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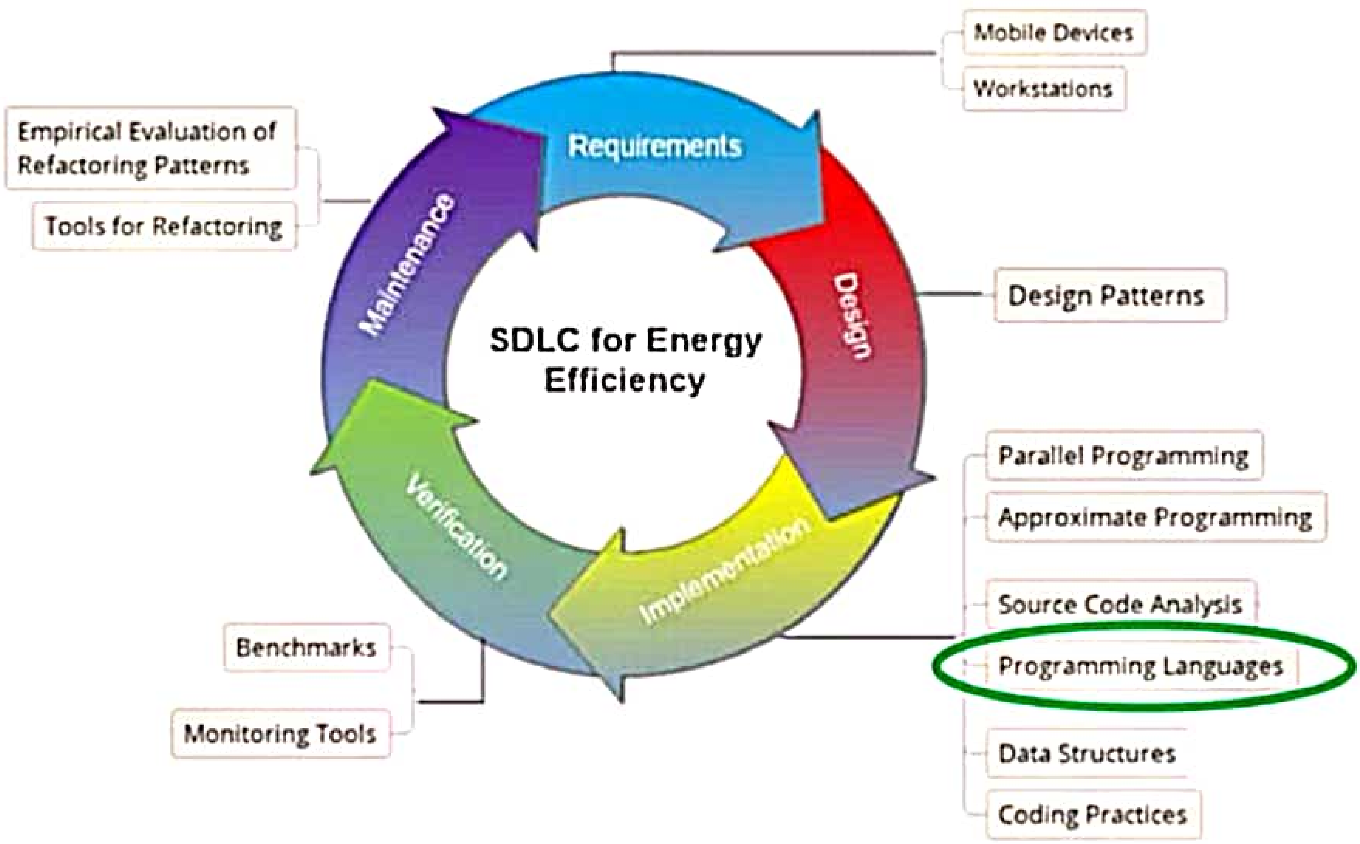
Motivation



Mobile Devices
Workstations
Empirical Evaluation of Refactoring Patterns
Tools for Refactoring
Requirements
Maintenance
Design
SDLC for Energy Efficiency
Design Patterns
Parallel Programming
Approximate Programming
Verification
Implementation
Source Code Analysis
Programming Languages
Benchmarks
Monitoring Tools
Data Structures
Coding Practices

Existing Work and Research Gap

- *Comparative study on Programming Languages in Rosetta Code*, 2015 [Nanz and Furia].
- *Android App Energy Efficiency: The Impact of Language, Runtime, Compiler, and Implementation*, 2016 [Chen and Zong].
- *Program energy efficiency: The impact of language, compiler and implementation choices*, 2014 [Abdulsalam and Lakomski]

Selected Programming Languages

Sep 2017	Sep 2016	Change	Programming Language	Ratings	Change
1	1		Java	12.687%	-5.55%
2	2		C	7.382%	-3.57%
3	3		C++	5.565%	-1.09%
4	4		C#	4.779%	-0.71%
5	5		Python	2.983%	-1.32%
6	7		PHP	2.210%	-0.64%
7	6		JavaScript	2.017%	-0.91%
8	9		Visual Basic .NET	1.982%	-0.36%
9	10		Perl	1.952%	-0.38%
10	12		Ruby	1.933%	-0.03%
11	18		R	1.816%	+0.13%
12	11		Delphi/Object Pascal	1.782%	-0.39%
13	13		Swift	1.765%	-0.17%
14	17		Visual Basic	1.751%	-0.01%

Methodology

860 Tasks
670 Languages

Data-Set

TIOBE SOFTWARE
THE SOFTWARE QUALITY COMPANY

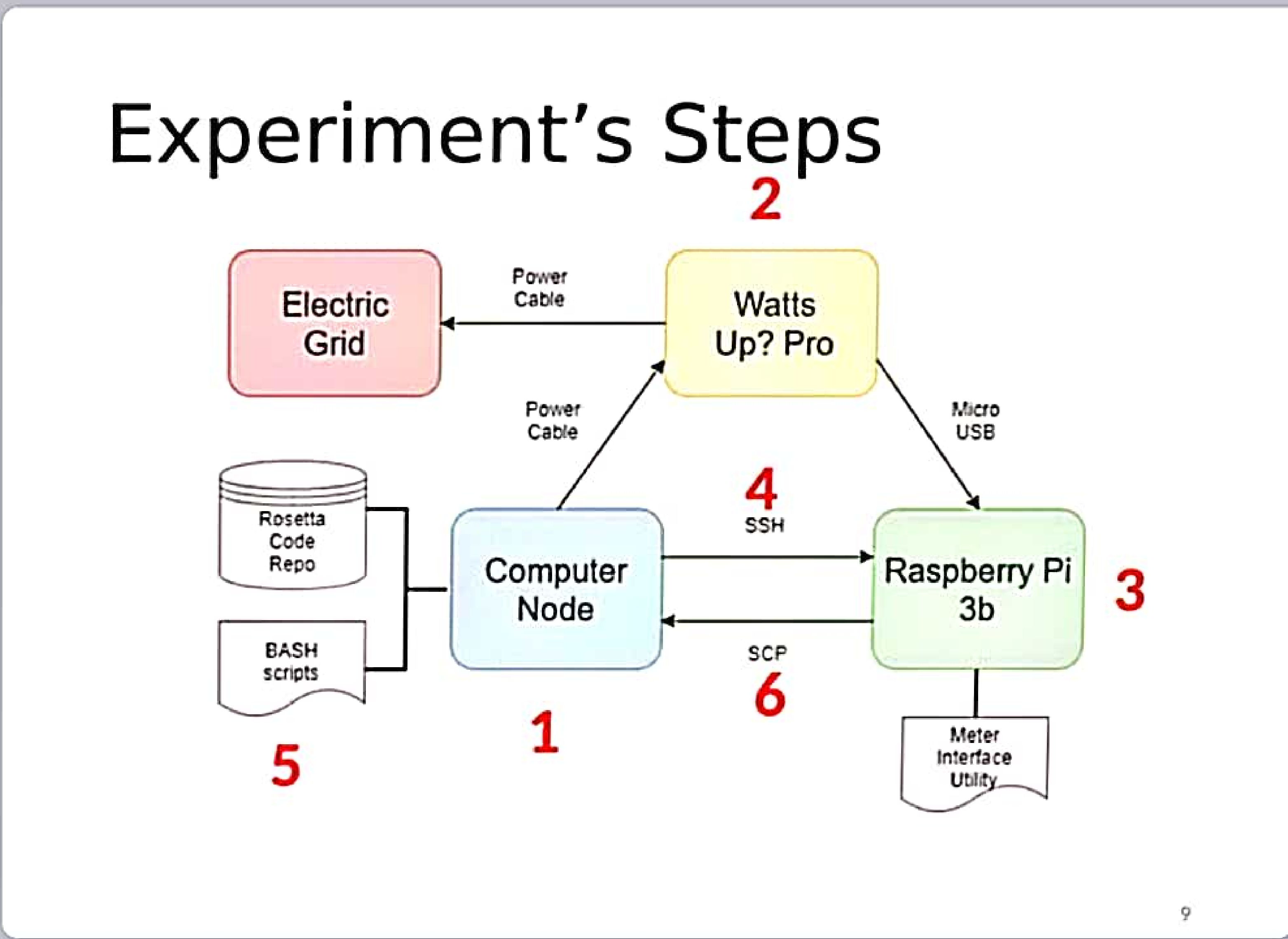
Programming Languages

```
#!/bin/bash
```

Extracting most popular tasks

Tasks
Array-Concat., Classes, Bubble- ,Insertion-, Merge-, Quick-, Selection- Sort, URL-Encoding and Decoding

Test-Bed


Experiment's Steps
2
Electric Grid
Power Cable
Watts Up? Pro
Power Cable
Micro USB
4
SSH
Rosetta Code Repo
Computer Node
Raspberry Pi 3b
3
BASH scripts
SCP
6
1
5
Meter Interface Utility
9

Results – Interpreted Languages

Tasks Name	Implementations		Comparative
	Most Efficient	Most Inefficient	Results
Array-Concat	PHP, Ruby	Swift	888%
Classes	PHP	Python	1616%
Bubble	JavaScript	Swift	12694%
Insertion	JavaScript	Perl	9430%
Merge	JavaScript	R	2894%
Quick	PHP	Swift	1212%
Selection	JavaScript	R	6657%
Url-Decode	PHP	Python	2963%
Url-Encode	PHP	R	3239%

Results – Compiled Languages

Tasks Name	Implementations		Comparative
	Most Efficient	Most Inefficient	Results
Array-Concat	–	–	–
Classes	Go	Java	119%
Bubble	Java	VB.NET	473%
Insertion	C	C#	13450%
Merge	Go, C++	VB.NET	19560%
Quick	C, Go, Rust	VB.NET	57300%
Selection	C++, C	VB.NET	19880%
Url-Decode	Rust	C	17370%
Url-Encode	Java	Rust	256%

Results – All in a Basket

Tasks Name	Implementations		Comparative
	Most Efficient	Most Inefficient	Results
Array-Concat	Compiled	Swift	32300%
Classes	Go	Python	2328%
Bubble	Java	Swift	55715%
Insertion	C	Perl	623300%
Merge	Go, C++	R	1664800%
Quick	C, Go, Rust	Swift	1254100%
Selection	C++, C	R	686400%
Url-Decode	Rust	Python	180400%
Url-Encode	PHP	R	3239%

Results – Compiler Optimization Effects

- Energy usage decreased for most of tasks
- Java's JIT reduced energy usage for all tasks
- C#'s energy usage increase from 1-10% on 4 of the selected tasks
- VB.NET's energy gains where the least
- C, C++, Go, and Rust compiler optimizations offer the most gains (6-98%)

Conclusion

- Energy Consumption varies in large scales for both interpreted and compiled languages.
- Compiler optimization apart from performance offers energy usage optimizations too, in most of cases.
- C, C++, GO, and Java most energy efficient
- JavaScript, PHP, and Ruby most energy efficient
- Not a single winner for all cases

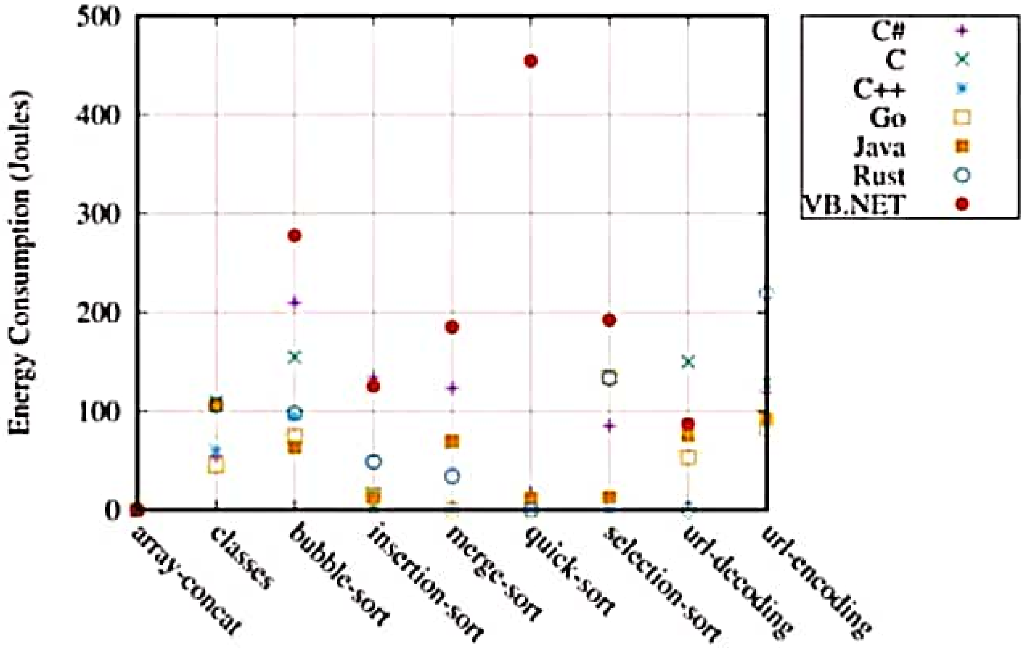
Future Work

- Adding functional programming languages and tasks in our dataset
- Catalogue with top solutions of different tasks in terms of Energy Delay Product
- Compare on different platforms (e.g., RPi)
- Languages features that makes them more energy efficient/consuming

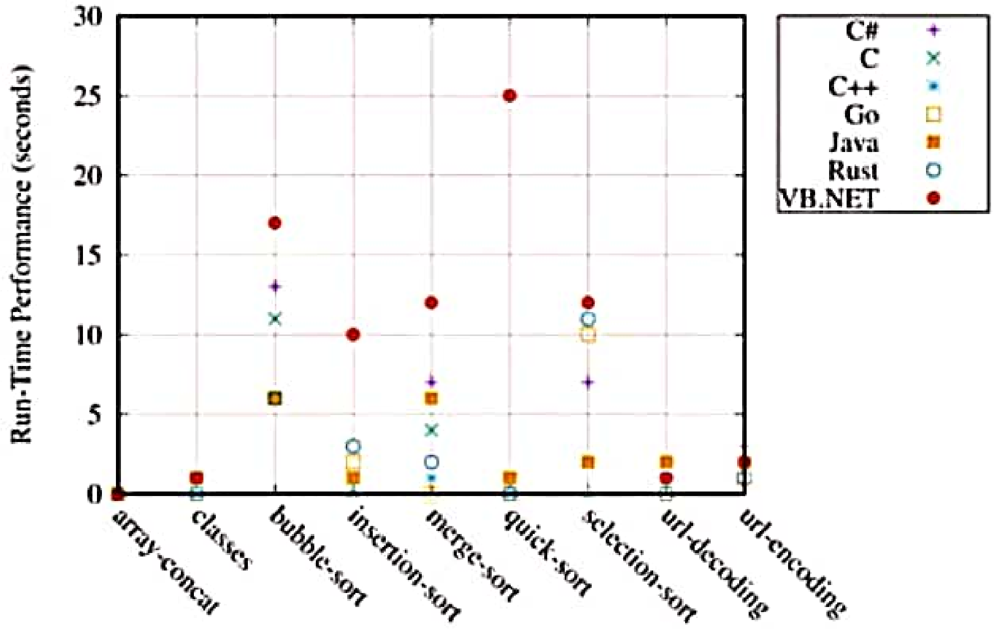
Results – Compiler Optimization Effect

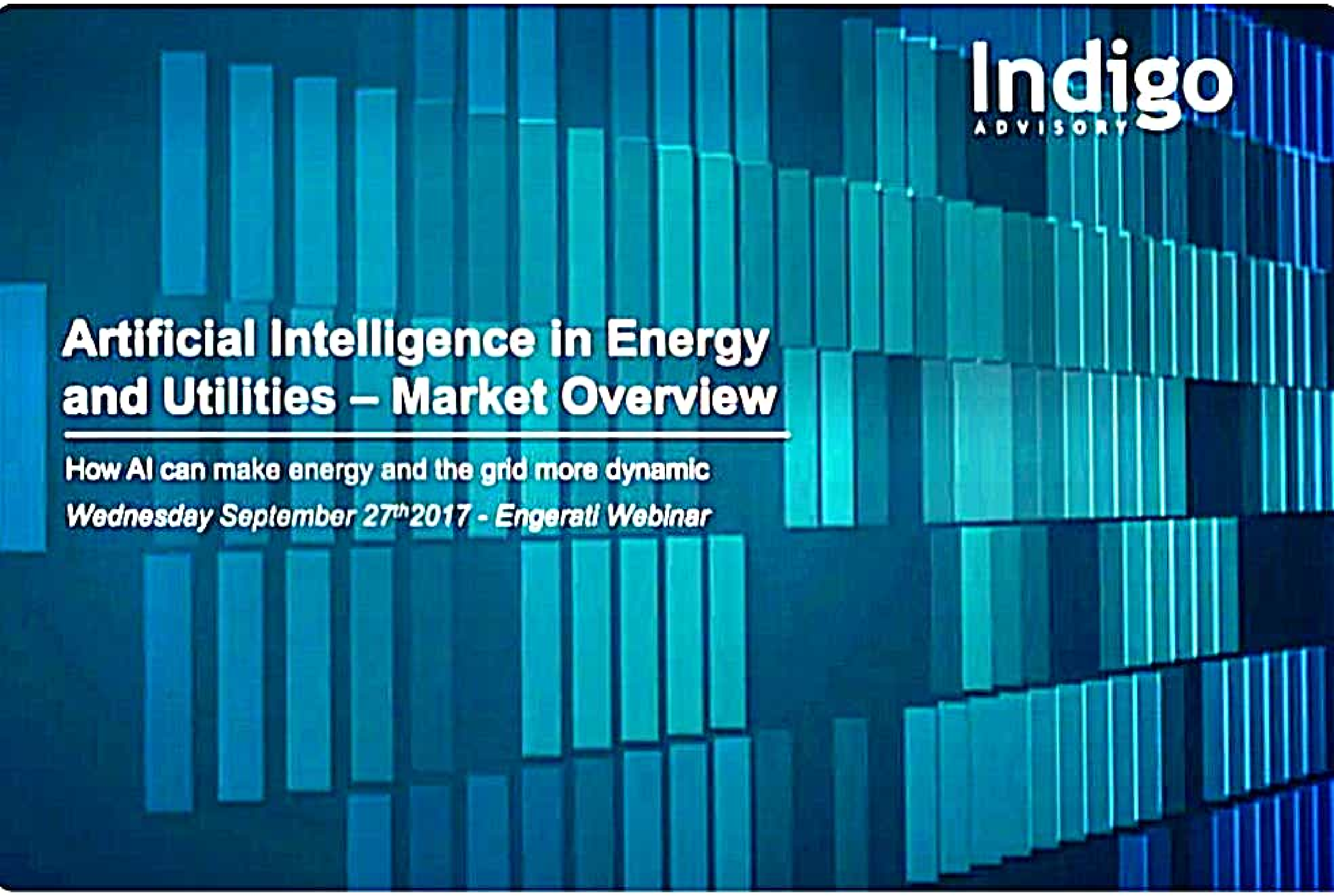
	C	C++	C#	Go	Java	Rust	VB.NET
ArrayCon			1-10%			15-97.7%	
Class						15.4%	
Merge			3.8-36.6%	14-31.5%			
Selection	43.3-99.6%	0.9-98.4%			6-98.4%		<10%
Bubble						15-97.7%	
Quick			1-10%				
Insertion				15.3-62%			
URL-Enc.			3.8-36.6%				
URL-Deco	14.7%	33.33%	1-10%	14-31.5%			

Energy usage Compiled Languages



Performance of Compiled Languages

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Artificial Intelligence in Energy and Utilities – Market Overview
How AI can make energy and the grid more dynamic
Wednesday September 27th 2017 - Engerati Webinar

Three Discussion Topics

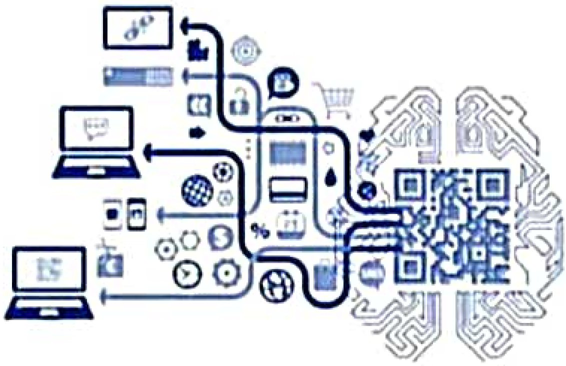
1. Brief Definition of Artificial Intelligence

2. The Energy and Utilities Opportunity – 3 major Application Areas

3. In context, AI and Exponential Technologies

Defining Artificial Intelligence

Artificial Intelligence has been around for decades, however, over the past 2-3 years the technology has been finding applications across a series of sectors, including energy and utilities. AI is among the fastest-growing tech sectors, with investment in AI startups growing to a record $5 billion across 550 deals, according to CB Insights.



Artificial intelligence (AI) has been defined as "the ability of a machine to perform at the level of a human expert". Rooted in science and engineering, the domain includes machine learning, natural language processing, pattern recognition, search and inference and planning. While the concept has been understood for some time we are increasingly seeing the development of expert systems that solve complex problems in a particular domain, at a level of extraordinary human intelligence and expertise. These systems combine factual knowledge and heuristic knowledge relating to practice, accurate judgement, and the ability to evaluate.

Some 2017 "AI in Energy Developments" – Momentum is Gaining

"Combined with the ability to estimate energy production, AI would raise (wind turbine) power output by around 5% and lower maintenance costs by 20%" - GE 2017

"Two minutes after artificial intelligence took over control of the combustion unit, nitrogen oxide levels dropped by 20 percent" – Siemens 2017

"Google's DeepMind is in discussions with the UK's National Grid to use artificial intelligence to help balance energy supply and demand in Britain" – FT 2017

"Smart algorithms were able to predict load on the data centers' cooling systems and control equipment more efficiently, resulting in a 40 per cent reduction in the amount of energy used for cooling" – Google 2017

The Energy Opportunity

In combination with other emerging technologies such as distributed energy resources, analytics and distributed ledgers (blockchain), AI has the potential to deliver the active management that will be required for the grid of the future.

- Powerful intelligence will be able to balance grids, manage demand, negotiate actions, enable self-healing and facilitate a host of new products and services.
- Indeed, AI, will not just lend itself to the energy transition, it will also enable more efficient and effective utility operations by helping to analyze unstructured data which typically makes up to 80% of data in an organization.
- Three broad categories of AI in energy and utilities include:

1. Renewables Management
2. Demand Management
3. Infrastructure Management

The Energy Opportunity

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2. Demand Management

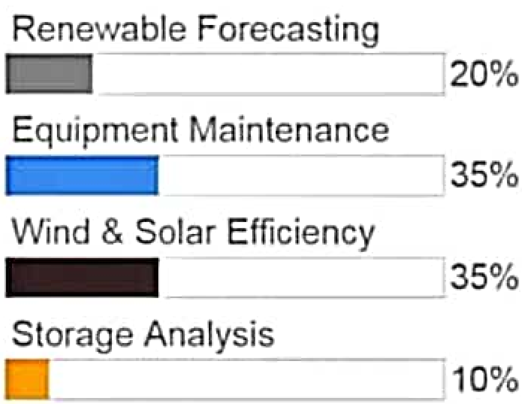
3. Infrastructure Management

Emerging Energy AI Applications -> 1. Renewables Management

Renewables Management - There are a number of AI use cases in this area that focus on enhancing short-term renewable forecasting and improving equipment maintenance.

- Across various pilots AI is being deployed to wind turbine operation data and solar panel sensor data that gauge sunlight intensity. This is then combined with atmospheric observations obtained by radar, satellites, and ground-weather stations.

Figure: Distribution of Renewable Management AI Use Cases in Energy and Utilities



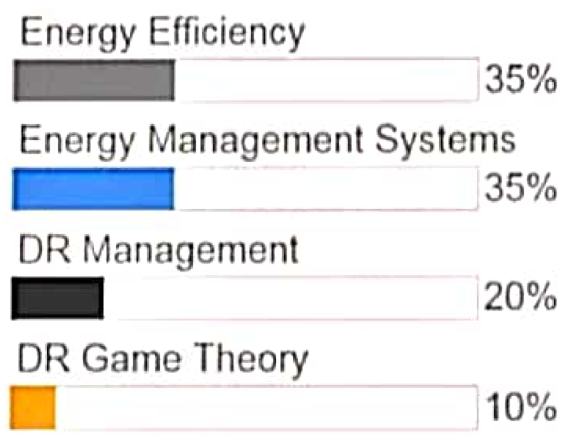
- Also in this area we are seeing AI being applied to energy storage and helping to estimate the useful lifetime of a battery pack or unit by applying prognostic algorithms.

Emerging Energy AI Applications -> 2. Demand Management

Demand Management - Various companies are working on demand management AI backed solutions that manage demand response of different devices that are run in parallel.

- Equally, a series of AI platforms are in development with a focus on energy efficiency, enhanced feedback on energy performance in buildings and solutions that gauge, learn and anticipate user behavior in order to optimize energy consumption.

Figure: Distribution of Demand Management AI Use Cases in Energy and Utilities



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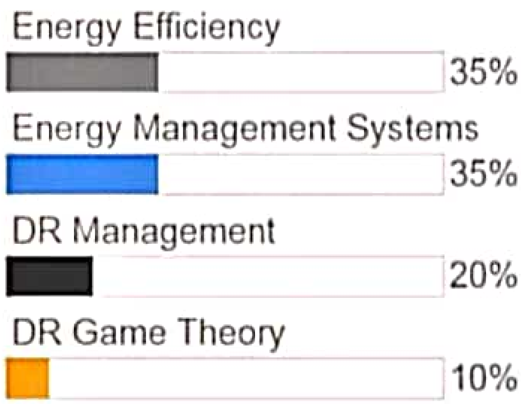


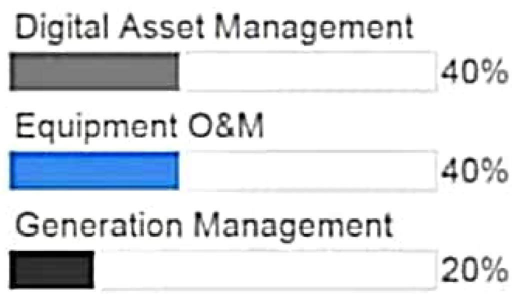
- Additionally, we are seeing AI and game theory applied to reward/penalty mechanisms to ensure enough customers in a DR pool are willing to participate, and actually respond when necessary.

Emerging Energy AI Applications -> 3. Infrastructure Management

Infrastructure Management - AI and digital asset management, where machine learning algorithms collate, compare, analyze, and highlight risks and opportunities across a utilities' infrastructure is providing opportunity for power companies.

- In these cases, AI methods are used to model possible scenarios, and advise on actions and impacts. Also, we are seeing AI being deployed for the operation and maintenance of generation sources such as gas turbines to minimize emission of nitrogen oxides.

Figure: Distribution of Infrastructure Management AI Use Cases in Energy and Utilities



- Siemens for example is using a neural model that alters the distribution of fuel in a turbine's burners to increase efficiency.

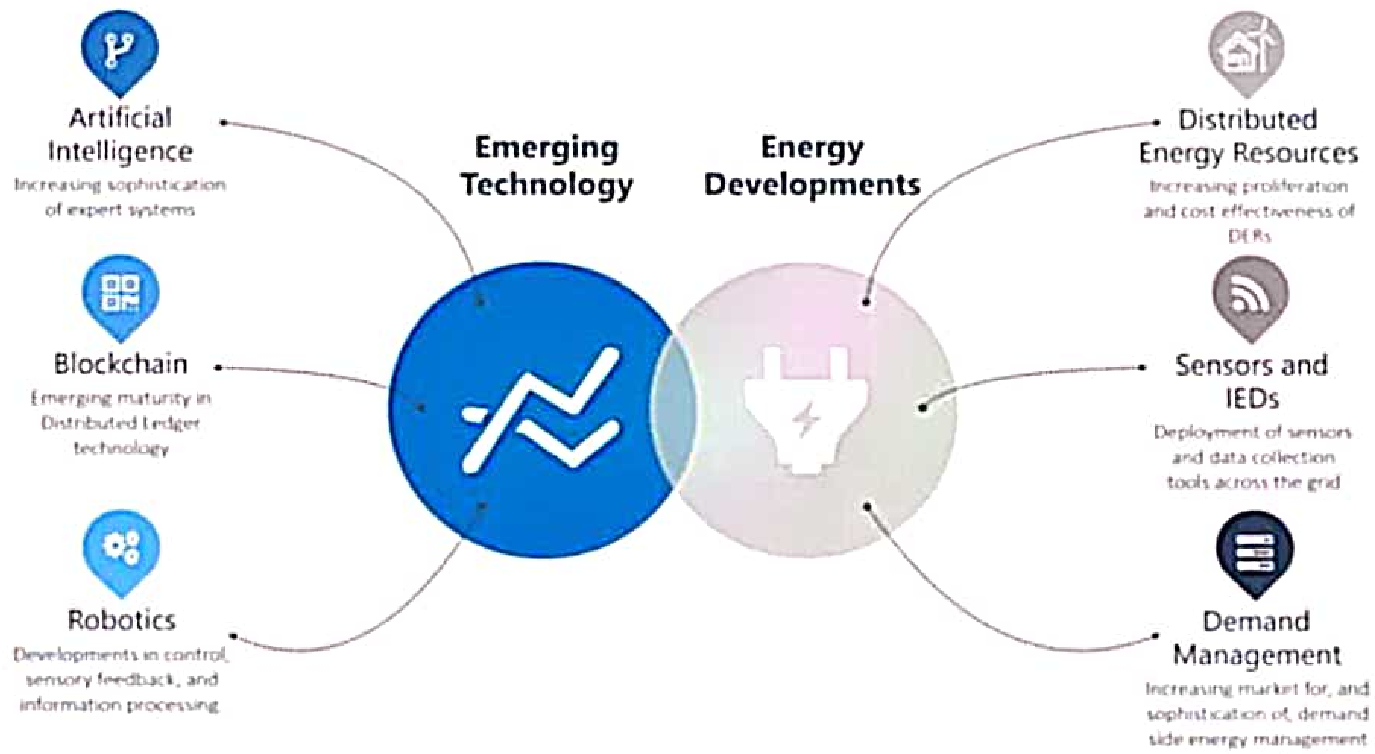
Three Areas to Address as we Deploy AI Applications

1. **Remove bias from training data for AI algorithms** - Not everyone can afford a Nest smart thermostat or a learning device so consumption patterns an AI training data should be based on the broadest datasets available to make it equitable.

2. **Build Trust** - Energy companies seeking to win consumer trust with AI-enabled energy and customer services will also need to consider transparency. Some customers will want to know how the algorithm arrived at a particular decision. Explanations of why energy consumption may have changed year on year are better than automation at building trust. You can't just set it and forget it.

3. **Design Thinking** - Focus on the customer and end users to build the strongest business cases. Over the past decade, the best smart grid business cases and deployment successes included detailed information on how customers will be able to use the technology e.g. obtain daily usage information, leverage bring your own device (BYOD) programs etc. These deployments were also able to evolve quickly as technology develops and leverage flexible infrastructure to adapt to changing customer and operational needs.

Convergence – AI is part of a suite of technologies that will transform the sector



About Indigo and our Focus Areas

About Indigo Advisory Group

Indigo Advisory Group works with utilities and energy companies to deliver market leading strategy, emerging technology and innovation services. Our capabilities span the entire energy value chain and our approach is high value and outcome focused. #indigoinsights is our market perspectives and intelligence center, providing analysis and market research for utilities.

Agenda

The case for innovation in energy

Pathways for the future

Innovation and Sustainable Development at EDP

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The case for innovation in energy

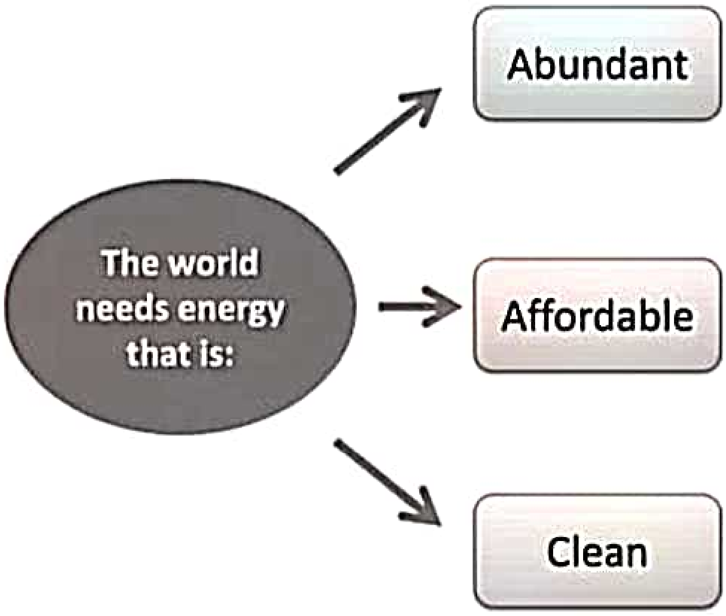
Pathways for the future

Innovation and Sustainable Development at EDP

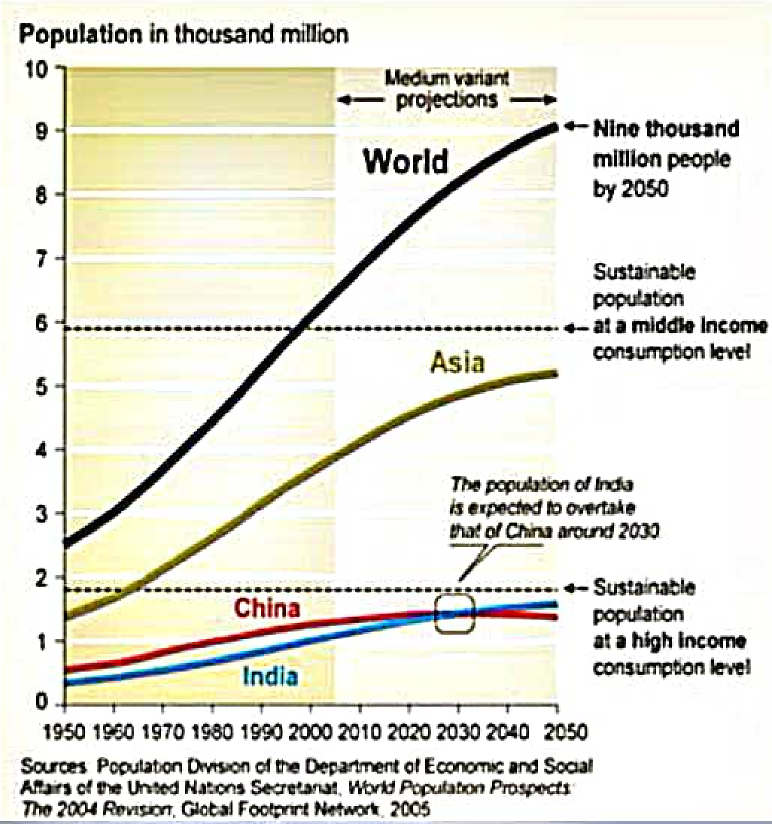
Innovation needed to tackle the key energy challenges

KEY ENERGY CHALLENGES

- **Increased energy consumption**
  - Population growth
  - Economic development
- **Limited availability of resources** and or more expensive
- **Global warming** and the need to reduce GHG emissions



Population will grow 50% between 2000 and 2050



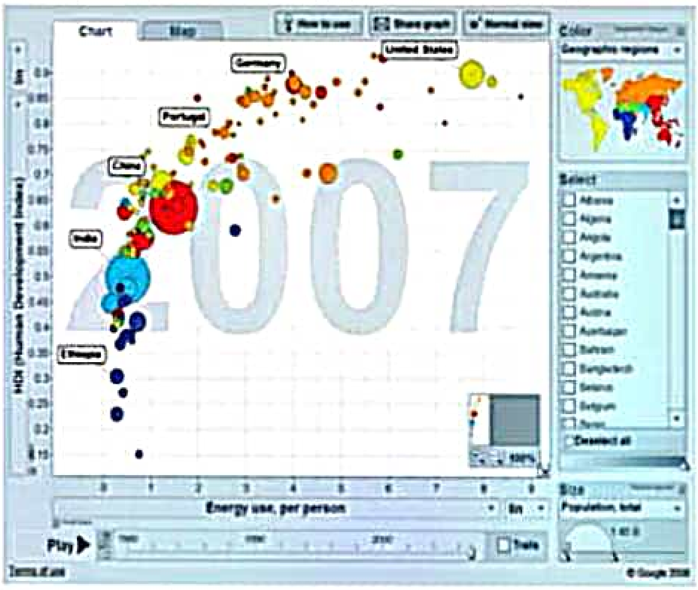
A case for energy hunger...

The wealthiest bilion is responsible for

50% of energy consumption...

While the poorest takes less than **4%**

Economic development and human development highly correlated with energy consumption



Source: www.gapminder.org

We need more energy

The population will grow

50% between 2000 and 2050…

Energy consumption is projected to grow

100%

Fossil fuels allowed a huge jump in the human development

Pre Industrial Revolution Farming

ERoEI ~ 1 a 5

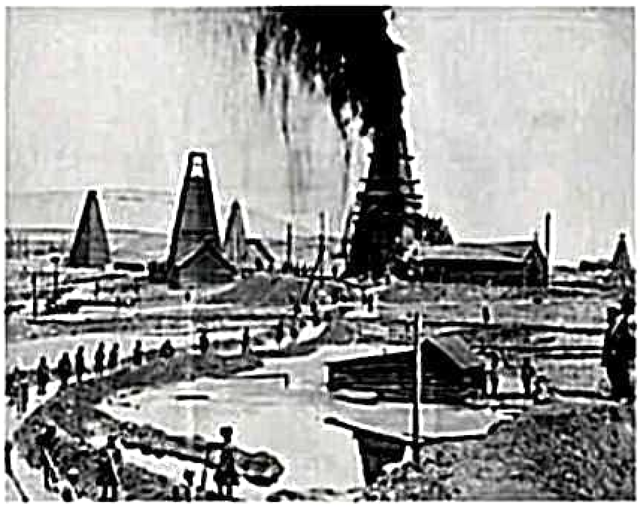
Current farming

ERoEI ~ 40 a 60

Fonte: Kurt Cobb, *The Net Energy Cliff*, Energy Bulletin, 2008

Oil ERoREI has been reducing dramatically

Oil exploration by early XX



1900: ERoEI > 100

Deep water oil exploration

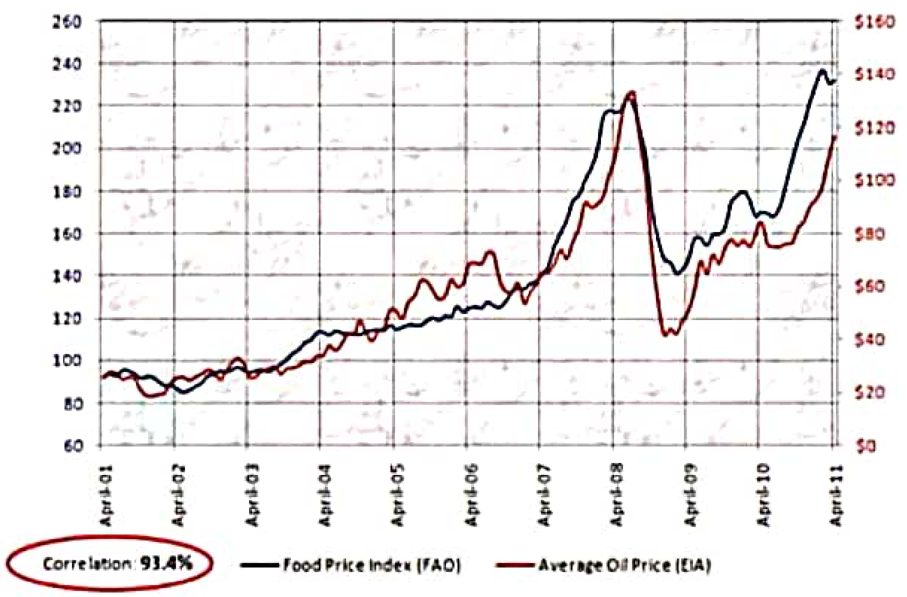
2010: ERoEI < 10

It takes a lot of oil to raise cattle!

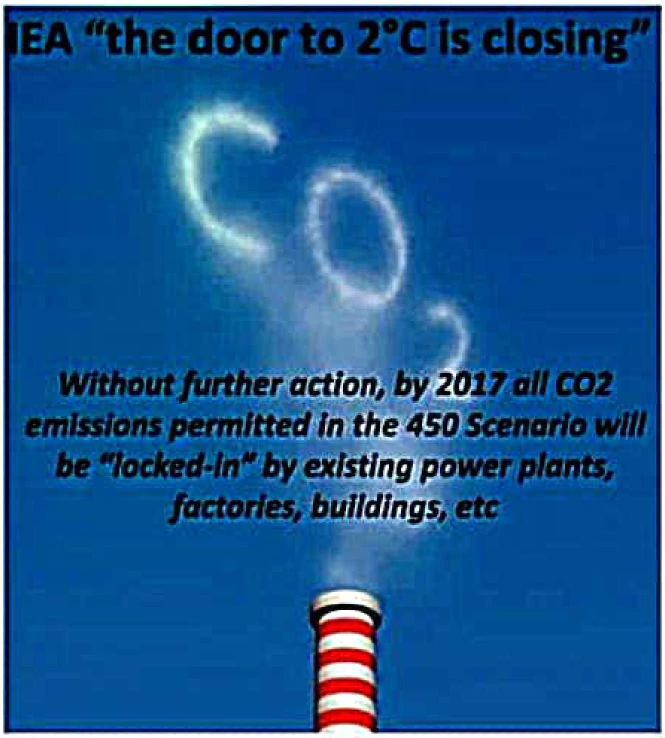
Source: National Geographic

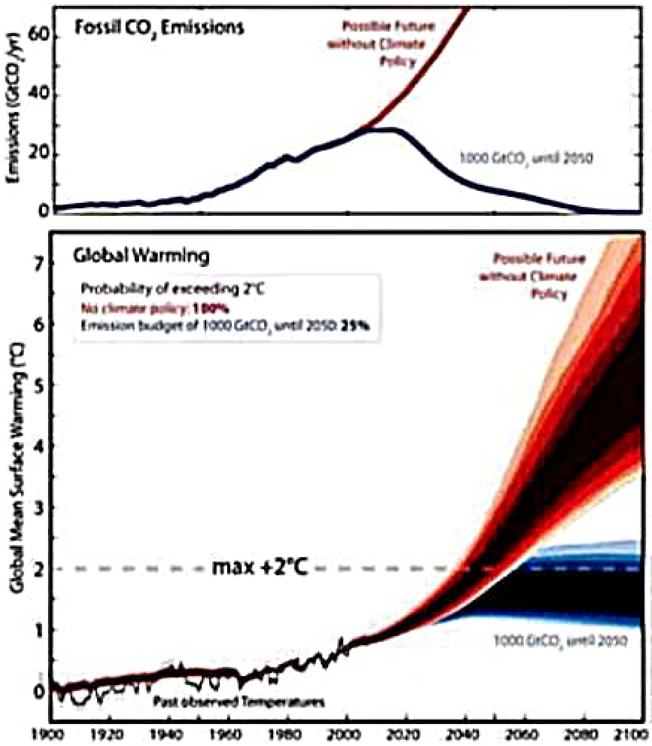
Energy prices highly correlated with food prices

Food price index vs. oil price
Index, $/bbl



Known reserves of fossil fuels exceed what the atmosphere can handle





Agenda

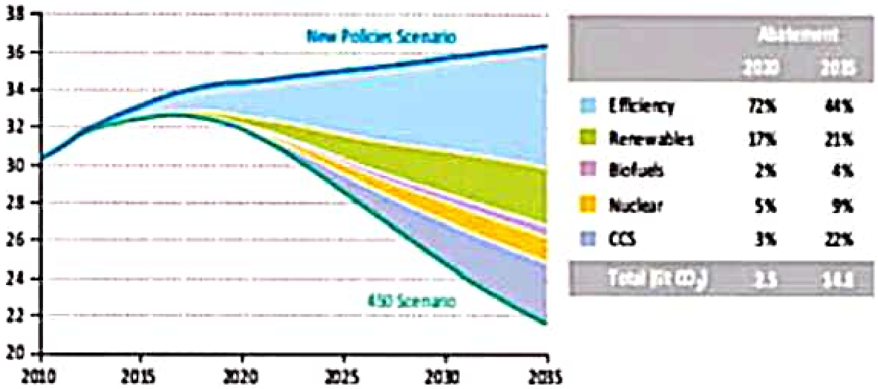
The case for innovation in energy

Pathways for the future

Innovation and Sustainable Development at EDP

Main trends: 1 Energy Efficiency

Breakdown of GHG abatement drivers
Gt of CO_2, 2005-2030E



Key characteristics of Energy Efficiency

Lowest-cost CO_2 abatement technology

Greater security of supply

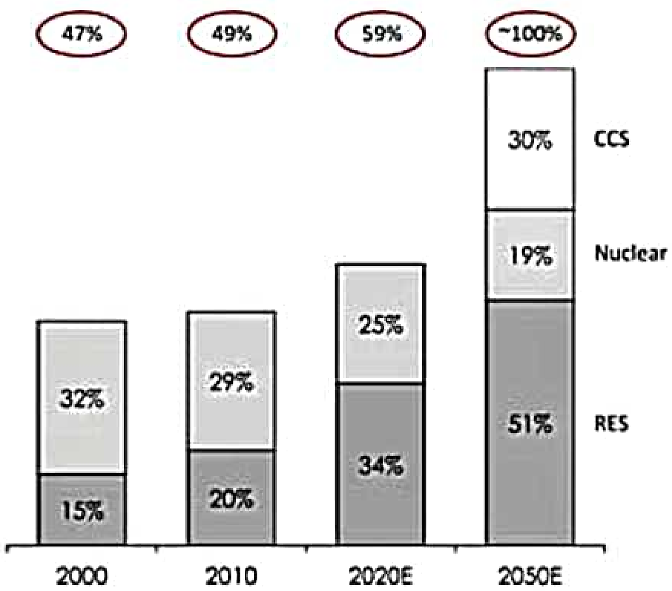
Key to economic recovery

- *Job creation* – labor intensive activity
- *Value creation* – avoids fossil fuel imports

Source: IEA - World Energy Outlook

Main trends: 2 Decarbonization

EU carbon-free power generation mix
%, 2000-2050



- Renewable energy will need to keep growing consistently
- Strong regional differences:
  - Highest RES penetration in Iberia & Scandinavia
  - Strong share of nuclear in France
  - CCS mostly located in Central & Eastern Europe
- Emissions only allowed for peaking units working few hours

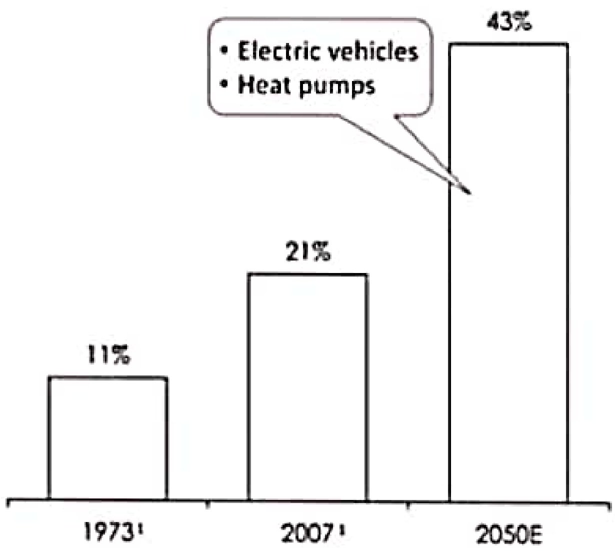
Source: IEA - Key World Energy Statistics (2009); 2050 values calculated as average of 5 European studies' forecasts (Eurelectric, PWC, ECF, New Energy Era)

Main trends: 3 Electrification

Major arguments for electrification

Higher efficiency	• Electricity based end-use technologies are much more efficient than fossil fuel based
Easier decarbonization	• Multiple zero carbon power generation technologies already exist at competitive costs • Economies of scale: power emits at generation plants, fuels emit at consumption points (many more)

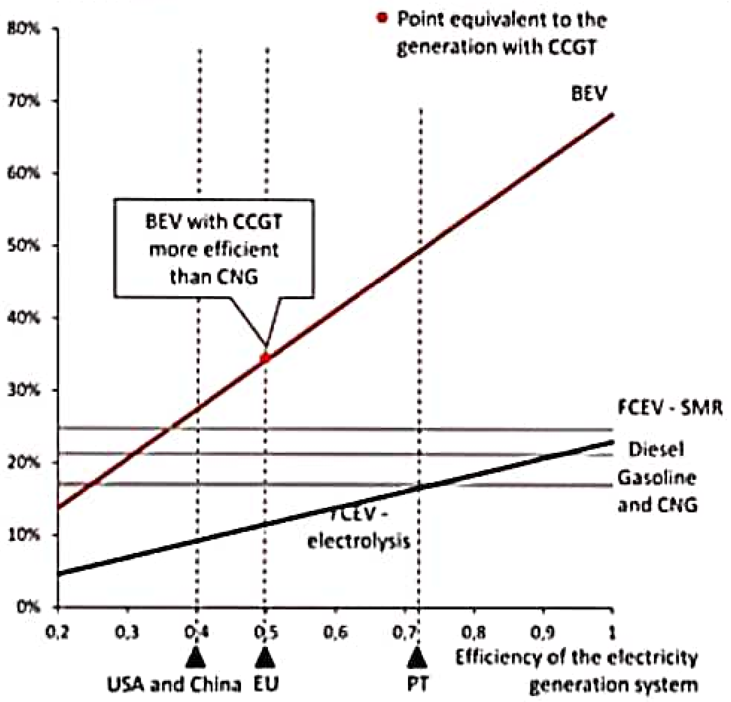
Share of electricity in final energy demand
%, Europe



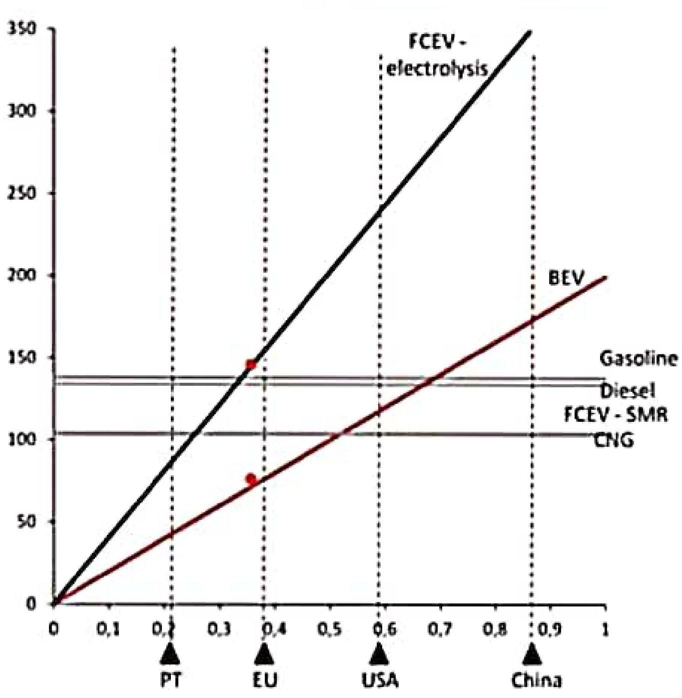
1. Values for OECD
Source: IEA - Key World Energy Statistics (2009); 2050 values calculated as average of 5 European studies' forecasts (Eurelectric, PWC, ECF, New Energy Era)

Electric mobility: a powerful tool to increase efficiency and reduce emissions

Global efficiency in the use of primary energy
%, 2009 and 2010 for Portugal



Specific emissions for different transportation techs
gCO_2/km, 2009 and 2010 for Portugal



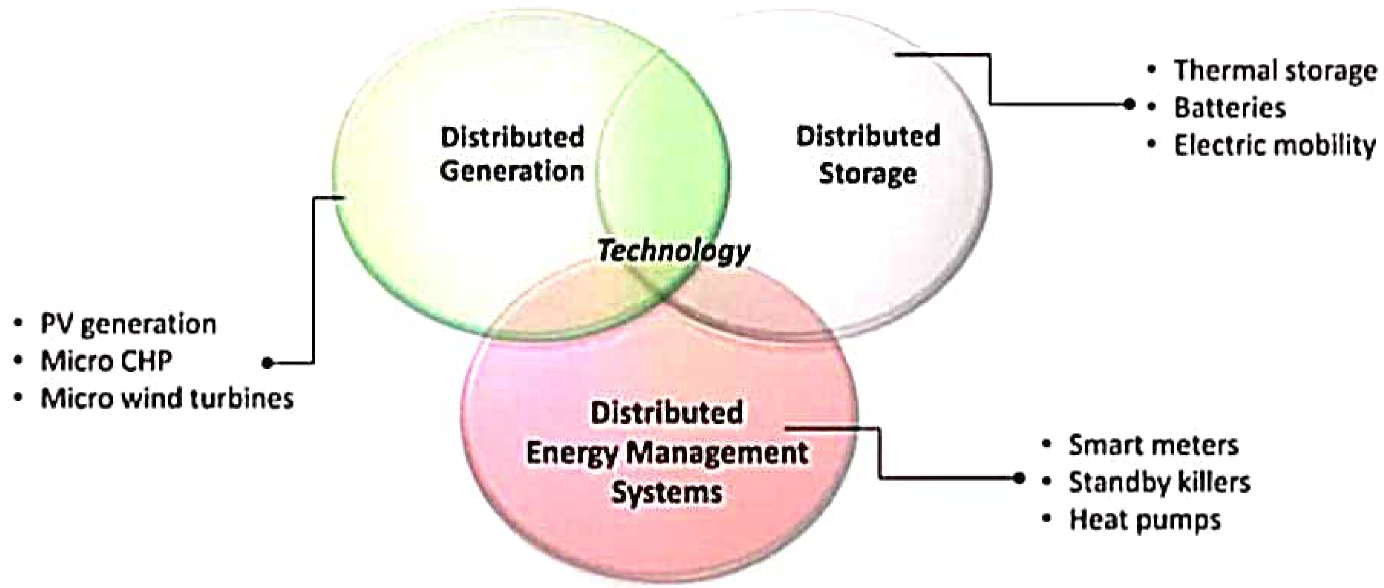
Source: ACAP, Eurelectric, DPE analysis

Main trends: 4 Grids

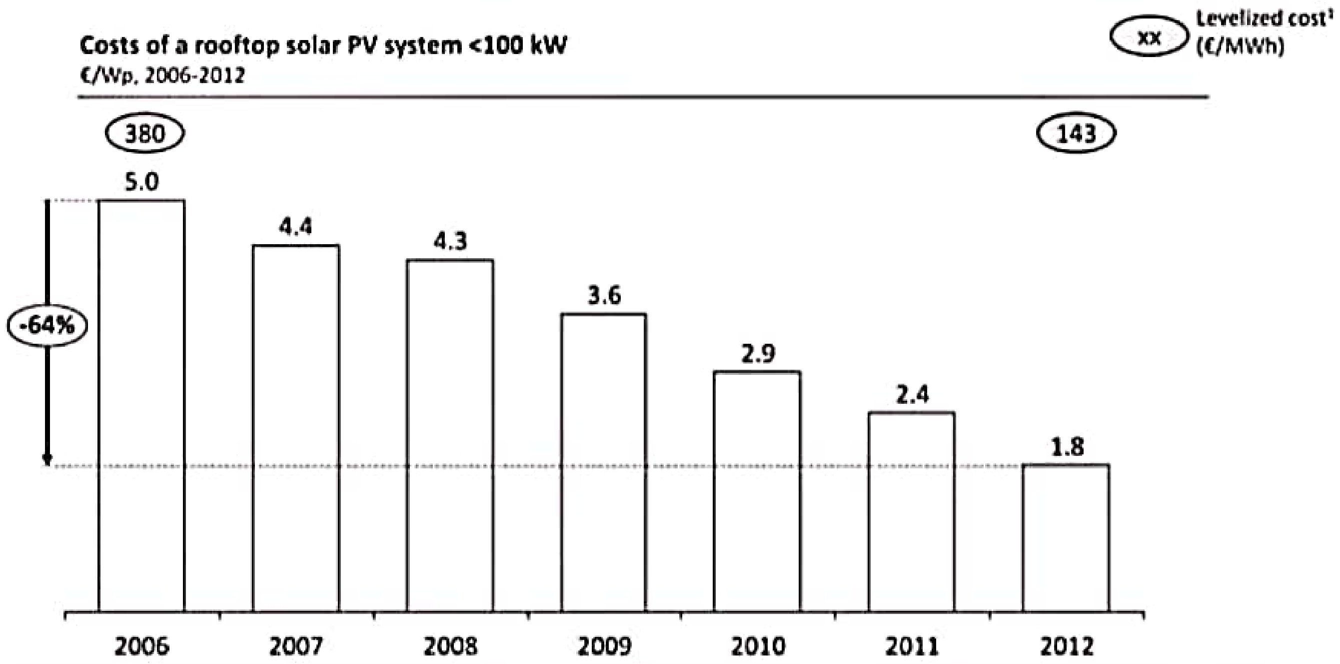
Large-scale integration of intermittent renewables

Instruments	What they allow
Transport grids	• Dilute local intermittency in a larger system • Reduce need for backup capacity • Take advantage of countries' comparative advantages in regard to renewable resources • Combine technologies with complementary seasonality (solar, wind) • Mature and cost-efficient technology
Distribution smart grids	• Facilitate adoption of energy efficiency • Allow integration of micro-generation • Enabler of electric mobility and distributed storage

Main trends: 5 Going Distributed



Grid parity is around the corner



Innovation has and will continue to be key in cutting the cost of solar generation

1. Assuming FOM 20 €$_{2010}$/kW, load factor 1 400 equivalent hours; WACC 9%
Source: BSW Solar PV Price Index 5/2012

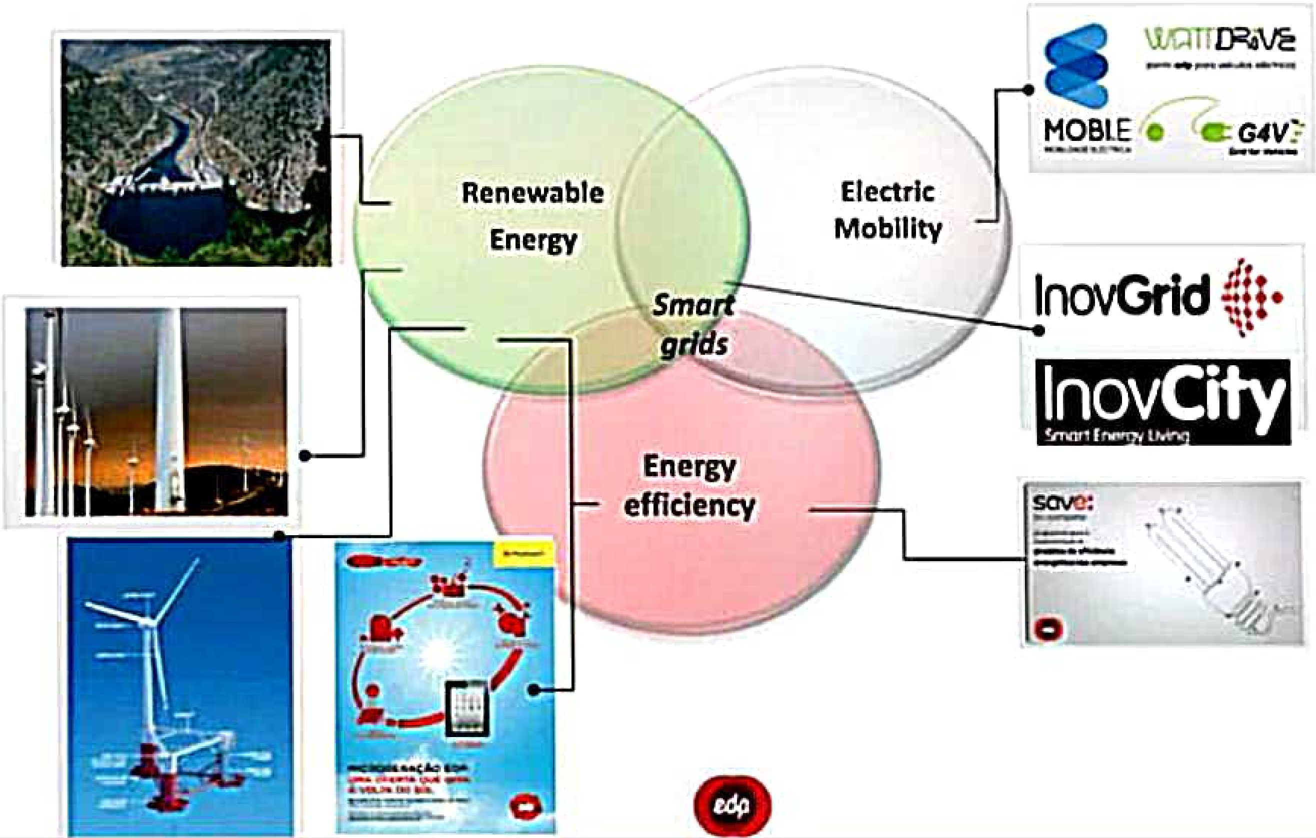
Agenda

The case for innovation in energy

Pathways for the future

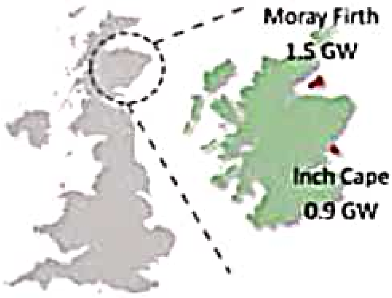
Innovation and Sustainable Development at EDP

EDP's strategy answering the main trends



EDP's research in deep wind offshore has been considered a leading example worldwide, having attracted several leading entities in the field

UK Wind Offshore Partnership



EDPR is leading the development of up to 2.4 GW of wind offshore projects with a 60% stake

Joint development of wind offshore project in UK

Wind Float Project

EDP recently installed a wind floating turbine in northern Portugal coast

First wind offshore project in the world without any heavy load support

InovGrid as the #1 project in Europe by the European Commission

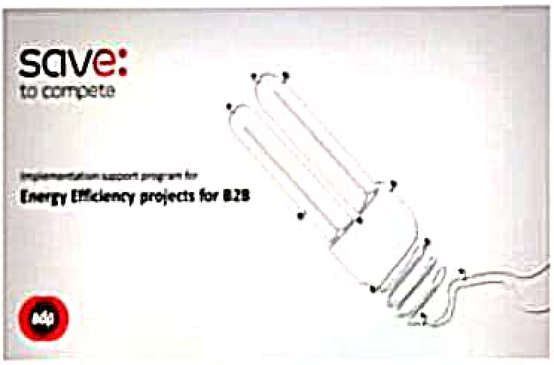
InovGrid

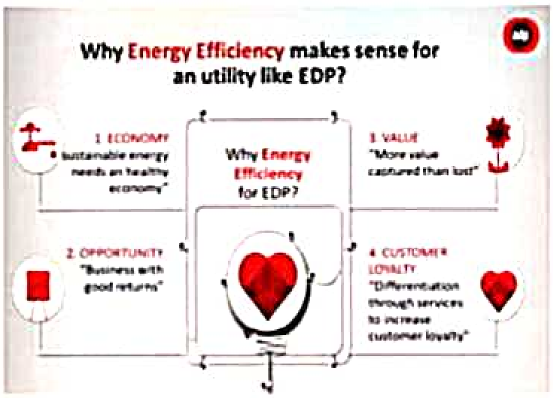
Benefitting consumers and offering a technological leap forward in network service and capabilities

- ✓ Operational Efficiency
- ✓ Energy Efficiency
- ✓ Service Quality
- ✓ Renewable Energy
- ✓ Electric Vehicles

- 31,300 smart meters are being commercially tested in the Portuguese city of Évora
- Expansion to the 6 million Portuguese client base set to start soon...
- First pilot project in Brazil replicating the same technology with be concluded also in 2012

SaveToCompete as an innovative program privately funded to promote Energy Efficiency in B2B





Kakuma: a pioneer example from a "nowhere land" to a place to live

- Project developed in Kenya in a partnership with the UNHCR (UN Refugee Agency)
- 10 projects with significant impacts in the community
- EDP invested 1.3 million euros invested
- Benefiting 77.000 refugees, 11 institutional buildings, 15 schools and 2 hospitals

Main takeaways

- Technology and innovation are needed to meet energy consumption growth in a sustainable way
- Going forward, the main trends in energy systems involve energy efficiency, decarbonization, electrification and going distributed
- EDP is strongly committed in promoting innovation and sustainable development pursuing opportunities aligned with the main trends