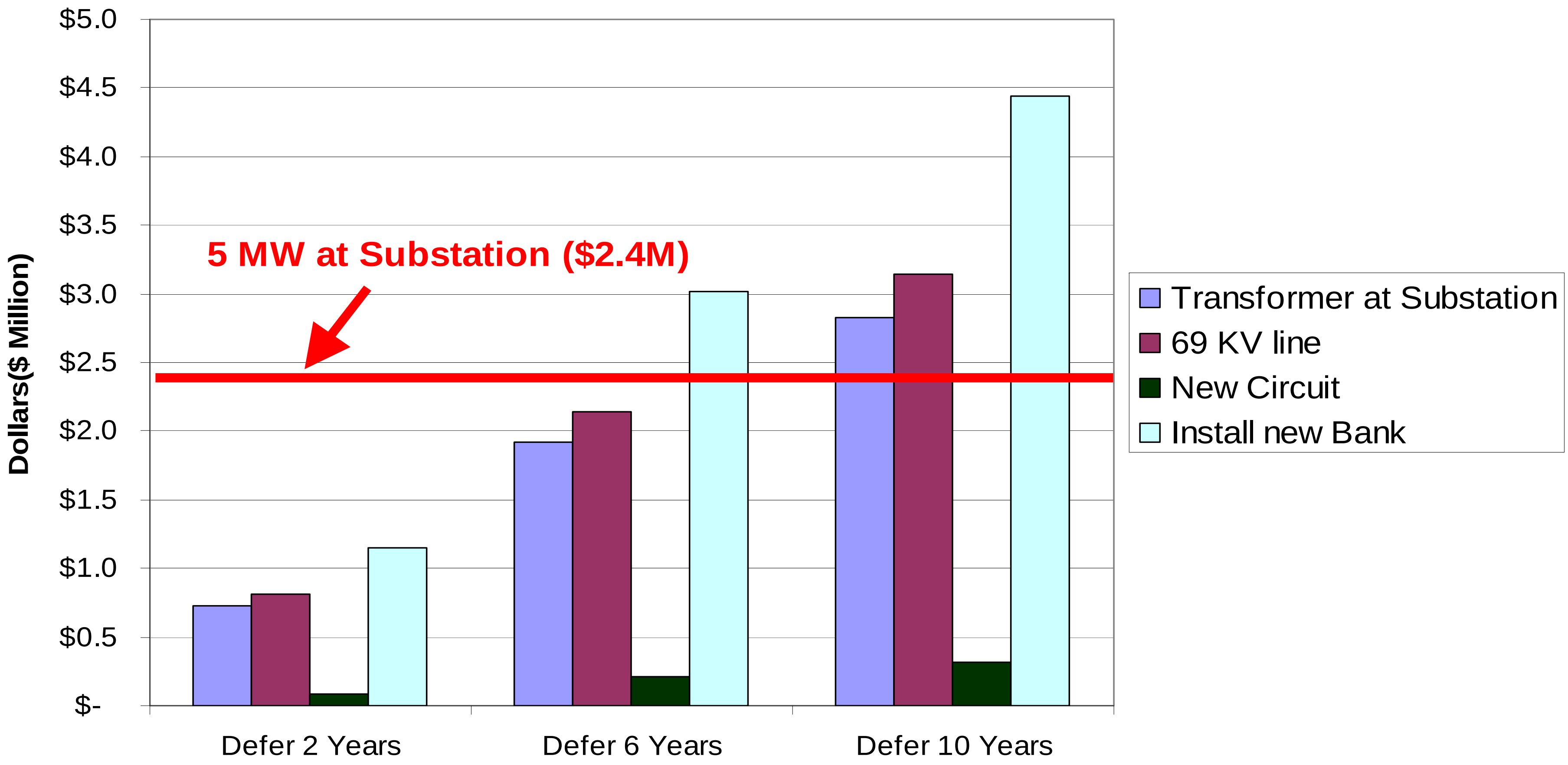
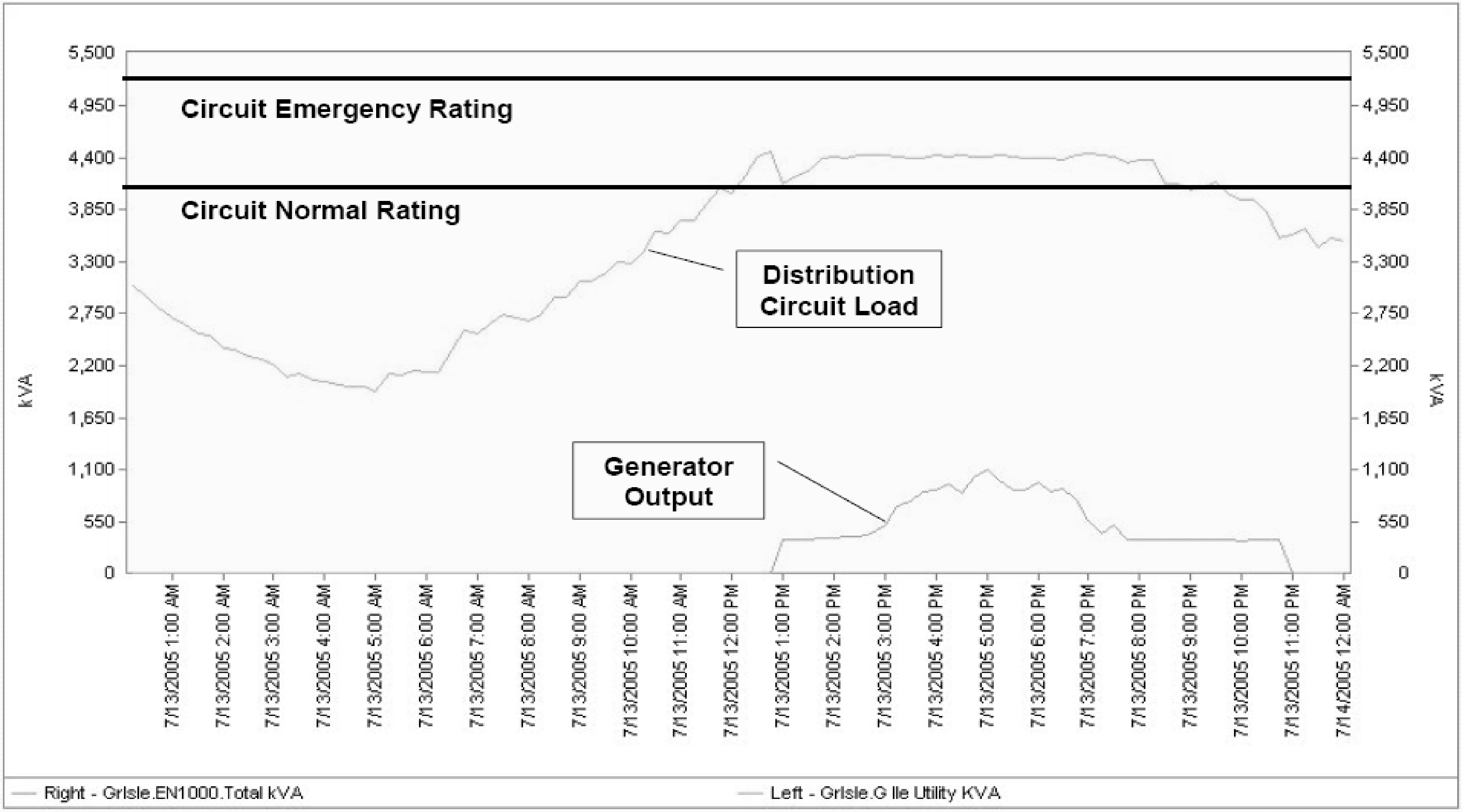
Micro Grid Enables Delaying Distribution Investments

Deferment Benefit



Peak Power Management

Some Utilities are using Micro Grid to relieve peak loading - Today



Source: EEI Transmission, Distribution and Metering Fall Conference (10/9/2006) – Detroit Edison

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