Green Energy Technologies: Challenges & Opportunities for Africa

Presentation at the IEEE Africon 2015

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Dr Tobias Bischof-Niemz
Head of CSIR's Energy Centre

Professional Experience

- Member of the Ministerial Advisory Council on Energy (MACE)
- Extraordinary Associate Professor at Stellenbosch University
- Jul 2014 – today: Centre Manager at the CSIR, responsible to lead the establishment of an integrated energy research centre
- 2012 – 2014: PV/Renewables Specialist at Eskom in the team that developed the IRP; afterwards 2 months contract work in the DoE's IPP Unit on gas, coal IPP and rooftop PV
- 2007 – 2012: Senior consultant (energy system and renewables expert) at The Boston Consulting Group, Berlin and Frankfurt, Germany

Education

- Master of Public Administration (MPA) on energy and renewables policies in 2009 from Columbia University in New York City, USA
- PhD ("Dr.-Ing.") in 2006 in Automotive Engineering from TU Darmstadt, Germany
- Mechanical Engineering at Technical University of Darmstadt, Germany (Master – "Dipl.-Ing." in 2003) and at UC Berkeley, USA

The Context

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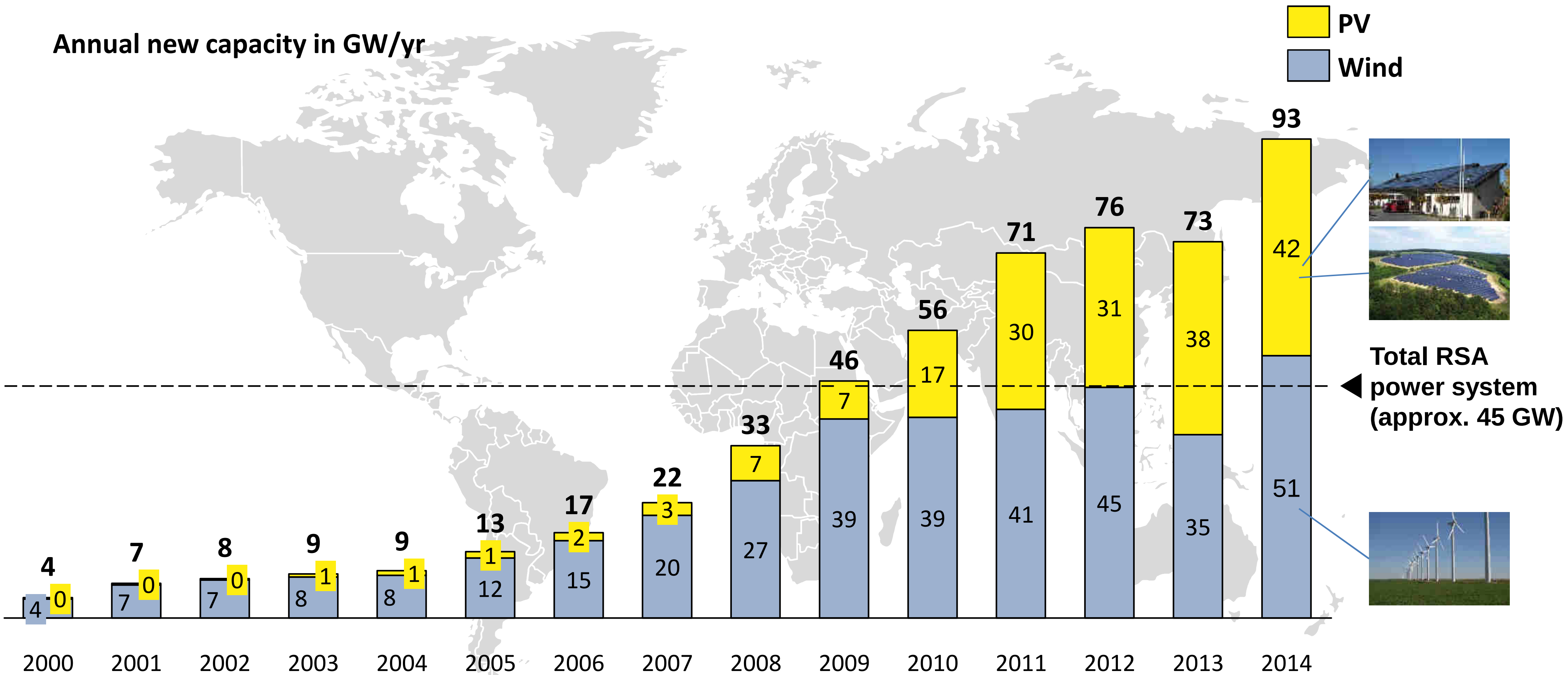
In 2014, 93 GW of wind and PV were newly installed globally

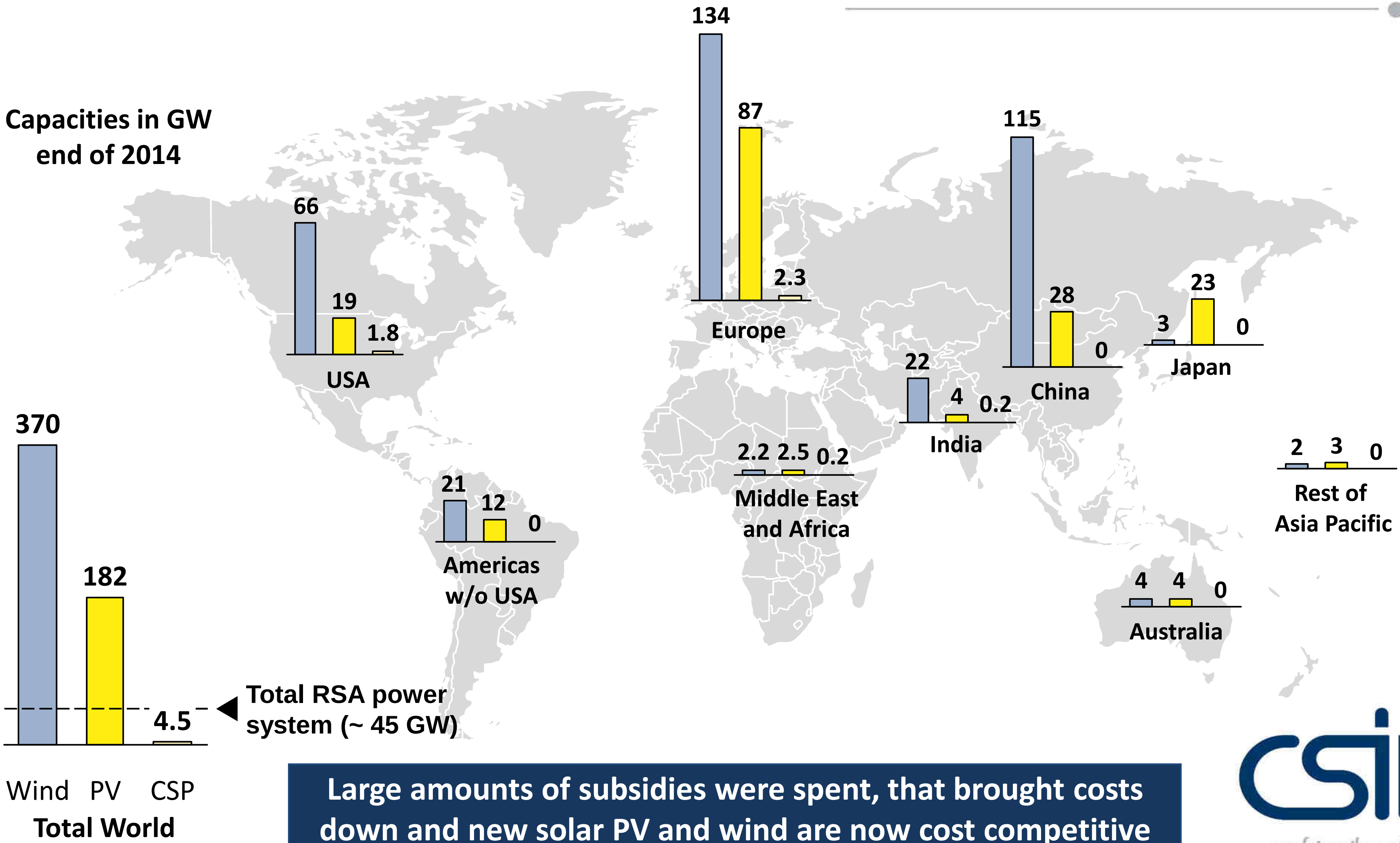


This is all very new: Almost 90% of the globally existing PV capacity was installed during the last five years alone!

Sources: International Energy Outlook of the EIA; GWEC; EPIA; CSIR analysis

Renewables until today mainly driven by US, Europe and China

Globally installed capacities for three major renewables wind, PV and CSP end of 2014



Large amounts of subsidies were spent, that brought costs down and new solar PV and wind are now cost competitive

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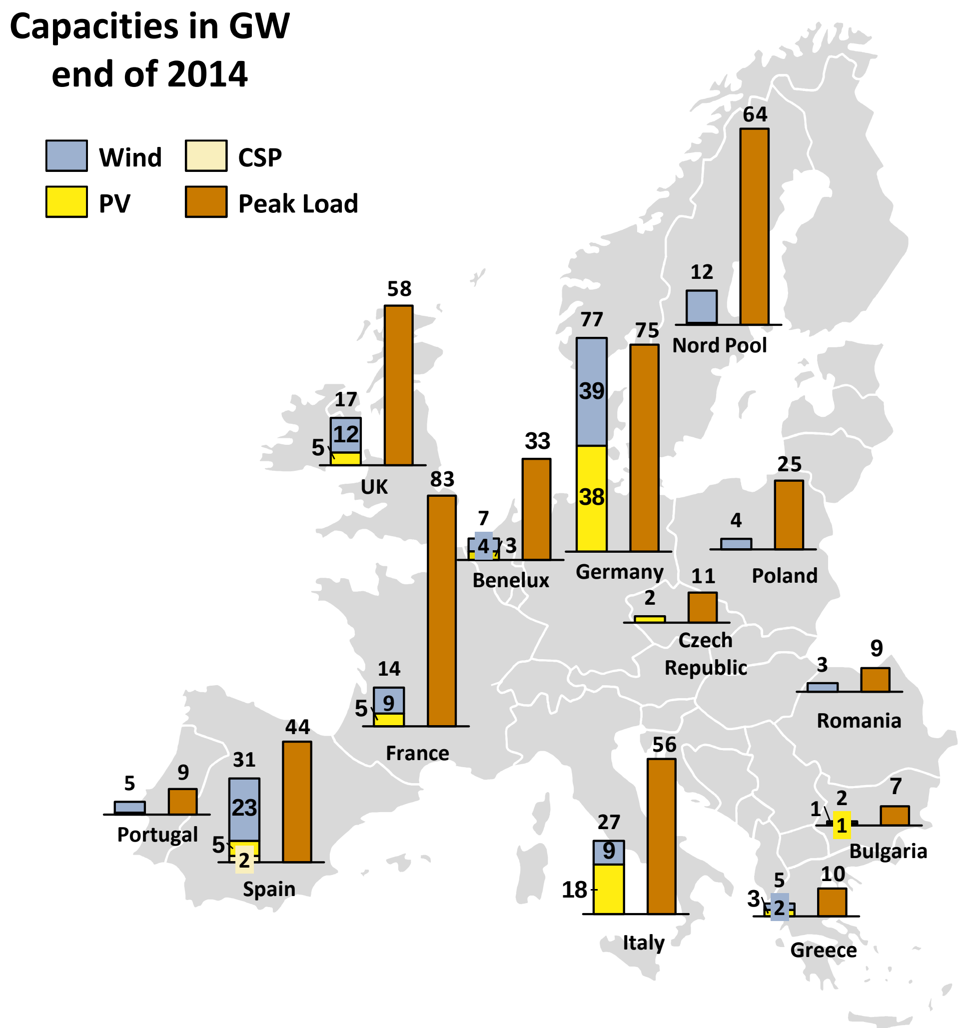
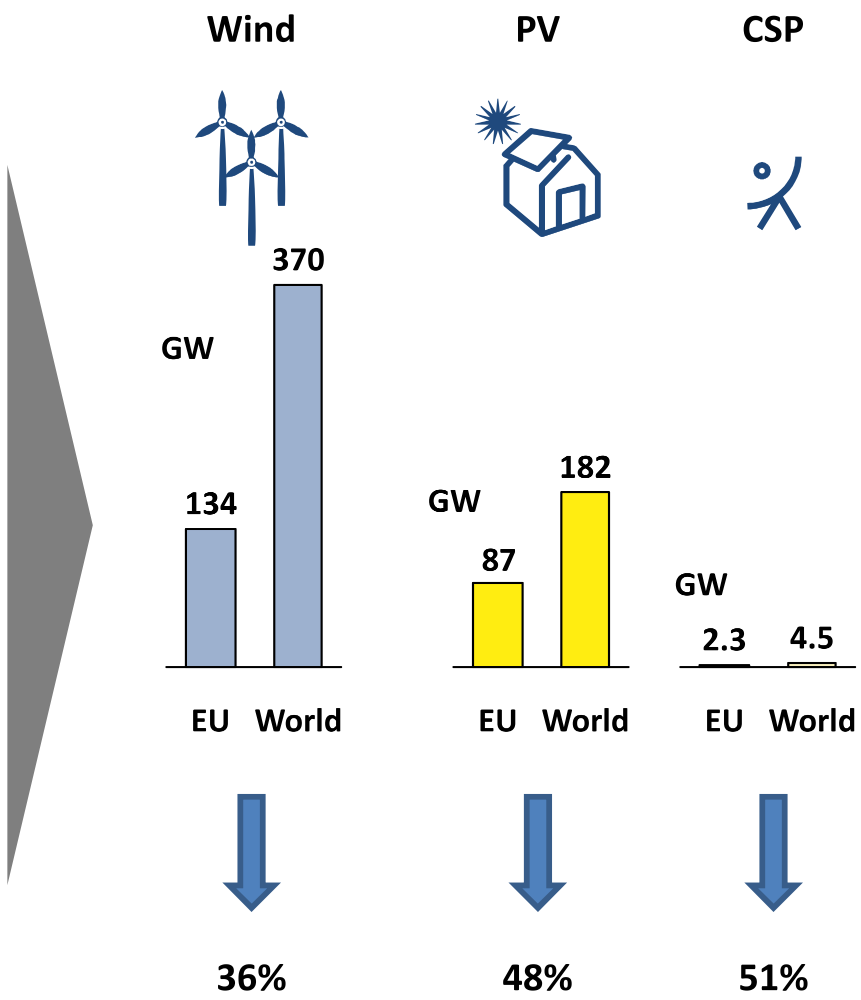
Sources: GWEC; EPIA; CSPToday; CSIR analysis

End 2014, Europe hosted ~40% of total global RE capacities – penetration levels vary widely, very high in some countries





Sources: RED, National Grid, Terna Rete Italia, Nord Pool, EWEA, EPIA, CEER, GWEC, CSIR analysis

Phasing out of fossil fuels by 2100 – "greeny" or business sense?

G7 announcement on 8 June 2015

theguardian
Winner of the Pulitzer prize 2014

G7 leaders agree to phase out fossil fuel use by end of century

German chancellor Angela Merkel announces commitment to 'decarbonise global economy' and end extreme poverty and hunger

G7 leaders, including Angela Merkel (in pink jacket), and invitees line up for the traditional group photo at the end of the summit. Photograph: Sven Hoppe/dpa/Corbis

The G7 leading industrial nations have agreed to cut greenhouse gases by phasing out the use of fossil fuels by the end of the century, the German chancellor, Angela Merkel, has announced, in a move hailed as historic by some environmental campaigners.

On the final day of talks in a Bavarian castle, Merkel said the leaders had committed themselves to the need to "decarbonise the global economy in the

Most popular

Black children are not even safe from police violence at a pool party | Steven W Thrasher

Is Richard Dawkins destroying his reputation? | Sophie Elmhirst

'You think you're

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France will phase out “10 Koebergs” by 2025 – replaced by renewables

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French energy transition bill adopted

23 July 2015

France's National Assembly yesterday gave final approval of the country's energy transition bill. Under the legislation, France's reliance on nuclear energy will be reduced to 50% of power generation by 2025.

Energy minister Royal speaks to the National Assembly following adoption of the energy transition bill (Image: French energy ministry)

French president Francois Hollande's 2012 election pledge was to limit nuclear's share of French generation at 50% by 2025, and the closure of France's oldest nuclear power plant, Fessenheim, by the end of 2016. In June last year, following a national energy debate, his government announced that the country's nuclear generating capacity would be capped at the current level of 63.2 GWe. It will also be limited to 50% of France's total output by 2025. Nuclear currently accounts for almost 75% of the country's electricity production, making closures of power reactors appear inevitable.

Debate about France's Energy Transition for Green Growth bill began in the lower house of parliament - the National Assembly - last October, with deputies agreeing on the overall objectives of the bill. These include: a 40% reduction in greenhouse gas emissions by 2030 and a 75% reduction by 2050, compared with 1990 levels; halving overall energy consumption by 2050 compared with 2012; increasing renewable energy's share of final energy consumption to 32%; and cutting the share of nuclear in electricity generation to 50% by 2025.

Yesterday, following 150 hours of parliamentary debate - during which 5034 amendments were discussed in open session and 970 amendments were passed - the National Assembly adopted the

Related Stories

- French parliament approves energy transition
- Nuclear to fund French energy transition
- France to debate 'energy transition'
- Four years left for Fessenheim

WNA Links

- Fessenheim 1
- Flamanville 3
- Nuclear Power in France

Related Links

- French National Assembly

http://www.world-nuclear-news.org/NP-French-energy-transition-bill-adopted-2307155.html

France has by far the highest nuclear penetration of any country in the world, with 75% of its electricity coming from nuclear

France has passed a bill on 23 July 2015: mandates a reduction of the share of nuclear in the electricity mix to 50% by 2025

That's a <u>reduction</u> by 140 TWh/yr of nuclear power generation, which is the same amount of energy produced by 10 Koebergs

This energy will be replaced by renewables

This emphasises again the recently achieved cost-competitiveness of renewables

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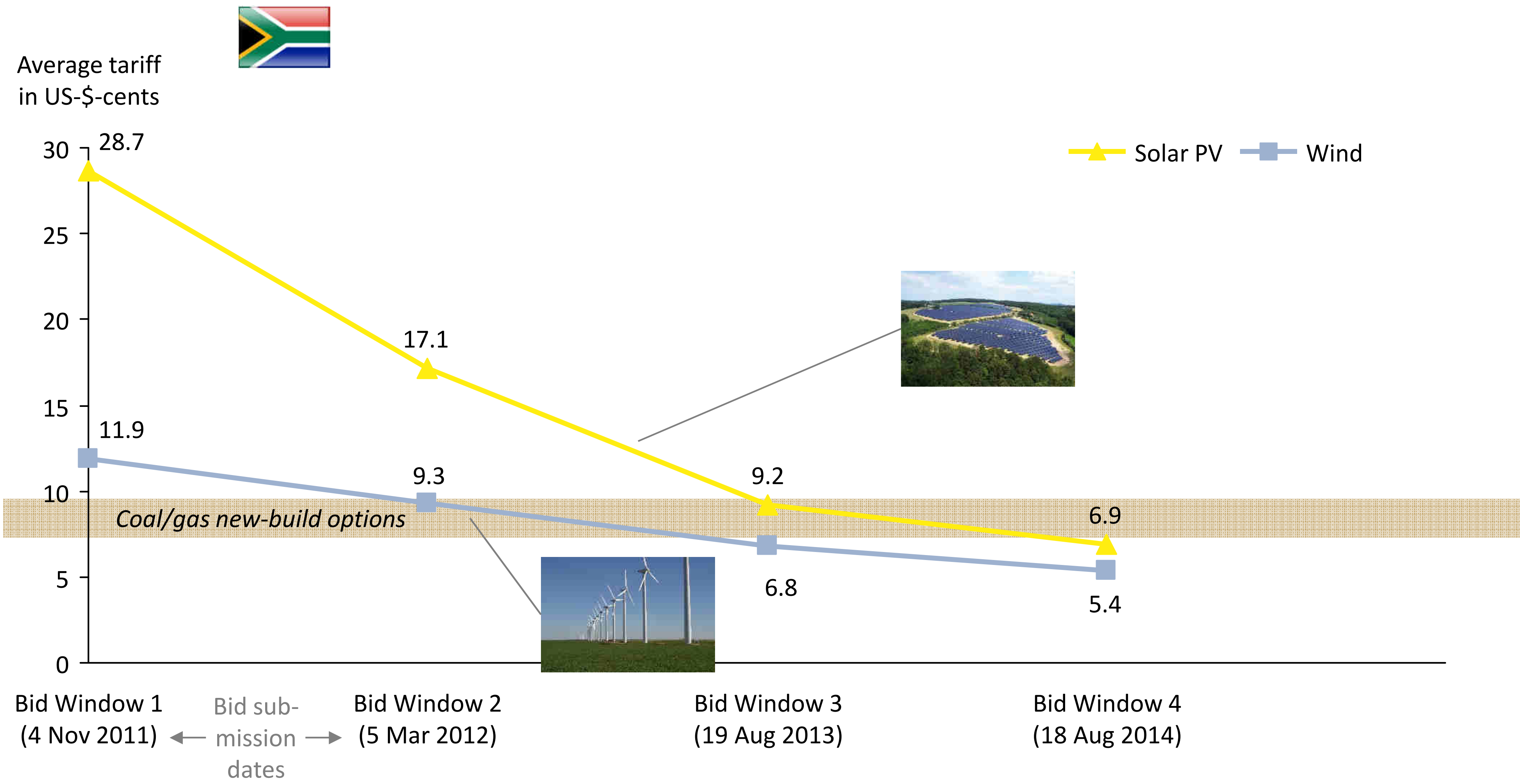
Actual results: solar PV & wind in South Africa cost competitive today

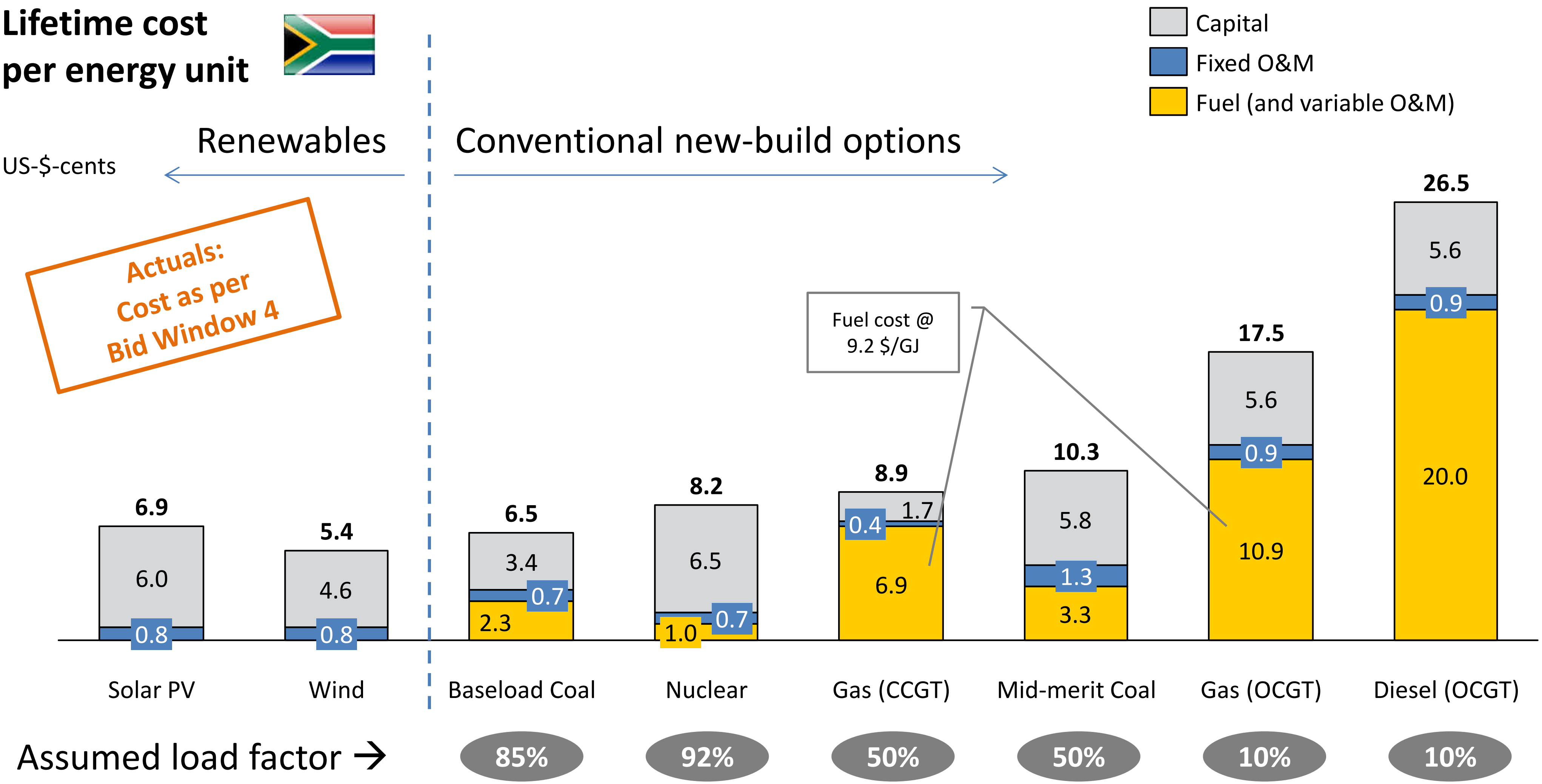
First four bid windows' results of Department of Energy's RE IPP Procurement Programme (REIPPPP)



Notes: For CSP Bid Window 3, the weighted average of base and peak tariff is indicated, assuming 50% annual load factor

Sources: StatsSA on CPI; Department of Energy's publications on results of first four bid windows http://www.energy.gov.za/IPP/List-of-IPP-Preferred-Bidders-Window-three-04Nov2013.pdf; http://www.energy.gov.za/IPP/Renewables_IPP_ProcurementProgram_WindowTwoAnnouncement_21May2012.pptx; http://www.ipprenewables.co.za/gong/widget/file/download/id/279; CSIR analysis

Consequence of renewables' cost reduction: Solar PV & wind cheapest new-build options per kWh in South Africa



Note: Changing full-load hours for conventionals drastically changes the fixed cost components per kWh (lower full-load hours → higher capital costs and fixed O&M costs per MWh); Assumptions: average efficiency for CCGT = 50%, OCGT = 35%; coal = 37%; nuclear = 33%; IRP cost from Jan 2012 escalated with CPI to May 2015; assumed EPC CAPEX inflated by 10% to convert EPC/LCOE into tariff; CSP: 50% annual load factor and full utilisation of the five peak-tariff hours per day assumed to calculate weighted average tariff from base and peak tariff

Sources: IRP Update; REIPPPP outcomes; StatsSA for CPI; Eskom financial reports on coal/diesel fuel cost; CSIR analysis

The New Energy World

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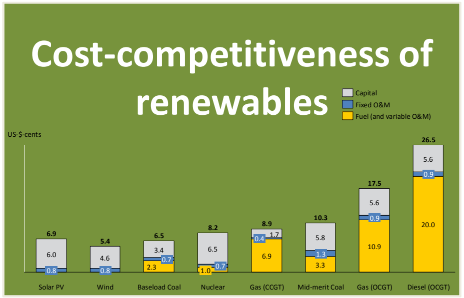
Cost competitiveness of renewables has two consequences



I — Distributed Power Generation

Because renewables are inherently smaller and more distributed than conventionals

II — System Planner's / Operator's Paradigm Shift

Because the two mainstream renewables solar PV and wind are dispatched by the weather, and not by the System Operator

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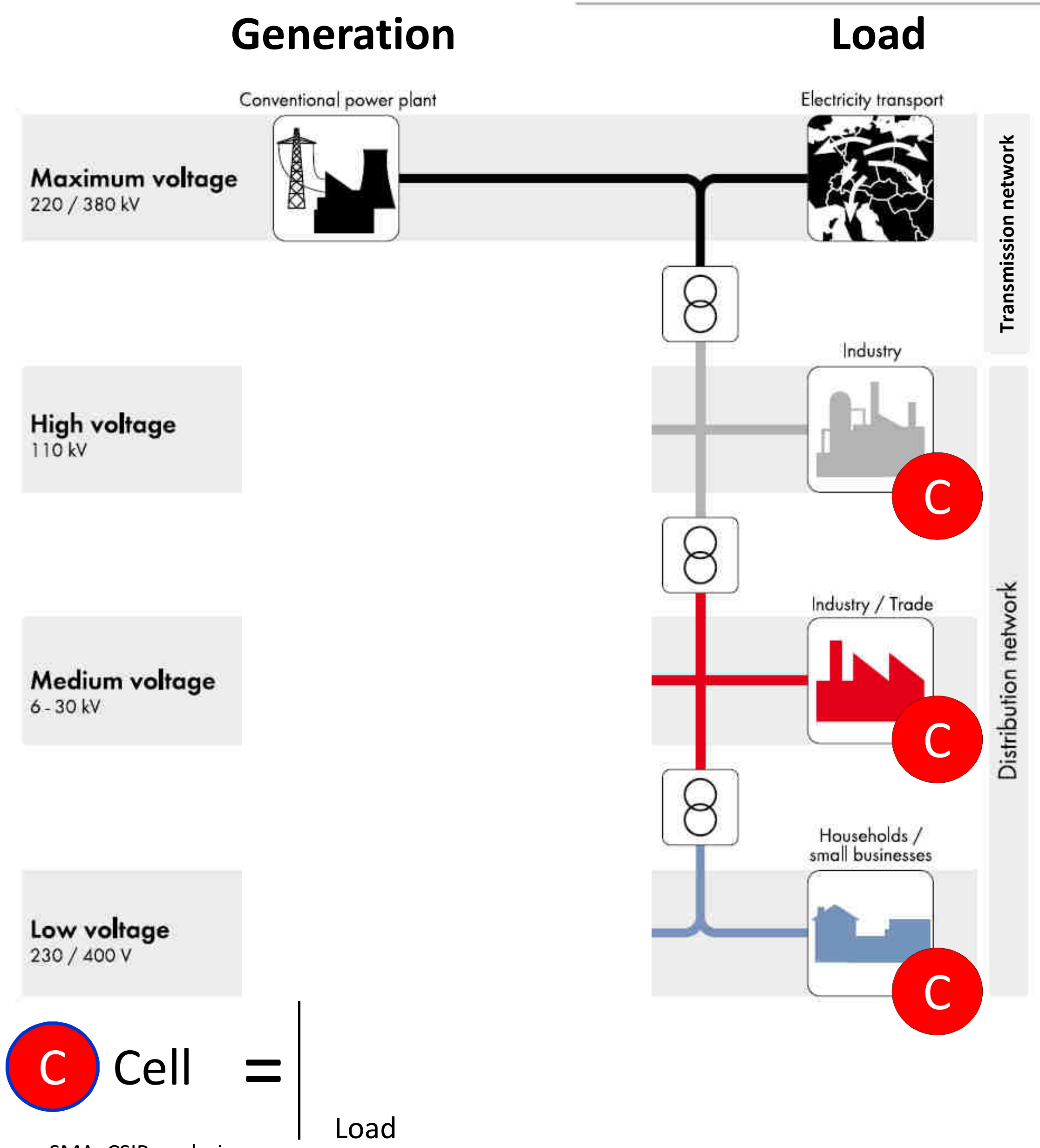
Today: production and balancing of supply/demand happens centrally

Today's system architecture



Balancing of supply/demand on central system level

One-directional power flow

On end-consumer level mostly no generation, no storage/balancing capabilities, no manageable load

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Sources: SMA; CSIR analysis

Where a "cell" today is simply a consumer (load), in future it will consist of generation, storage and manageable loads

A cell can be:

- A residential complex
- A commercial complex
- Individual buildings on CSIR's campus
- A whole village
- An industrial customer
- Etc.

C Cell = Generation / Storage / Load

Generation options can be:

- PV
- Wind
- micro CHP (mCHP), fuel cells
- Biogas

Storage options can be:

- Batteries
- Thermal storage for space heating
- Thermal storage for industrial process heat
- Power-to-gas / power-to-H2

Load options can be:

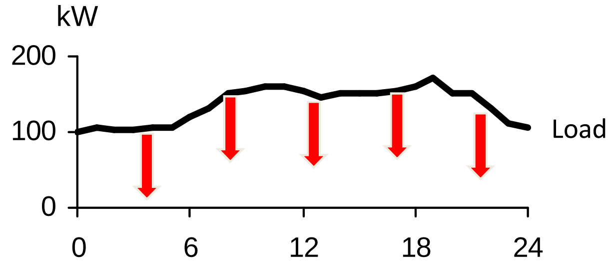
- Non-interruptable / non-manageable loads
- Manageable loads (e.g. fridges, space cooling, space heating, pool pumps, water heating, etc.)
- Fuel switch (e.g. electricity to gas)

Sources: CSIR analysis

Optimisation of generation, storage and load takes place on cell level to achieve lowest costs of energy supply

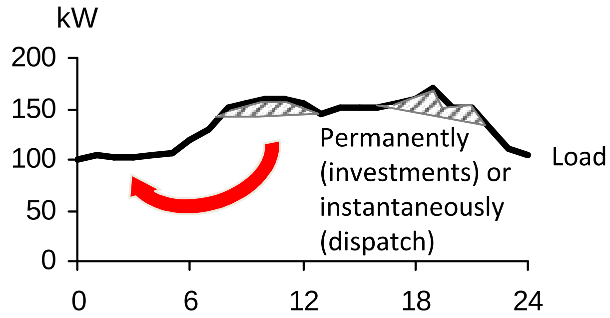
C Cell = Generation | Storage | Load

Energy Efficiency
- Reduction of total energy demand
- Can also influence shape of load curve



Structure of Load (investments)
- Investment decision with respect to optimal mix of loads
- Informs the shape of the load curve

Load Management (dispatch)
- Also known as demand-side management
- Shifting of loads instantaneously
- Utilisation of storage and exports

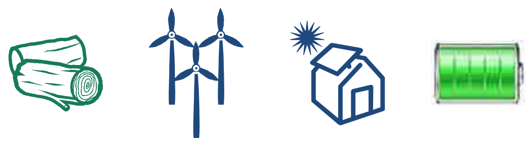


Structure of Generation (investments)
- Investment decisions with respect to optimal mix of supply sources
- Optimisation of design of individual power generators

Generation Management (dispatch)
- Which supply sources to use first, second, etc.?
- Utilisation of storage and imports

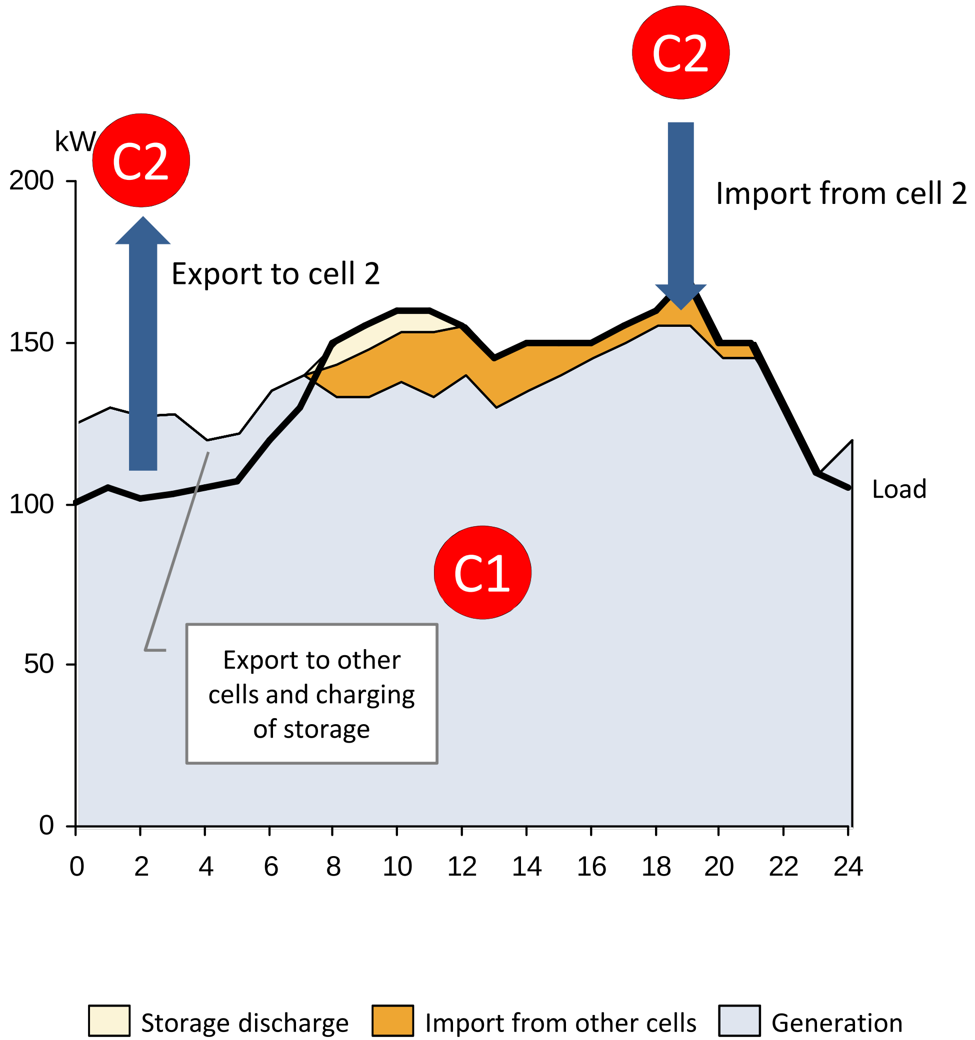
Invest:
What supply sources to build?

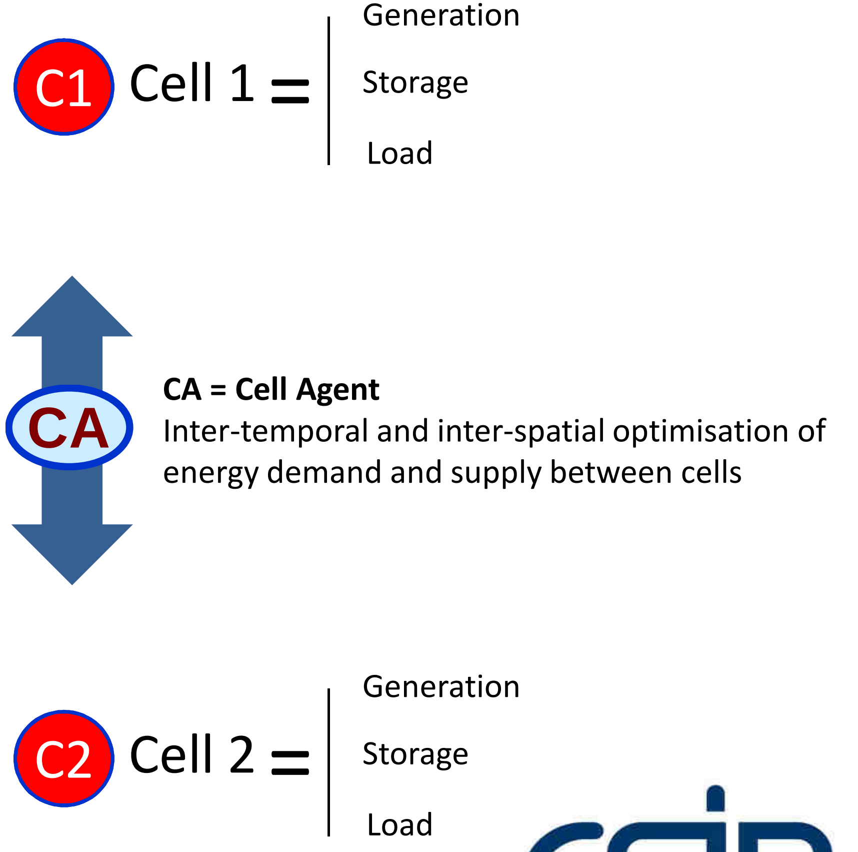
Dispatch:
How to utilise them once built?



Sources: CSIR analysis

Supply/demand that cannot be balanced cost efficiently on cell level leads to cell interactions, managed by cell agents

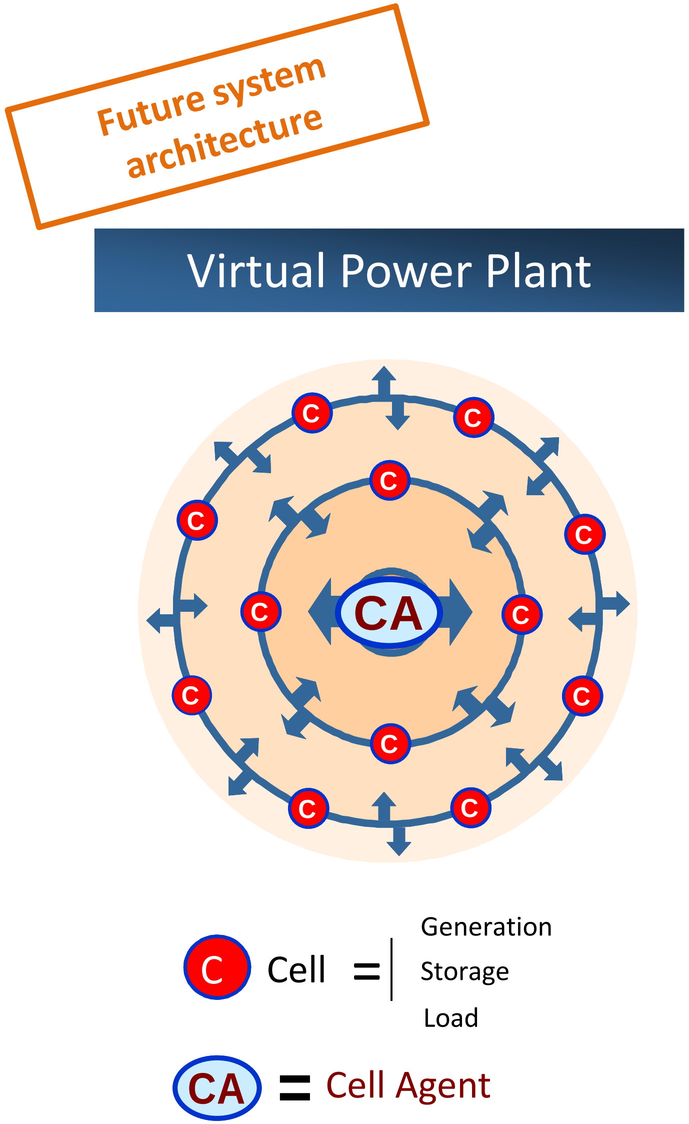


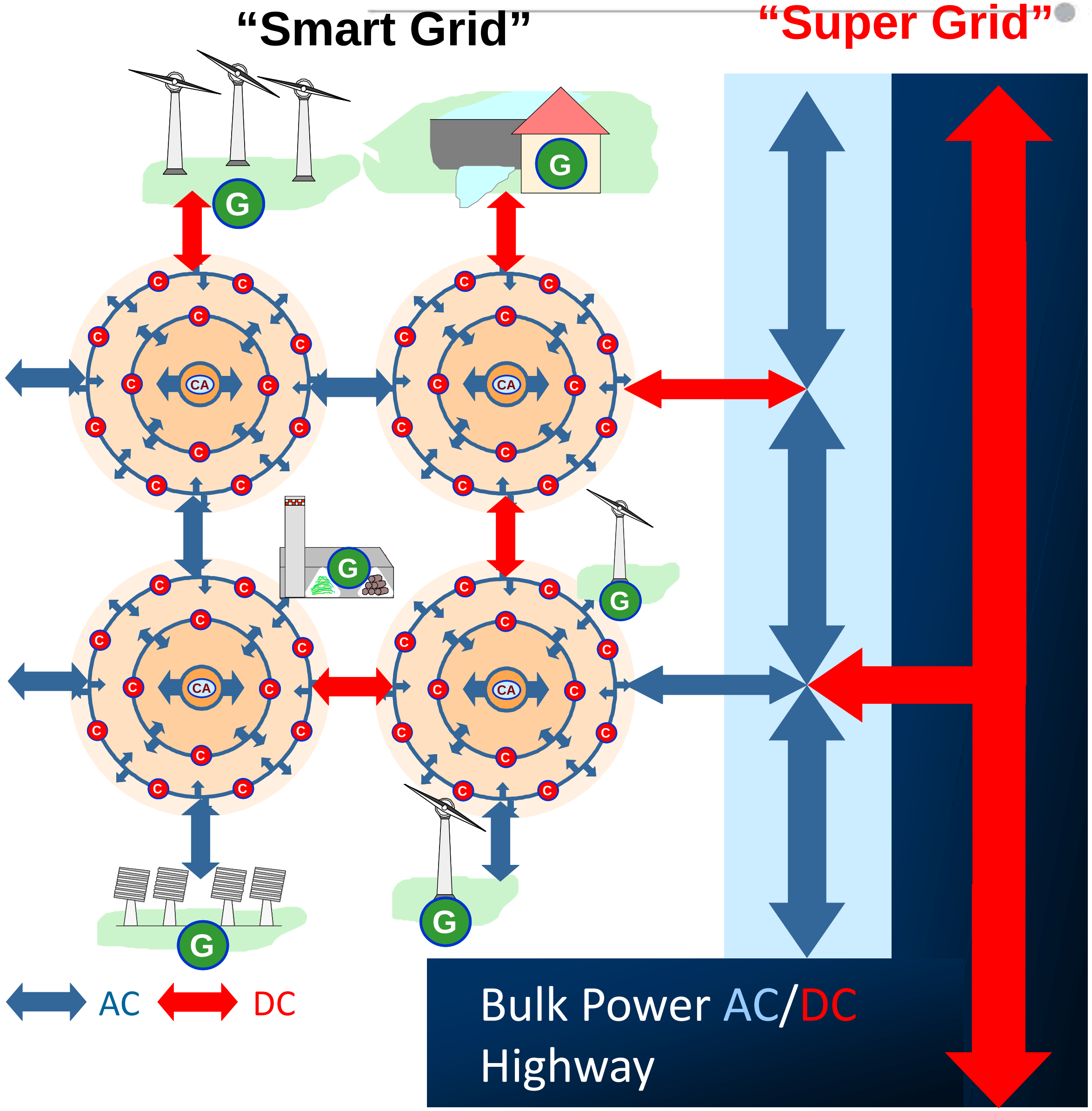


Sources: CSIR analysis

I

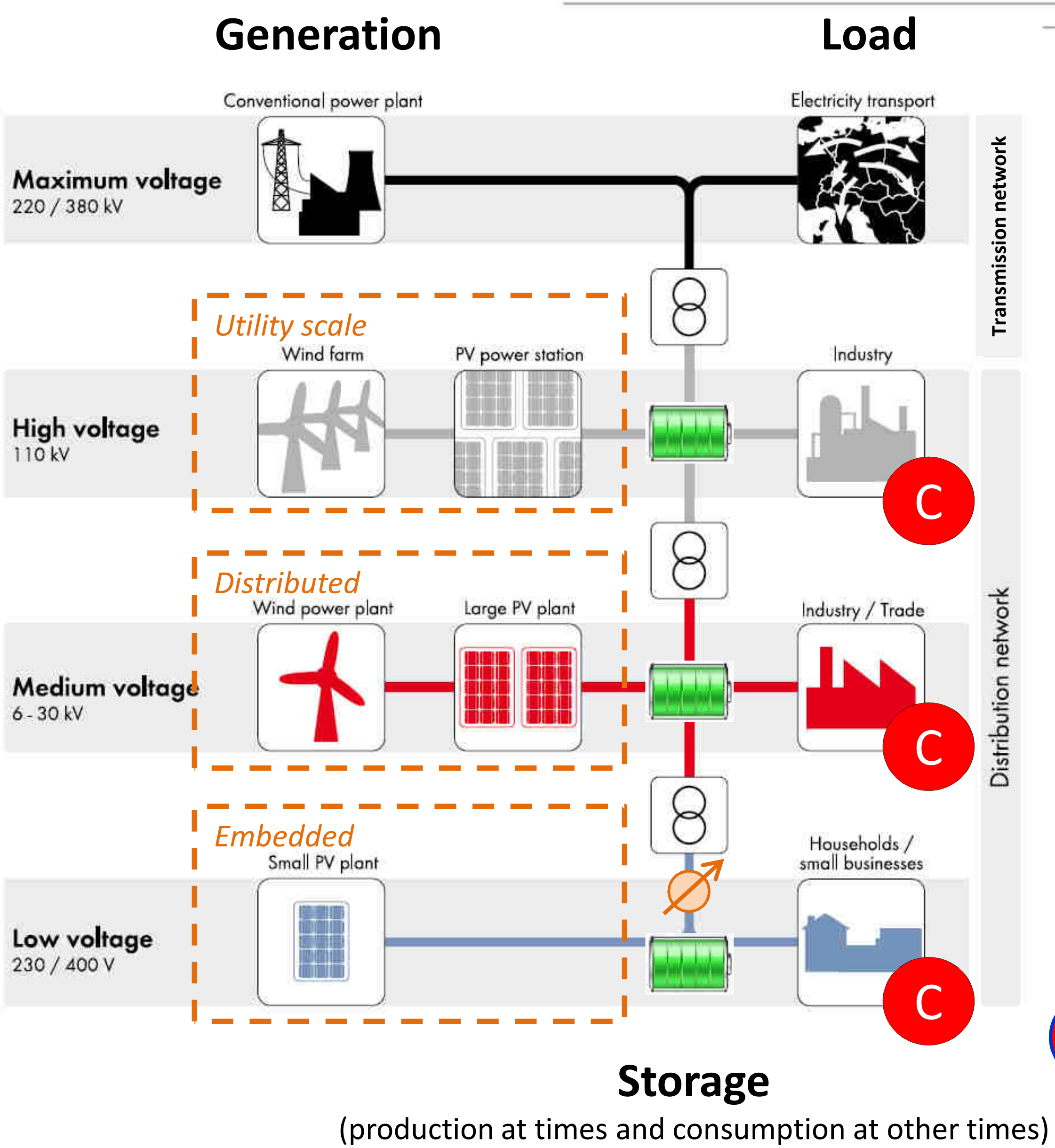
Future power-system architecture: multiple cells of generation, storage and load are balanced by cell agents and form a Virtual Power Plant





Sources: Siemens

Future: Production and consumption occurs on all levels, power flows are bi-directional, an ICT layer is required on top of the energy layer



Future system architecture

Balancing of supply/demand managed on central system level, executed on all voltage levels

Bi-directional power flow

ICT layer on top of energy layer

C Cell = Generation, Storage, Load

Sources: SMA; CSIR analysis

II Thought experiment: Build a new power system from scratch

Annual demand: **11.1 TWh/yr (4-5% of today's South African demand)**

Base load: **1 GW**

Day load: **1.3 GW in summer**
1.5 GW in winter

What is cheaper to supply that profile?

1) Base and mid-merit coal?
2) A blend of wind and solar PV, mixed with gas to fill the gaps?

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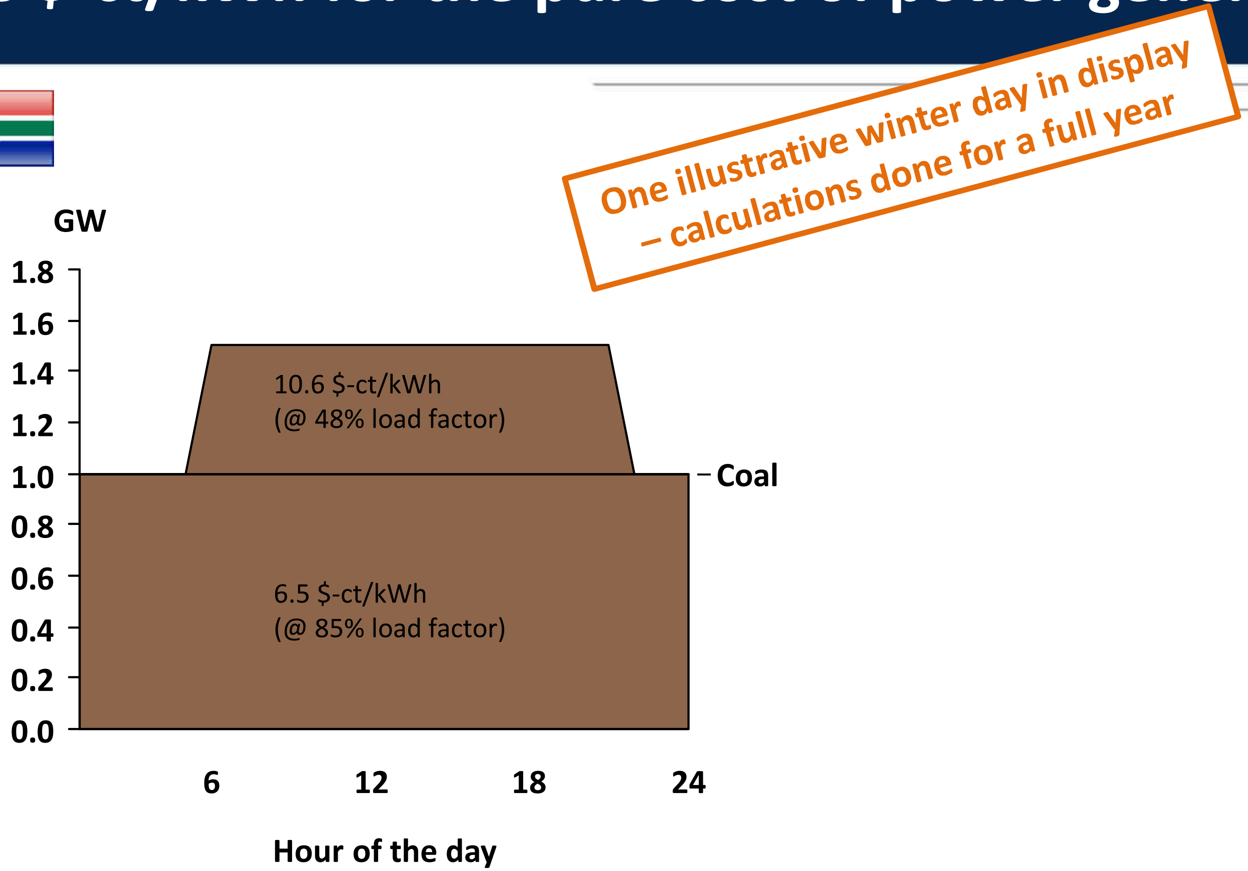
A mix of new baseload-operated coal and new mid-merit coal costs 7.3 $-ct/kWh for the pure cost of power generation



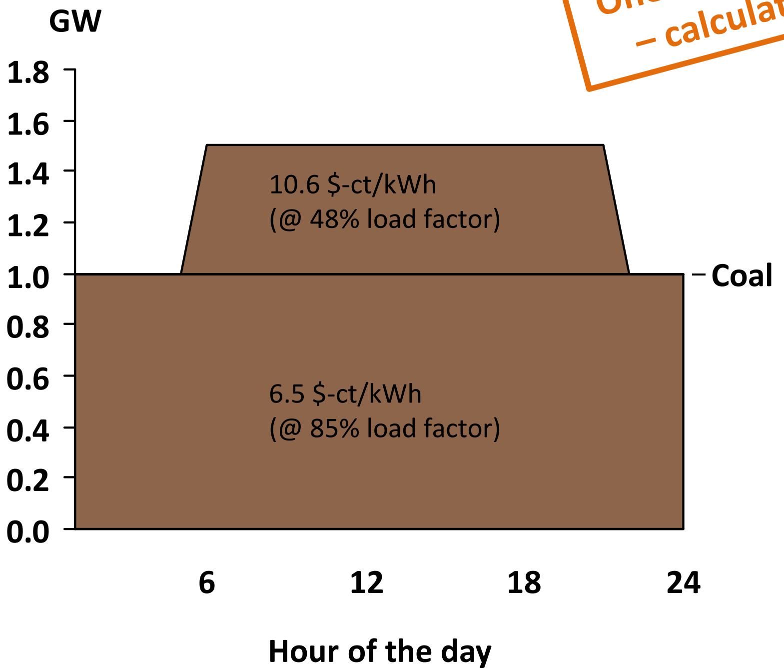
Technology: Coal base / coal mid-merit
Size: 1.18 / 0.56 GW
Energy: 11.1 TWh/yr

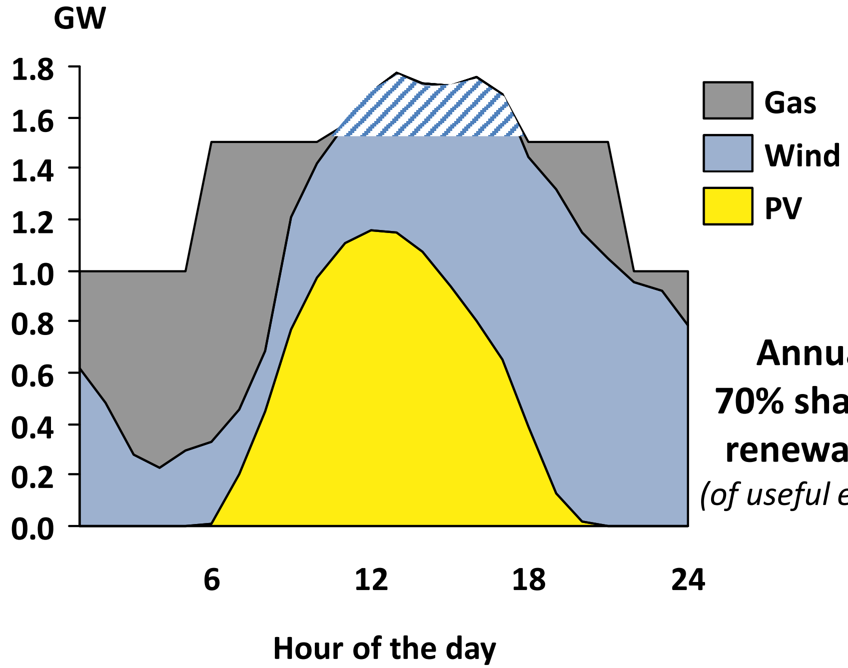
Weighted cost: **7.3 $-ct/kWh**

CO2: ~0.95 kg/kWh

II A fully dispatchable mix of PV, wind and flexible gas can supply the demand similarly in the same reliable manner as the coal mix

One illustrative winter day in display – calculations done for a full year





Annual:
70% share of renewables
(of useful energy)

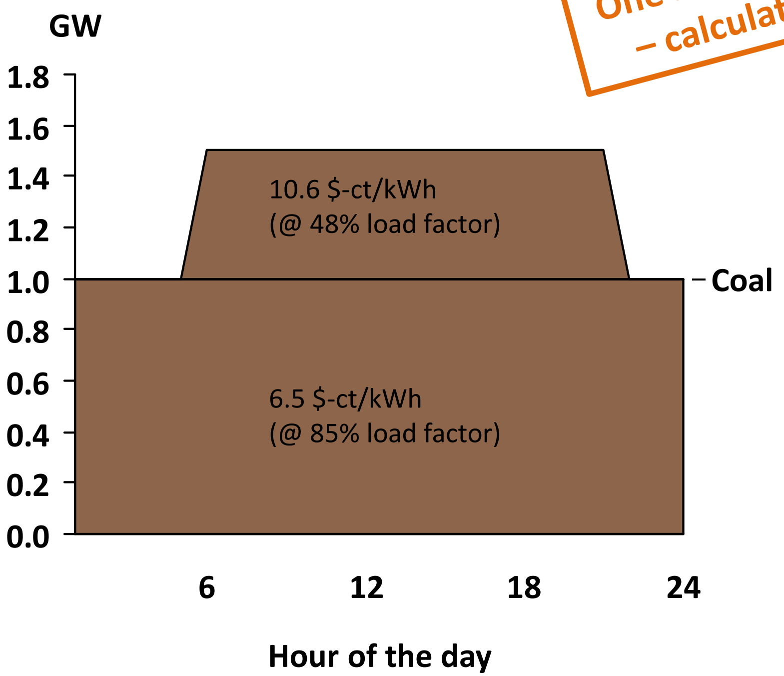
Technology: Coal base / coal mid-merit
Size: 1.18 / 0.56 GW
Energy: 11.1 TWh/yr

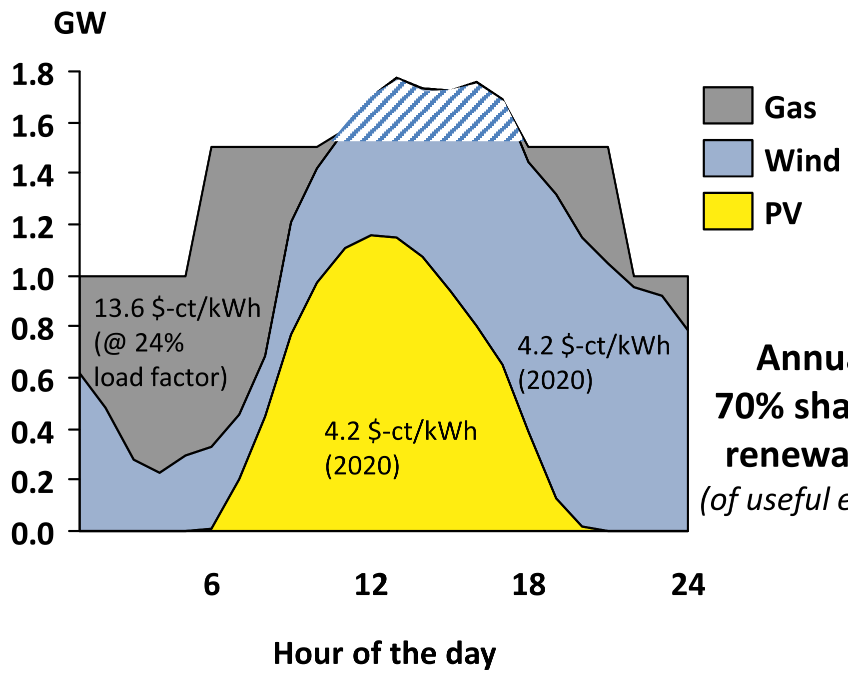
Weighted cost: **7.3 $-ct/kWh**

CO2: ~0.95 kg/kWh

II By 2020, a mix of PV, wind and flexible gas (LNG-based) costs the same as new coal, even without any value given to excess wind/PV energy

One illustrative winter day in display – calculations done for a full year





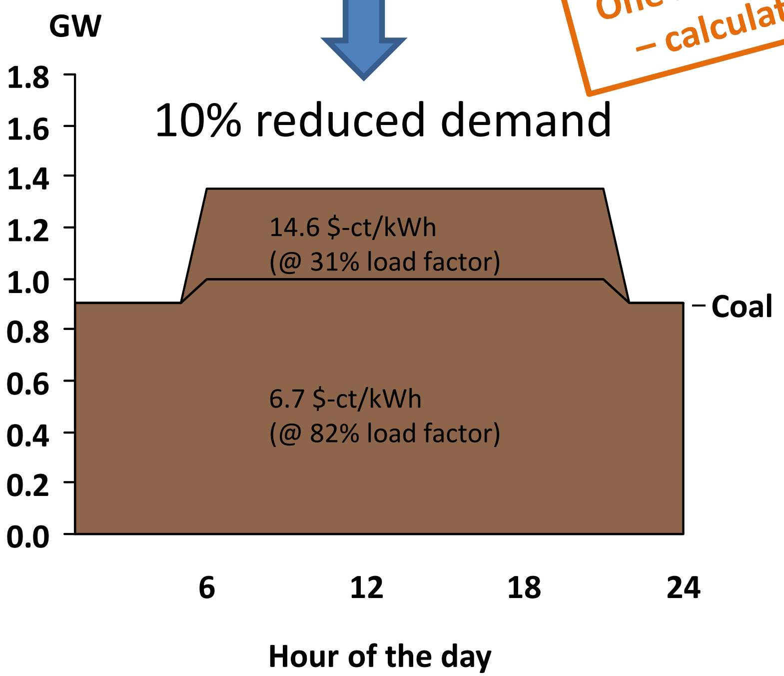
Annual: 70% share of renewables *(of useful energy)*

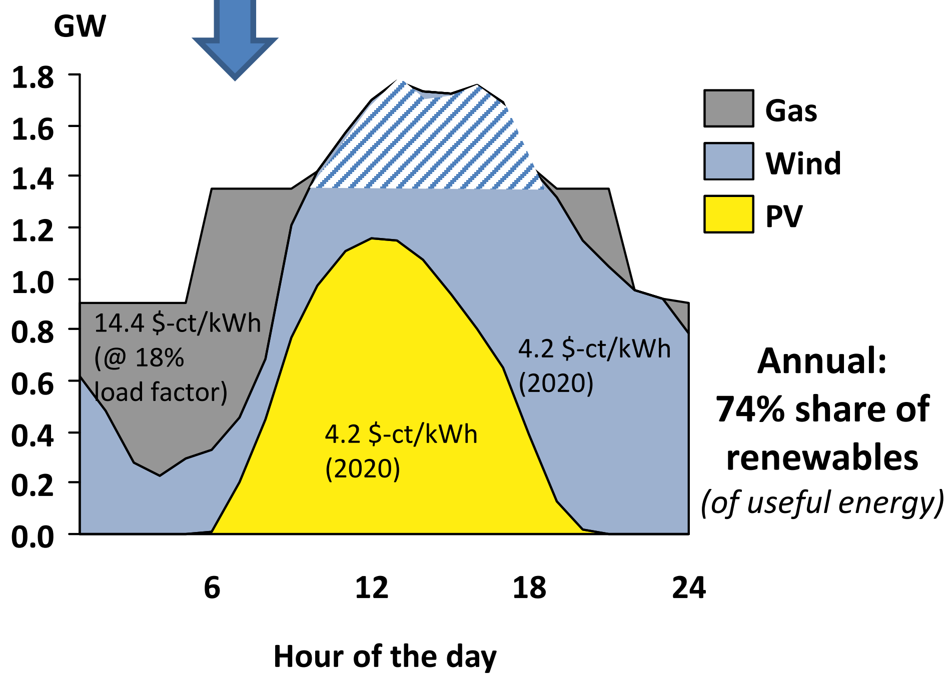
Technology:	Coal base / coal mid-merit
Size:	1.18 / 0.56 GW
Energy:	11.1 TWh/yr
Weighted cost:	**7.3 $-ct/kWh**
CO2:	~0.95 kg/kWh

Technology:	PV / wind / gas
Size:	1.5 / 2.0 / 1.61 GW
Energy (useful):	11.1 TWh/yr
Energy (total):	3.6 / 5.3 / 3.2 TWh/yr = 12.1 TWh/yr
Weighted cost:	**7.3 $-ct/kWh** *(per useful energy, i.e. no value given to excess)*
CO2:	~0.18 kg/kWh (per useful energy)

II In addition, the cost of a PV / wind / gas power plant scale more with reduced demand and thus unit cost per kWh stay more or less constant

One illustrative winter day in display – calculations done for a full year



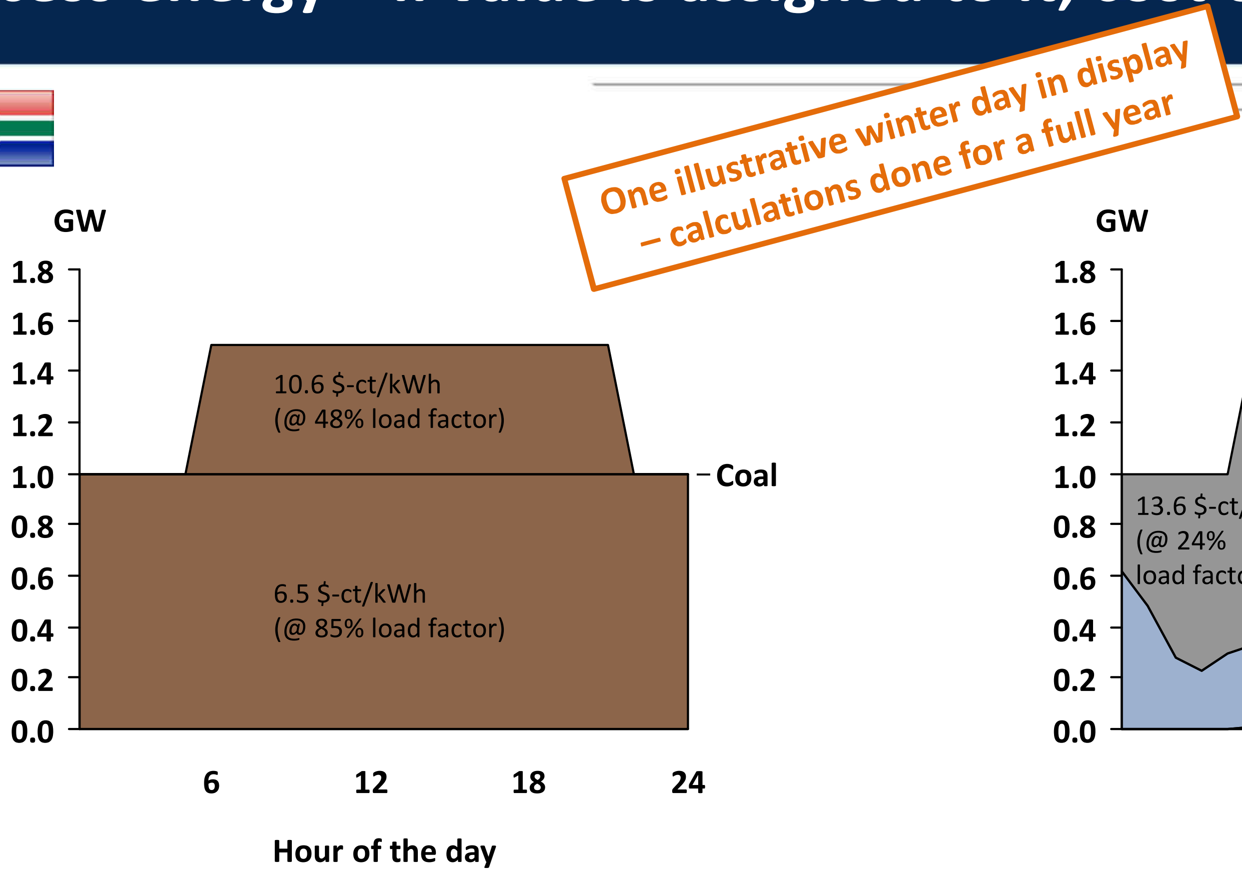


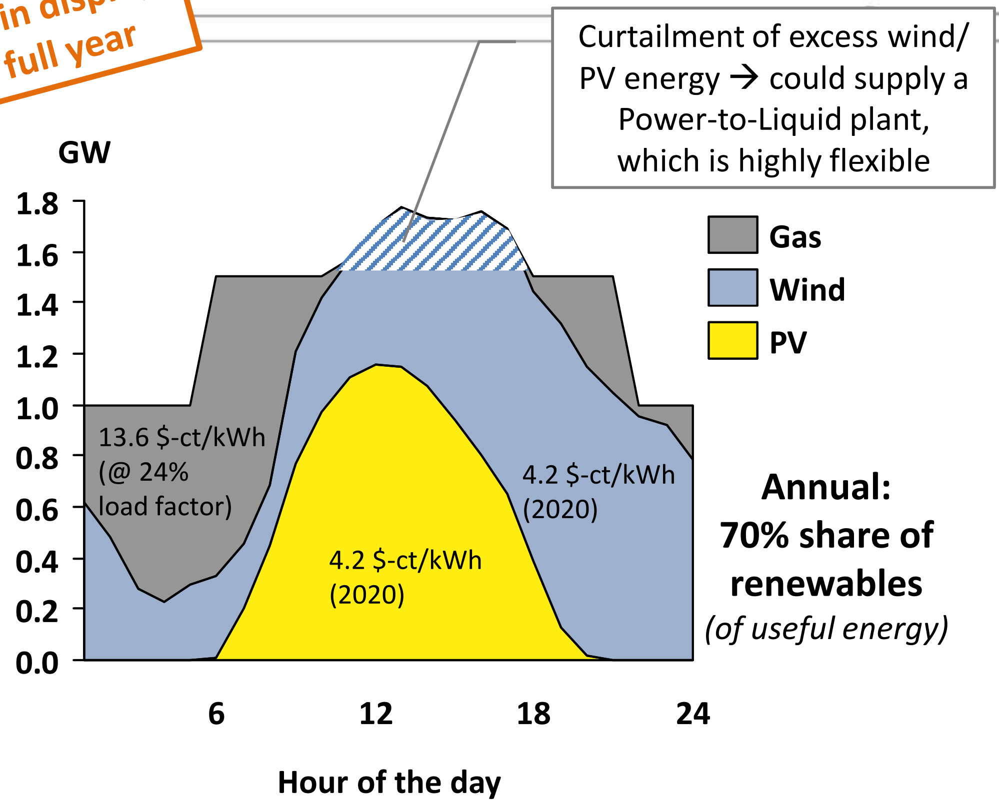
Annual:
74% share of renewables
(of useful energy)

Technology:	Coal base / coal mid-merit
Size:	1.18 / 0.56 GW
Energy:	10.0 TWh/yr
Weighted cost:	**7.8 $-ct/kWh** **(plus 7%)**
CO_2:	~0.95 kg/kWh

Technology:	PV / wind / gas
Size:	1.5 / 2.0 / 1.61 GW
Energy (useful):	10.0 TWh/yr
Energy (total):	3.6 / 5.3 / 2.5 TWh/yr = 11.4 TWh/yr
Weighted cost:	**7.3 $-ct/kWh** **(constant)** *(per useful energy, i.e. no value given to excess)*
CO_2:	~0.16 kg/kWh (per useful energy)

In reality, flexible, dispatchable loads and/or storage would utilise the excess energy – if value is assigned to it, cost of useful energy go down





Annual:
70% share of renewables
(of useful energy)

Technology:	Coal base / coal mid-merit
Size:	1.18 / 0.56 GW
Energy:	11.1 TWh/yr

Weighted cost: **7.3 $-ct/kWh**

Technology:	PV / wind / gas
Size:	1.5 / 2.0 / 1.61 GW
Energy (useful):	11.1 TWh/yr
Energy (total):	3.6 / 5.3 / 3.2 TWh/yr = 12.1 TWh/yr

Weighted cost: **6.8 ~~7.3~~ $-ct/kWh**

(7.3 $-ct/kWh goes down to 6.8 $-ct/kWh, even if only 4.2 $-ct/kWh value is given to excess energy)

The Opportunity for Africa

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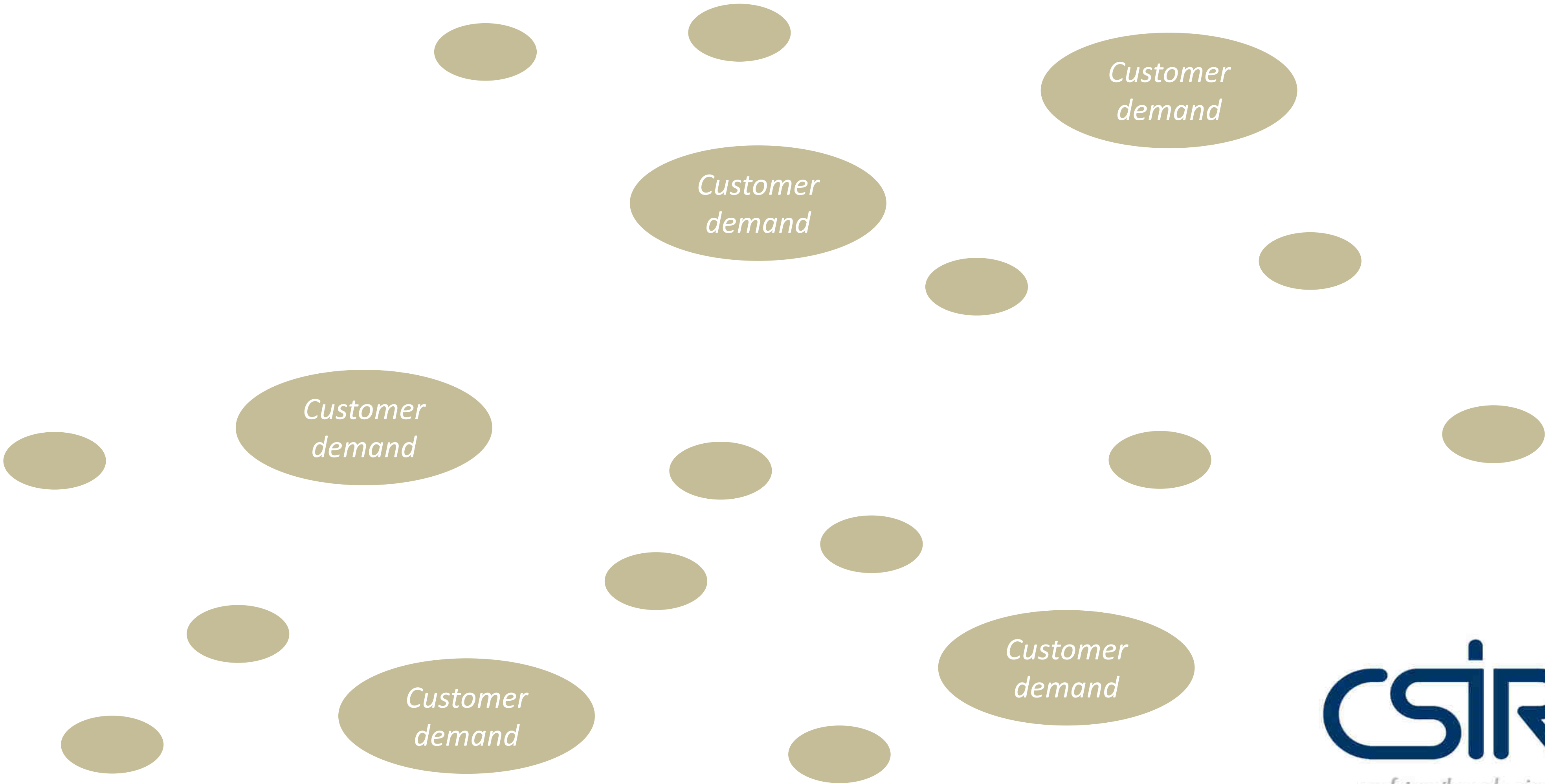
Customer demand is always scattered across more or less wide areas



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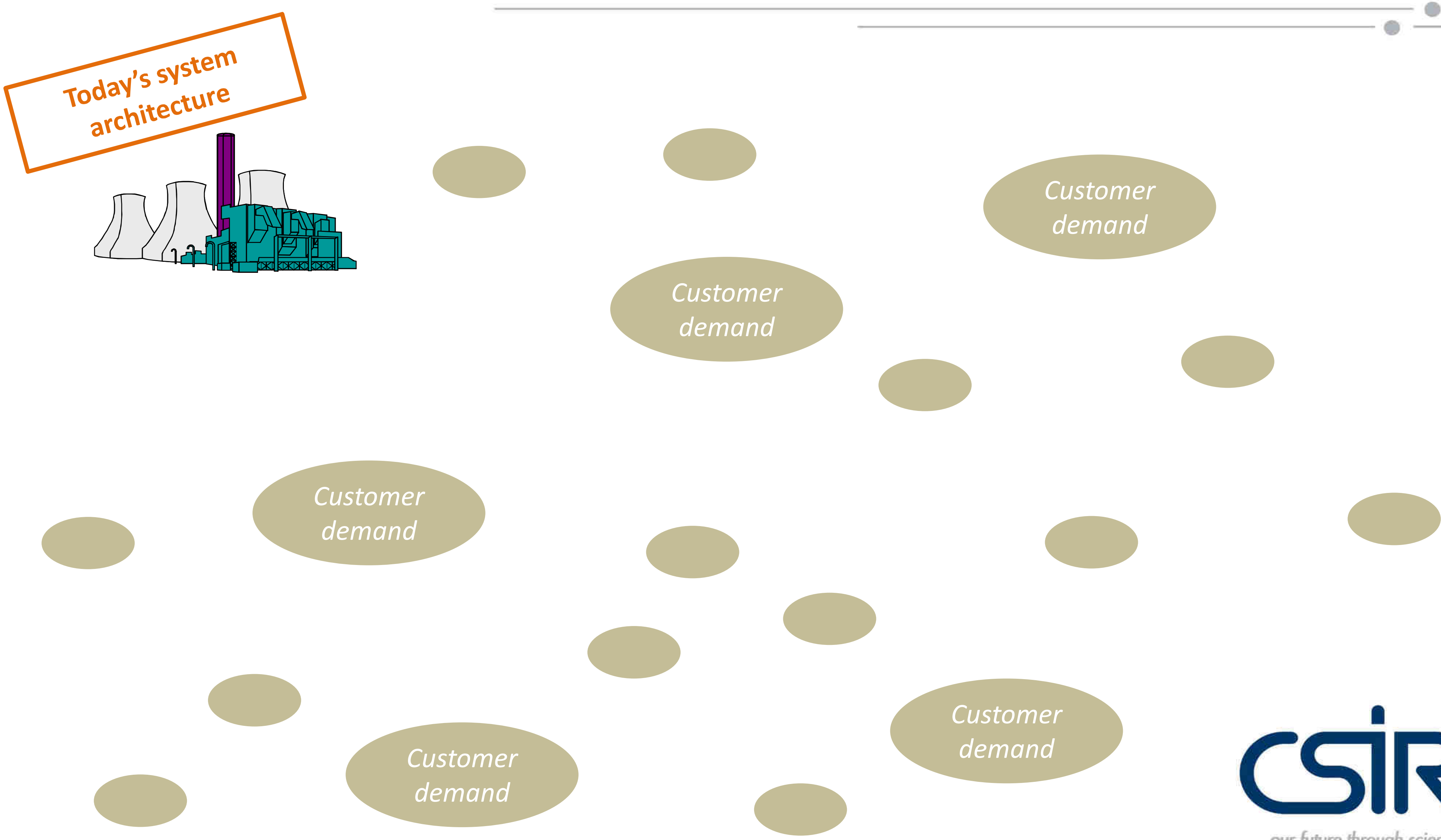
Historically, this demand was supplied by large, central power generators with a high-voltage backbone and an ever finer-getting grid



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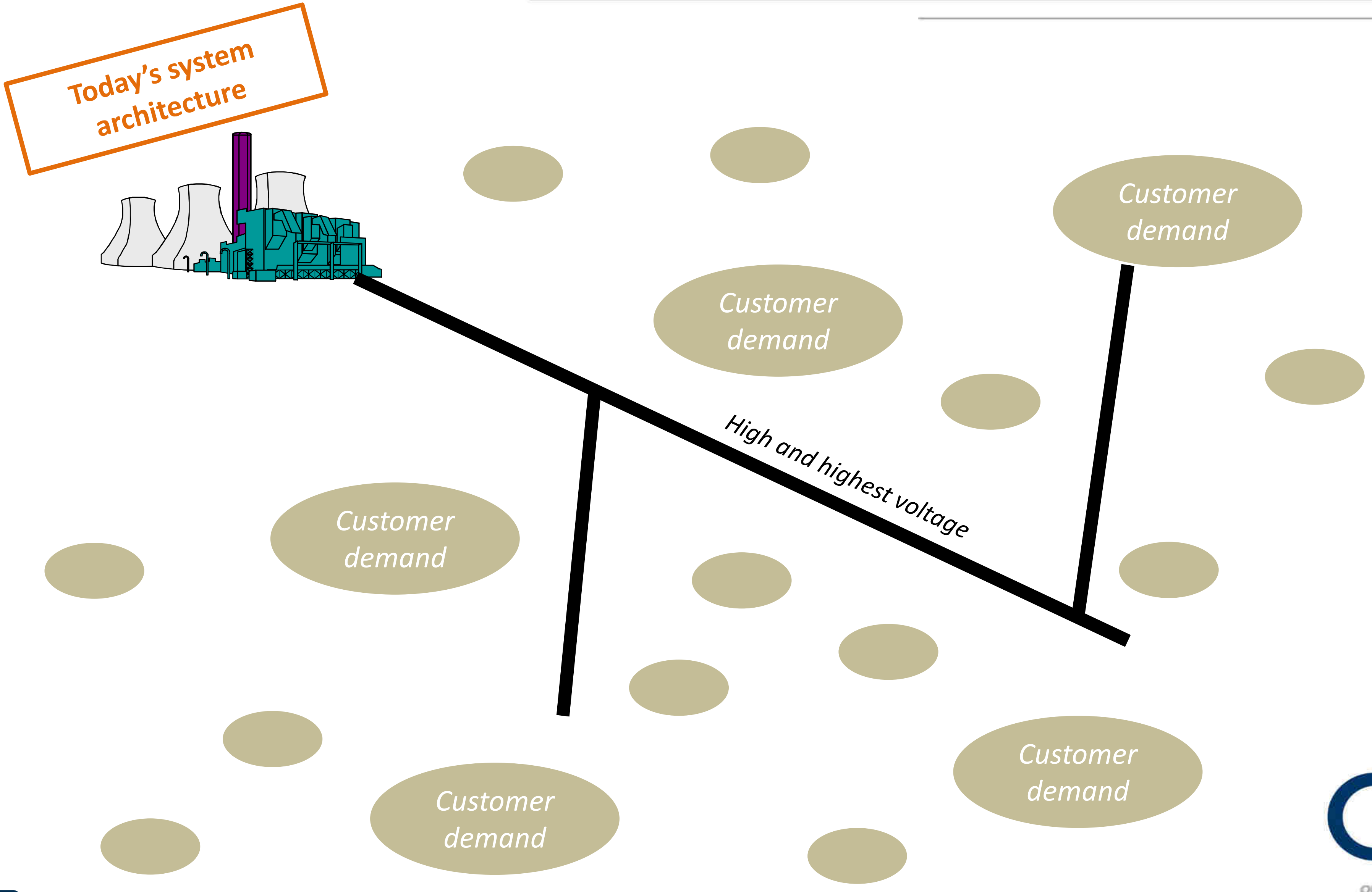

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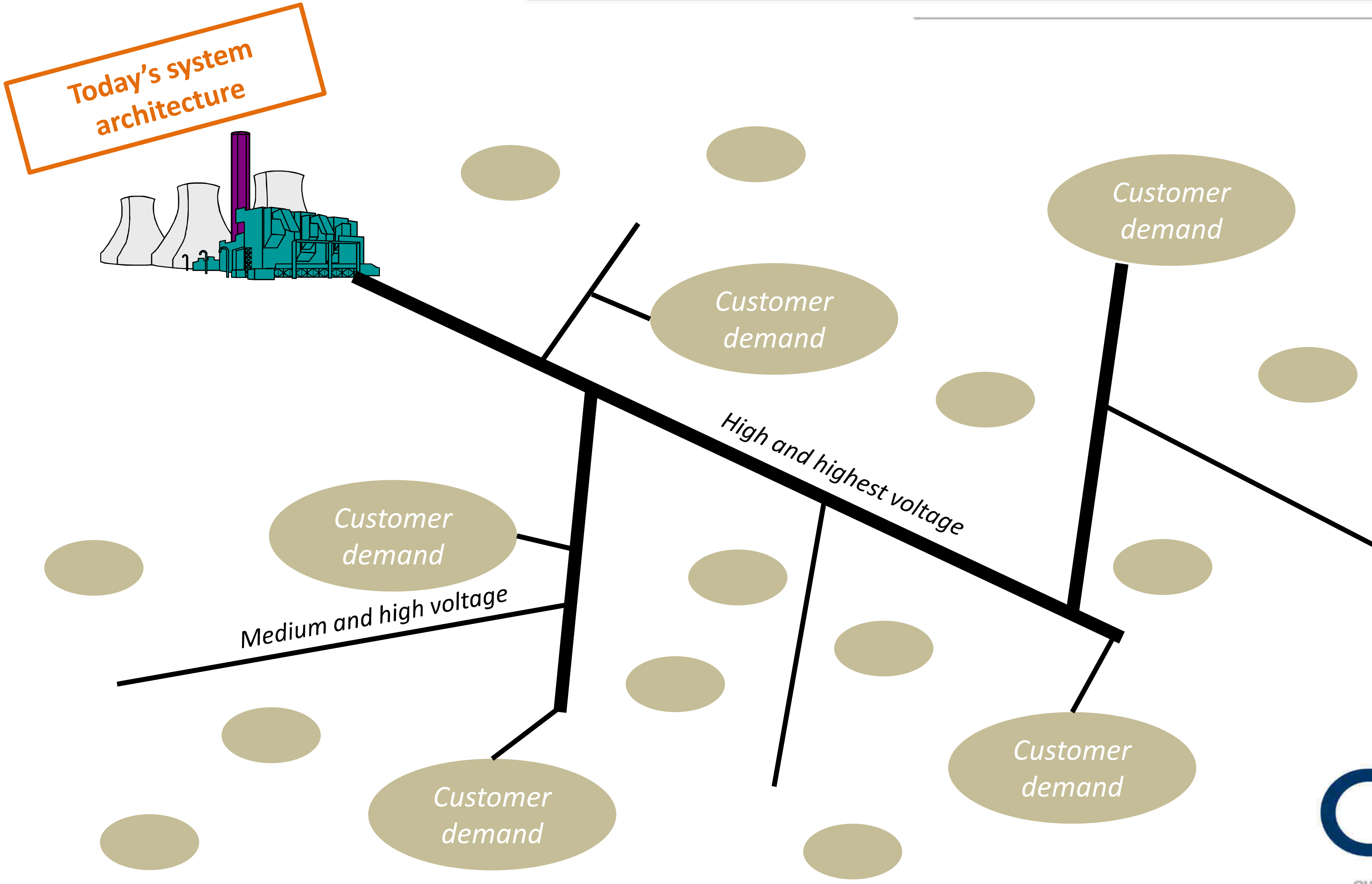

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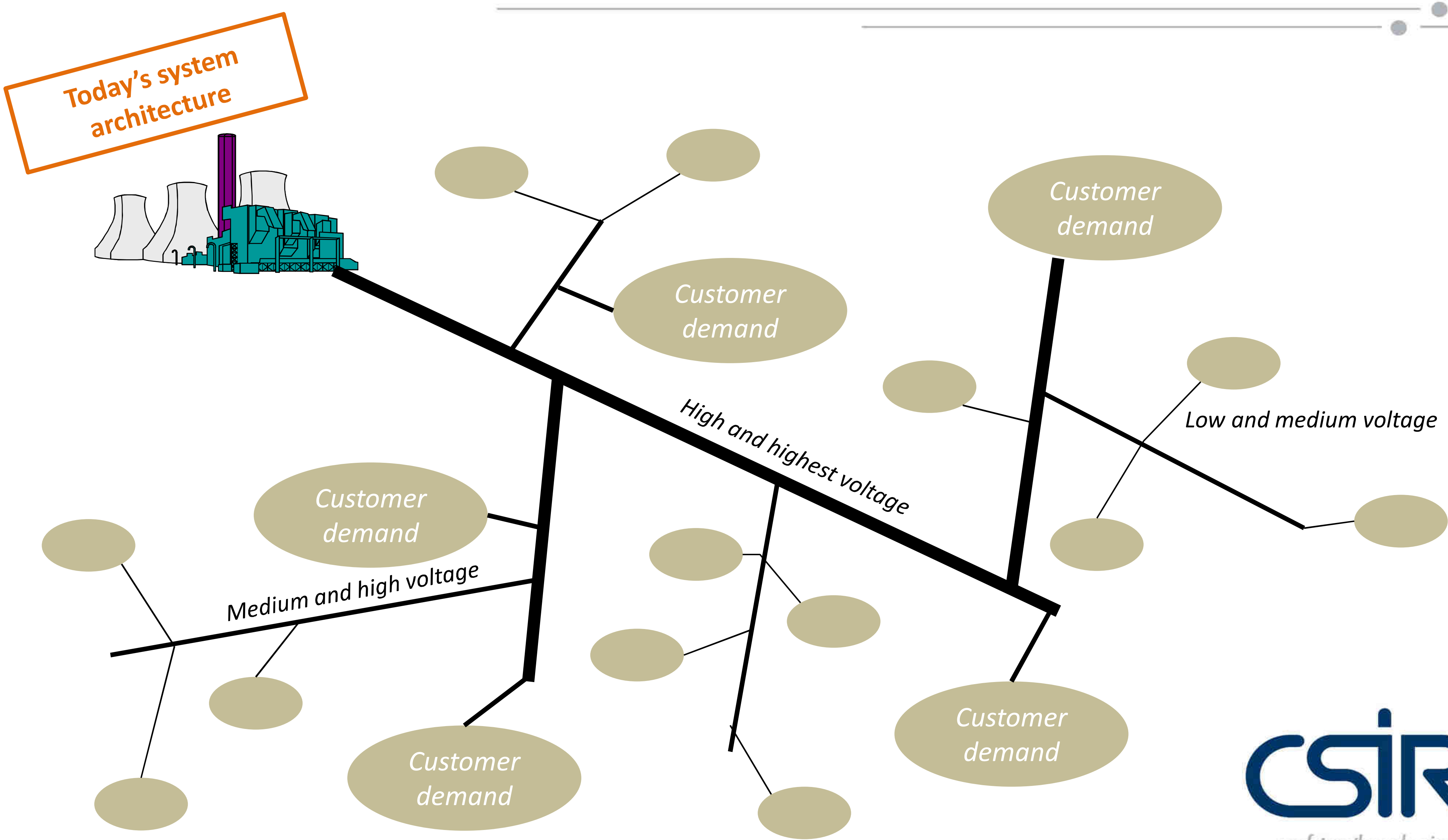
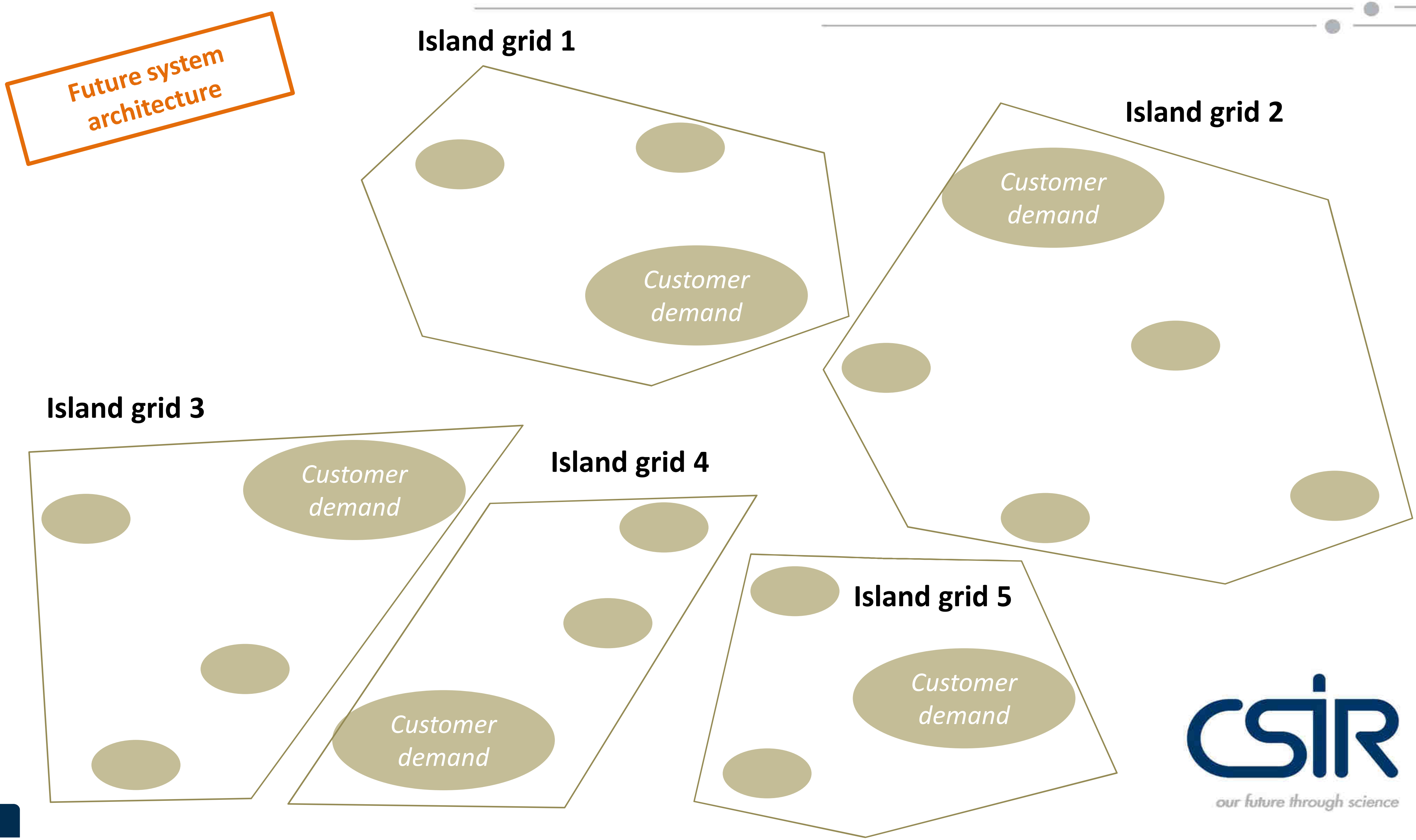


In future, because of cost-competitiveness of distributed renewables, the system architecture can be based on interconnected island grids



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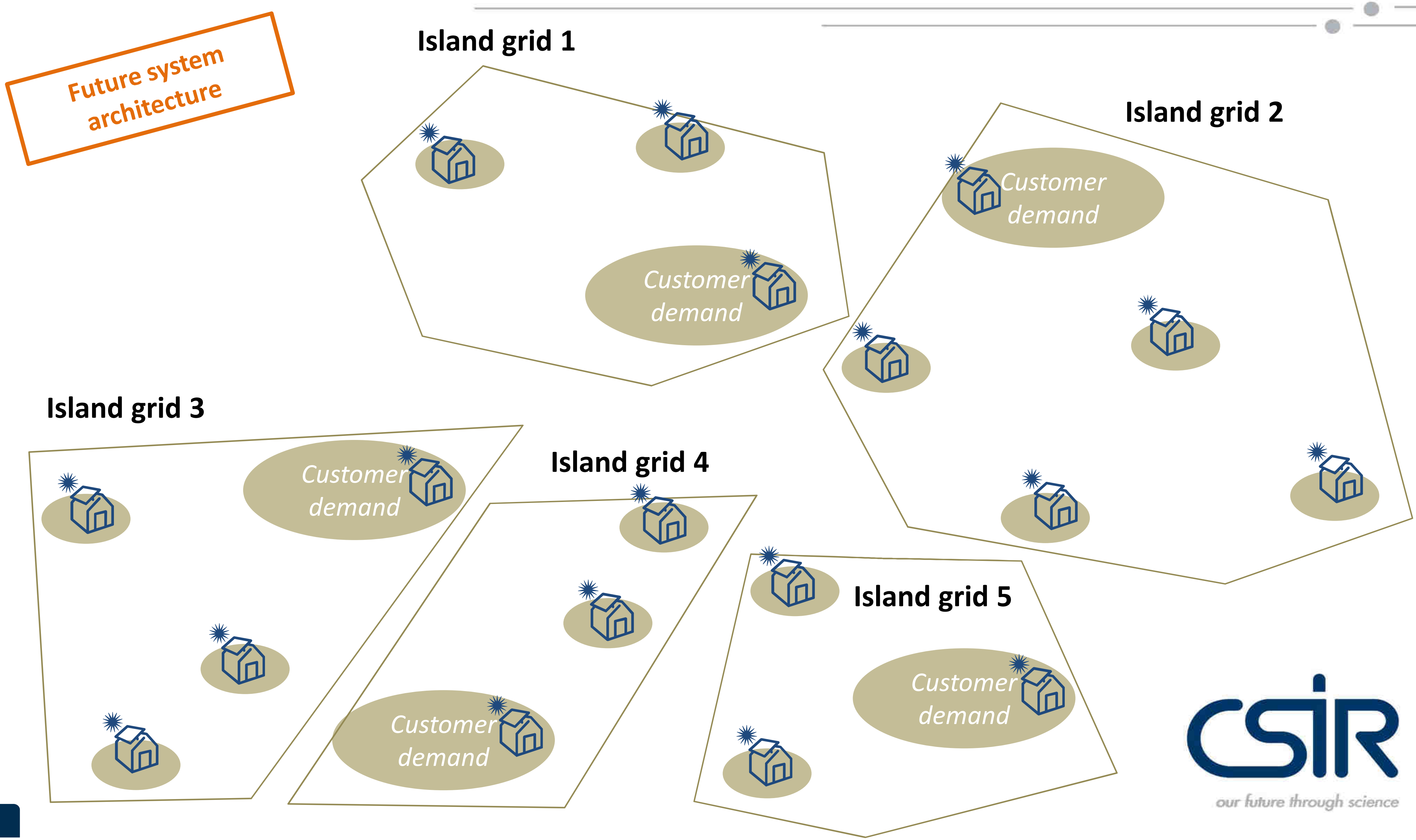
Solar PV (roof & ground-mounted) will be installed literally everywhere



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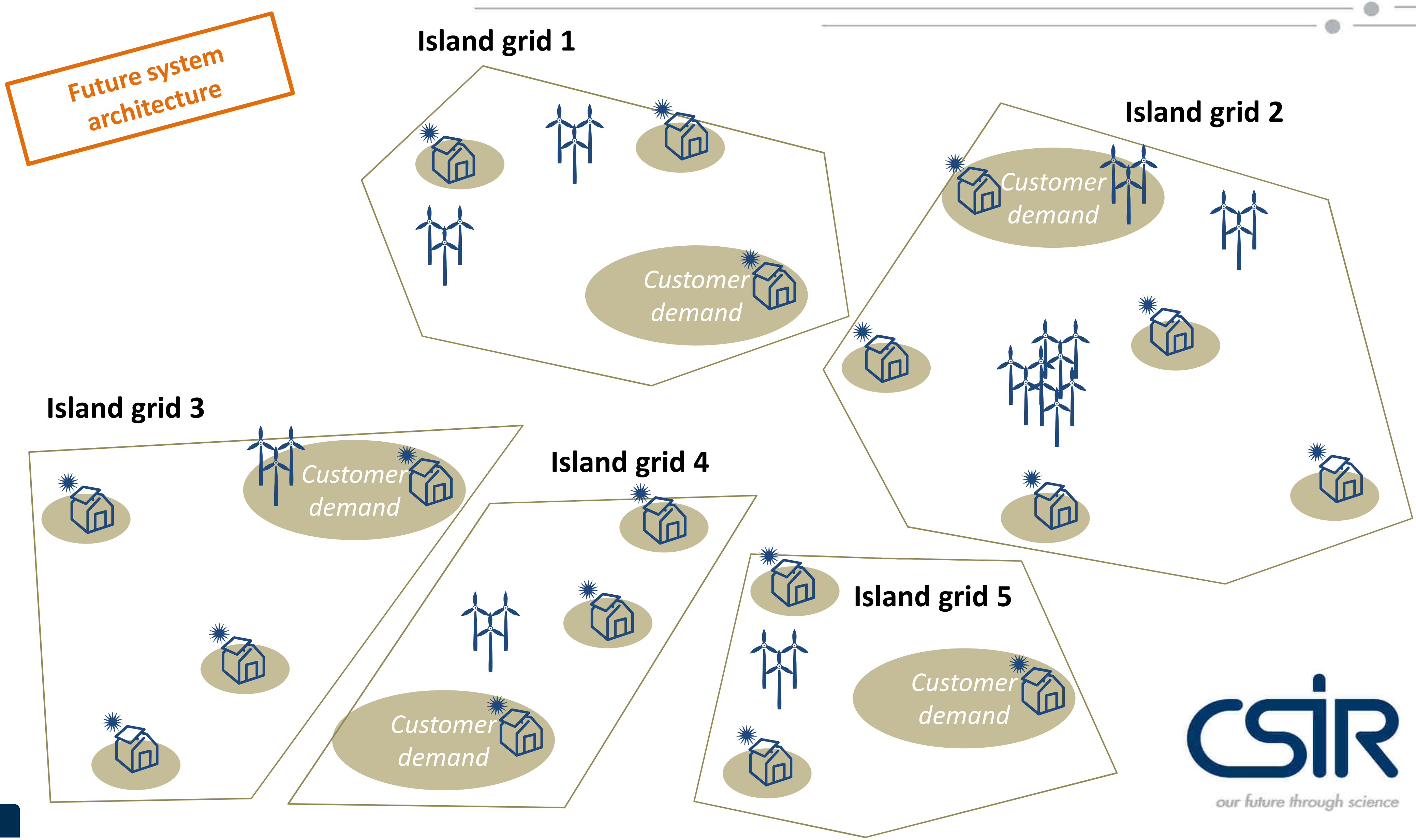
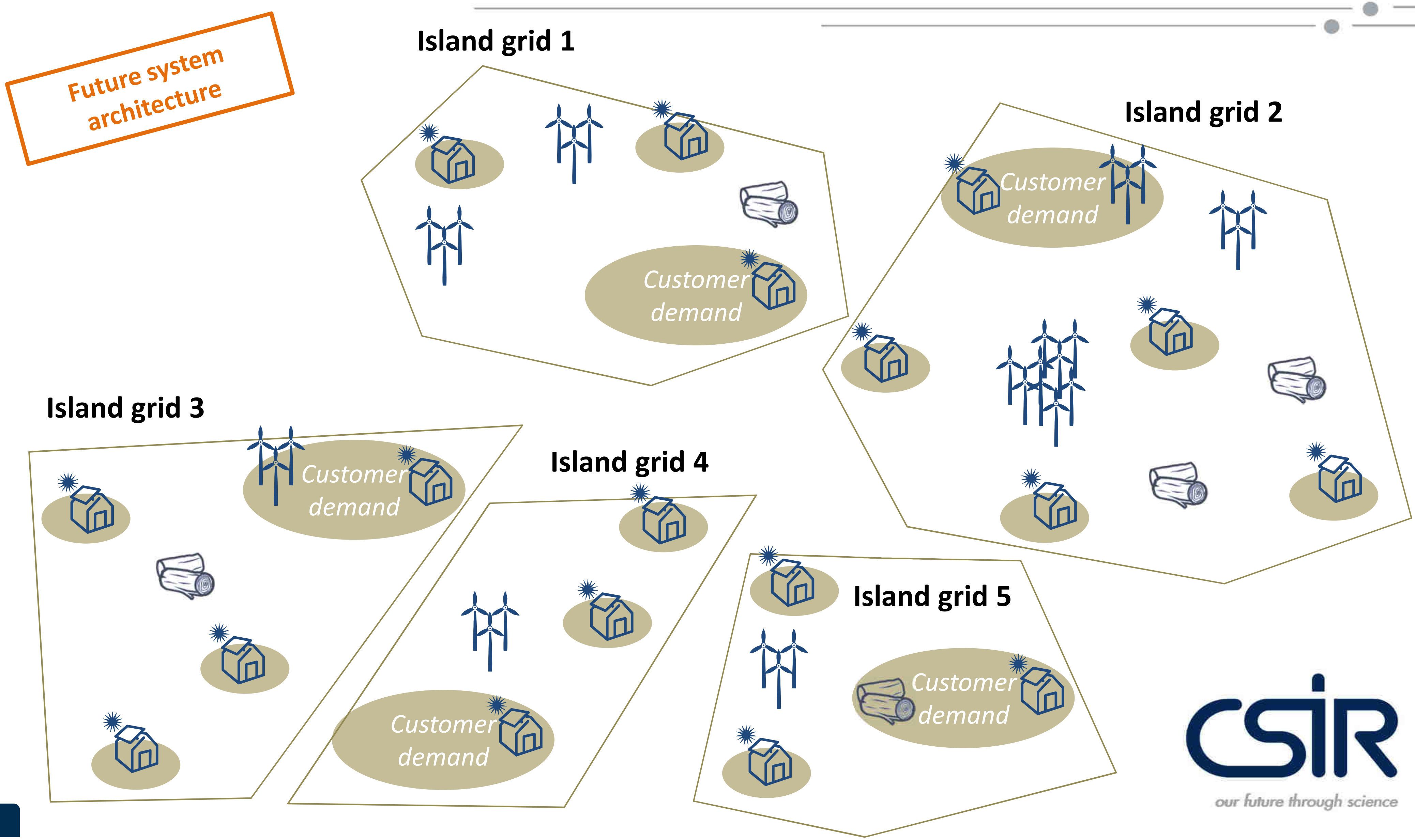
Wind turbines will complement where economically viable



Dispatchable generators (biogas, biomass, diesel, natural gas, hydro, potentially storage, etc.) will complement the local island grid



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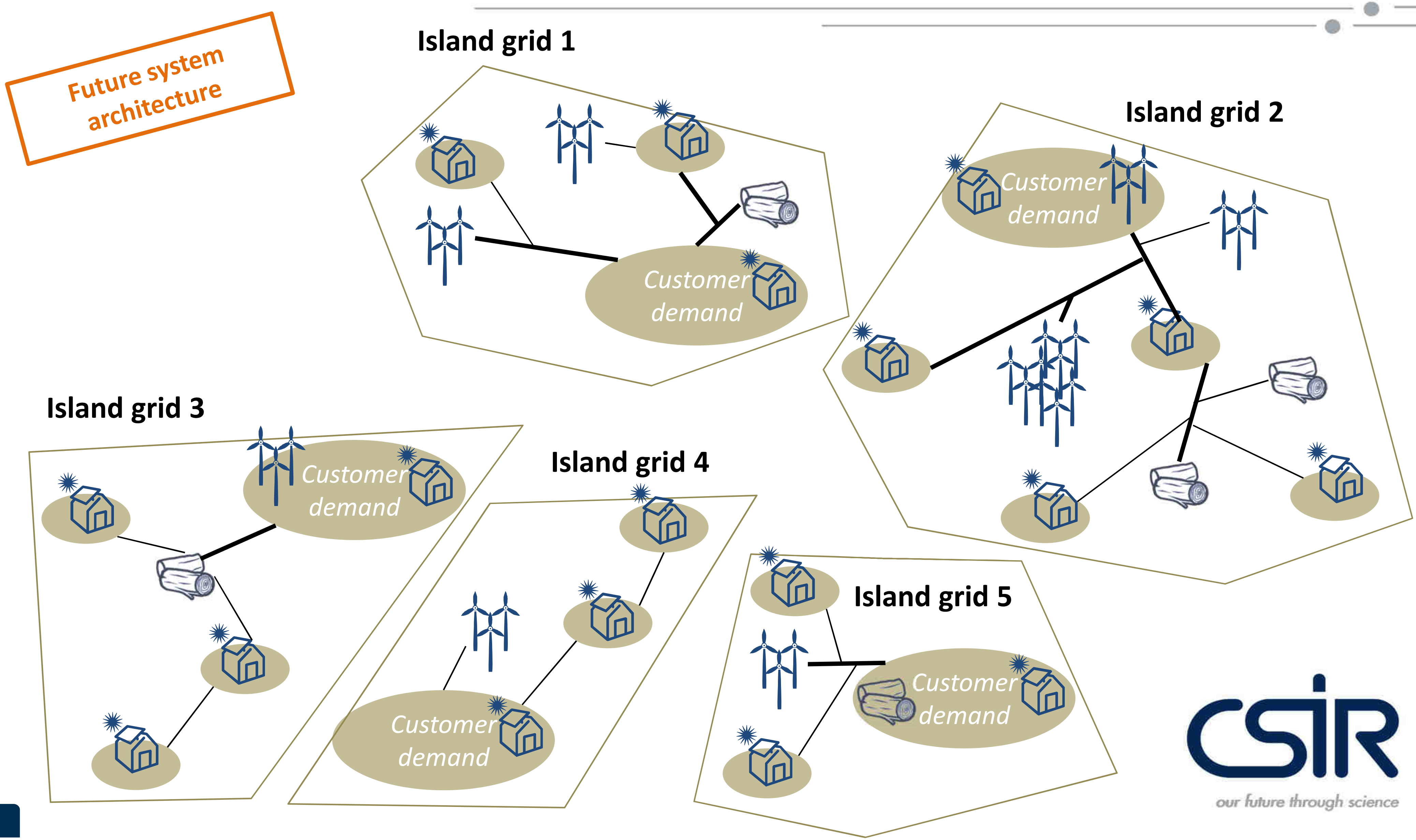
Each island grid can in principle run on its own...



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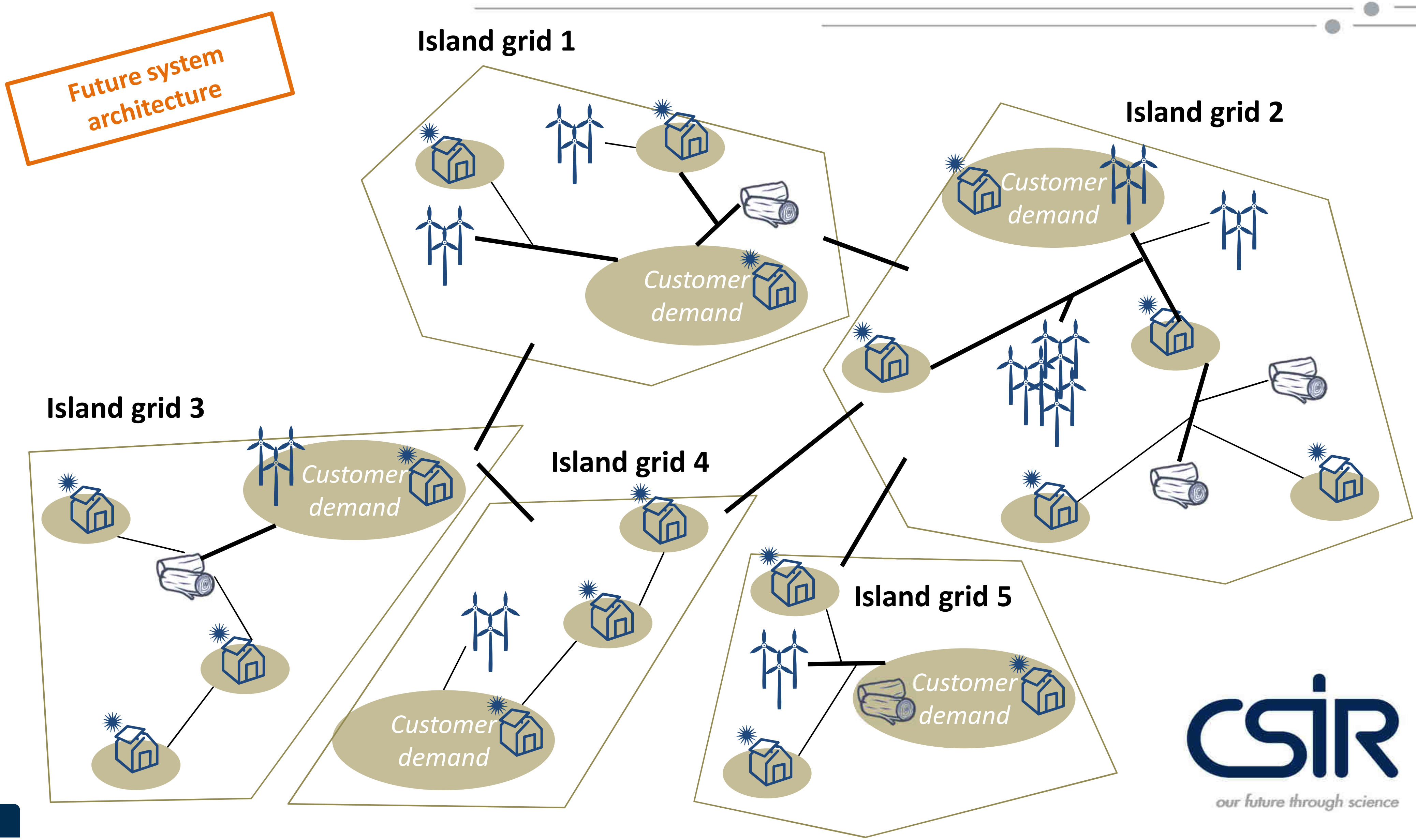
… but higher reliability & lower costs are achieved by interconnecting



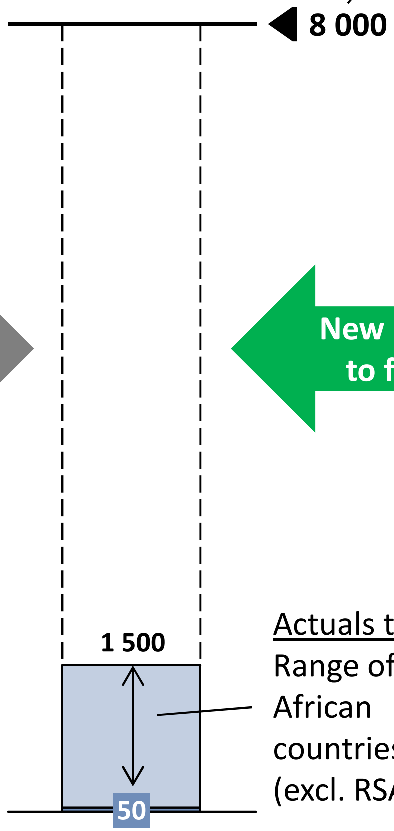
Potential for Africa: In the "old" world, the electricity gap was filled with coal, nuclear, gas – today leapfrogging to renewables is possible

<u>Long-term target</u>:
Typical demand for an economically prospering, yet energy-efficient country

"Old electricity world"

Central, big
- Coal
- Nuclear
- Natural gas

Traditional way to fill the gap

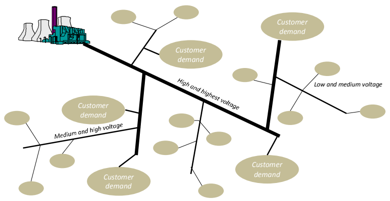


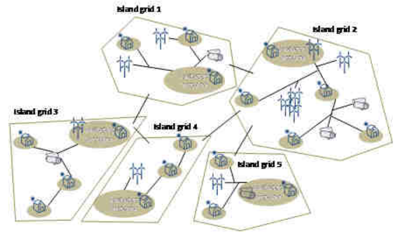
<u>Actuals today</u>
Range of African countries (excl. RSA)

"New electricity world"

Distributed, smaller
- Wind
- PV (some CSP)
- Biomass/-gas
- Natural gas
- Hydro

New alternatives to fill the gap





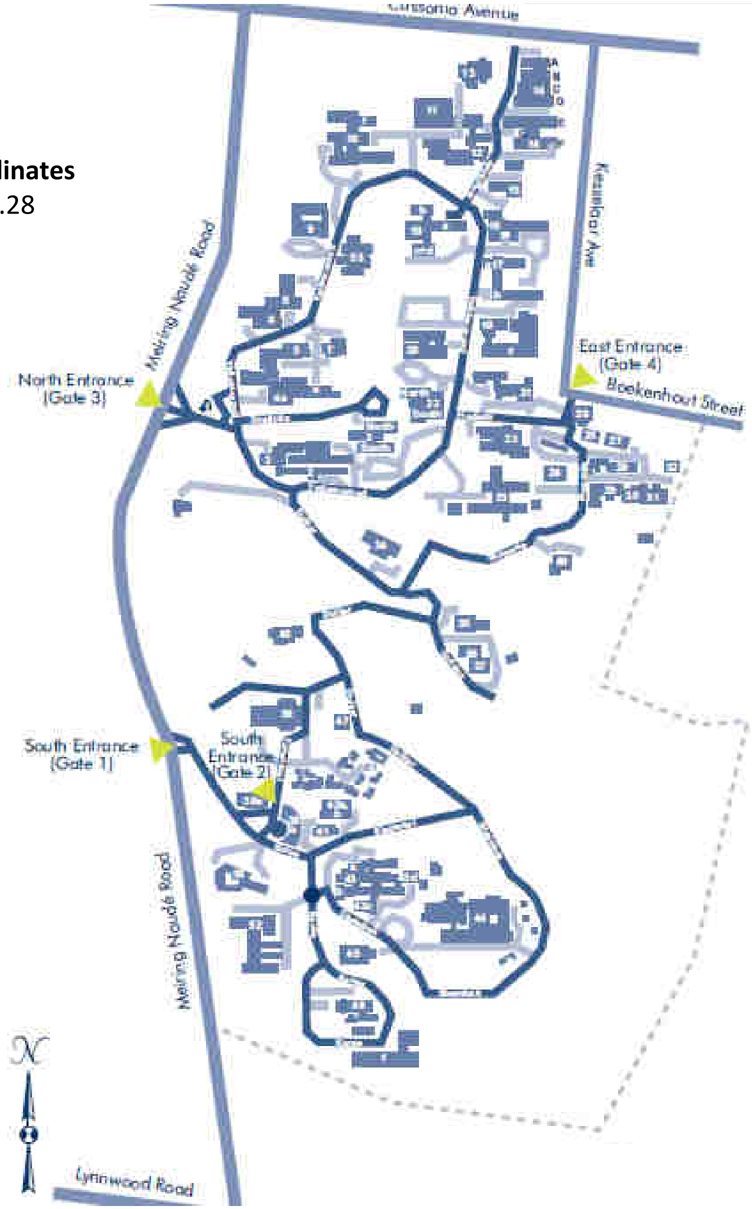
Opportunity for the African continent to "leapfrog" large-scale, central power system directly to distributed generation

CSIR our future through science

Sources: gapminder; CSIR analysis

Today: CSIR's main campus in Pretoria is a large electricity consumer

GPS coordinates
-25.75, 28.28



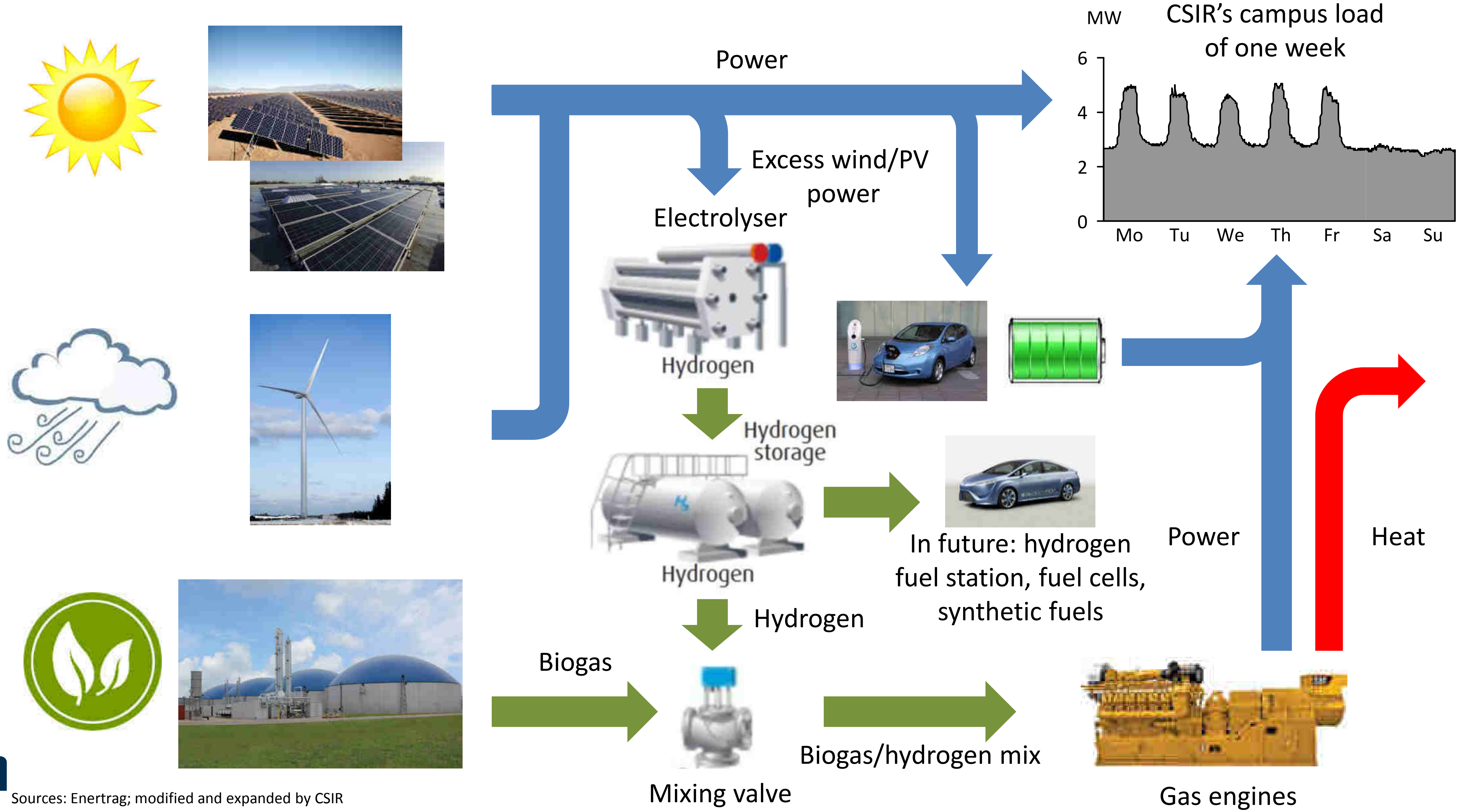
CSIR Campus today

- *52 buildings*
- *150 ha*
- *30 GWh/yr electricity demand*
- *3 MW base load*
- *5-6 MW peak load*

Equivalent of
7 500 German 4-person households

Sources: CSIR analysis

All energy on the campus will be supplied from renewables, and CSIR's campuses will be operated like a blueprint for a future energy system



Sources: Enertrag; modified and expanded by CSIR

Summary:
Great opportunity for Africa to leapfrog toward distributed renewables

Renewables-based electrification opportunity ahead of Africa

- The two mainstream renewables solar PV & wind are cost competitive today to alternative new-builds
- Chance for Africa to leapfrog central power architecture to distributed, renewables-based systems

Biggest challenge: capital-intensive cost structure of renewables

- Renewables are inherently capital intensive, because they do not exhibit any fuel costs
- Capital-intensive infrastructure always, everywhere requires long planning horizon and invest certainty

Renewables therefore require reduction in investment risks to be financeable

- Certainty about the off-take of the electricity generated over the lifetime of the asset
- Certainty about the tariff over the lifetime of the asset
- That is the only way to bring the cost of capital and as a consequence the tariffs down

A global approach could be a globally-funded tariff for renewables, wherever they are

- All countries contribute to a fund according to their GDP
- Tariff and off-take for any renewable generator anywhere in the world guaranteed from that fund

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Thank you!

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