Global Energy Assessment
Towards a Sustainable Future

Some remarks on GEA
with a focus on renewable energy

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Main GEA chapters dealing with renewable energy:

- Chapter 7: *Energy Resources and Potentials* - CLA: Hans Holger Rogner
- Chapter 11: *Renewable Energy* - CLA: Wim Turkenburg
- Chapter 17: *Energy Pathways for Sustainable Development* – CLA: Keywan Riahi
- Chapter 20: *Land and Water: Linkages to Bioenergy* - CLA: Suani T. Coelho

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Present Status

(based mainly on GEA chapter 11)

World Primary Energy Supply in 2009

(using GEA substitution method to calculate contribution from renewables)

Fossil fuels:		**412 EJ**	**(78 %)**
- oil	167 EJ		
- gas	106 EJ		
- coal	139 EJ		
Renewables:		**89 EJ**	**(17 %)**
- large hydro	30 EJ *)		
- traditional biomass	39 EJ		
- 'new' renewables	20 EJ *)		
Nuclear:		**27 EJ**	**(5 %)**
Total:		**528 EJ**	**(100 %)**

**) Assuming for hydro, wind, solar and geothermal electricity: 1 EJ(el) = 2.85 EJ savings on fossil fuels, and for solar and geothermal heat: 1 EJ(th) = 1.17 EJ savings on fossil fuels.*

Source: W.C. Turkenburg et al., 'Renewable Energy'. In: Global Energy Assessment, 2012, chapter 11.

Contribution 'modern renewables' to World Primary Energy Supply in 2009 *)

- Hydropower:	32	EJ
- Modern biomass energy:	12.1	EJ
- Wind electricity:	3.7	EJ
- Geothermal energy:	1.2	EJ
- Low temp. solar thermal energy:	0.5	EJ
- Solar PV electricity:	0.33	EJ
- Solar thermal electricity (CSP):	0.02	EJ
- Ocean energy:	0.005	EJ
Total:	**49.9**	**EJ**

**) Assuming for hydro, wind, solar, geothermal, and ocean electricity: 1 EJ(el) = 2.85 EJ savings on fossil fuels, and for solar and geothermal heat: 1 EJ(th) = 1.17 EJ savings on fossil fuels*

Source: W.C. Turkenburg et al., 'Renewable Energy'. In: Global Energy Assessment, 2012, p. 661-900.

Contribution 'modern renewables' in 2009 using different calculation methods

Technology	Primary Supply using the *substitution method*	Primary Supply using the *physical content method*	Primary Supply using the *direct equivalent method*
Hydropower	32	11.2	11.2
Modern biomass energy	12.1	12.1	12.1
Wind electricity	3.7	1.3	1.3
Geothermal energy	1.2	3.3	0.67
Low temp. solar thermal energy	0.5	0.43	0.43
Solar PV electricity	0.33	0.12	0.12
Solar thermal electricity (CSP)	0.02	0.05	0.007
Ocean energy	0.005	0.002	0.002
TOTAL SUPPLY	**49.9 EJ**	**28.5 EJ**	**25.9 EJ**

Source: W.C. Turkenburg et al., 'Renewable Energy'. In: Global Energy Assessment, 2012, p. 761-900.

Some general results and some trends

- The renewable resource based is sufficient to meet several times the present world primary energy demand, and potentially even more than 10 times this demand.

- Since 1990 energy provided by renewabels has risen with 2% a year, but in recent years with 5% a year.

- In last 5 years: many renewable technologies have experienced a high annual growth rate – some (biofuels, wind, solar electricity, solar thermal, and geothermal heat) even experiencing two-digit growth (up to 50% a year).

- In 2010 more than $230 bln investments ($-2005) in renewables. Investments in 'new renewables' from about $2 bln in 1990, to about $190 bln in 2010.

- Contribution to primary energy supply in 2009: 17% (89 EJ); contribution to electricity supply: 19% (3800 TWh).

- Renewable power capacity additions in 2010 represented more than one-third of all global power capacity additions.

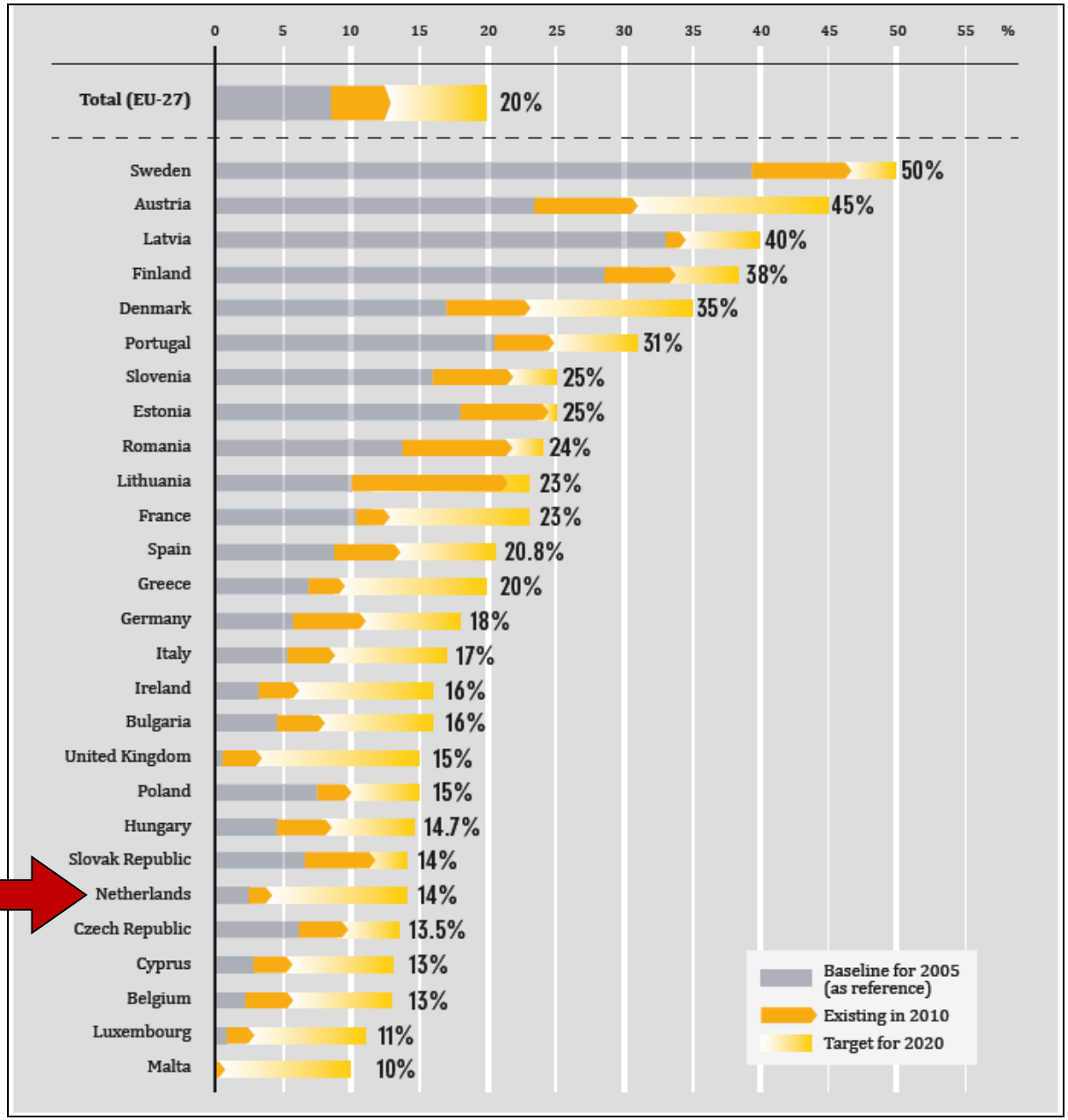
=► ***Renewables are beginning to change the energy paradigm!***

Major developments in 2011

- Renewables continued to grow strongly in all end-use sectors (power; heating and cooling; transport).
- Global investments in renewables increased by 17%, compared with 2010.
- Net investments in renewable power capacity (including larger-scale hydropower) exceeded that of fossil fuels.
- About half of the new electricity capacity installed worldwide was renewable based.
- European Union installed more renewable energy capacity during 2011 than ever before.
- Globally, an estimated 5 million people work directly or indirectly in renewable energy industries.
- At least 118 countries now have renewable energy targets in place, and 109 countries have policies to support renewables in the power sector.

Source: REN21, ''Renewables 2012 – Global Status Report', REN21, Paris, 2012, 171 pp.

EU renewables shares of final energy, in 2005 and 2010, with *targets* for 2020



NL is far behind other countries;
it is unlikely the 2020 target will be reached

Source:
REN21, "Renewables 2012 – Global Status Report', REN21, Paris, 2012, p. 66.

Towards a Sustainable Future

(based mainly on GEA chapter 17)

Objectives GEA Sustainable Development energy back-casting scenario for 2050

- **Support economic growth at recent historic rates** (2% a year increase of per capity income, on average**).**
- **Almost universal access to electricity and cleaner cooking by 2030** (diffusion of clean technology; extension of grids).
- **Reduce air pollution impacts on health, adhering to WHO guidelines** (reduced 5 million premature death due to air pollution by 50% by 2030).
- **Avoid dangerous climate change; stay below + 2 ºC above pre-industrial global mean temperature with more than 50% likelyhood** (CO2 emission peak by 2020; 30-70% reduction in 2050; negative emissions later).
- **Improve energy security through enhanced diversity, limited energy trade and resilience of energy supply by 2050** (reduce share oil import in primary energy by 30-80%; decrease energy intensity; increase local energy supply options; infrastructure expansion; storage and back-up capacity).
- And in the process: **address issues like *peak oil* and *nuclear proliferation* challenges.**

Allowable CO_2 emission budget, and required CO_2 price in GEA

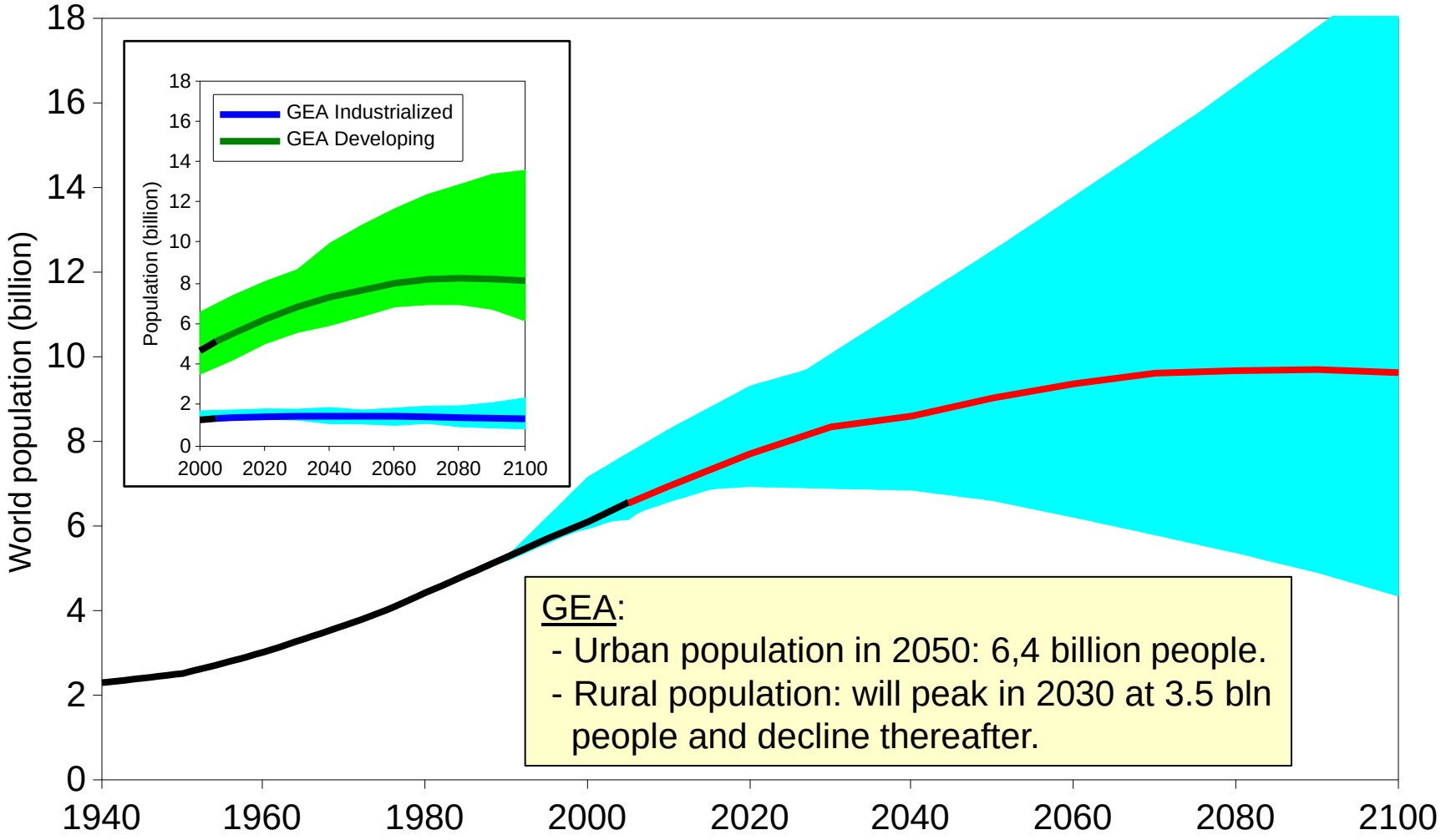
- In the period 2010-2100: 940-1460 $GtCO_2$ in total.

<u>Note</u>: This budget is achieved in 30-45 years if we stay at present level of CO_2 emissions!

- CO_2 price in GEA: at least 15-45 $/t$CO_2$ at present; up to 110 $/t$CO_2$ or above in later years.

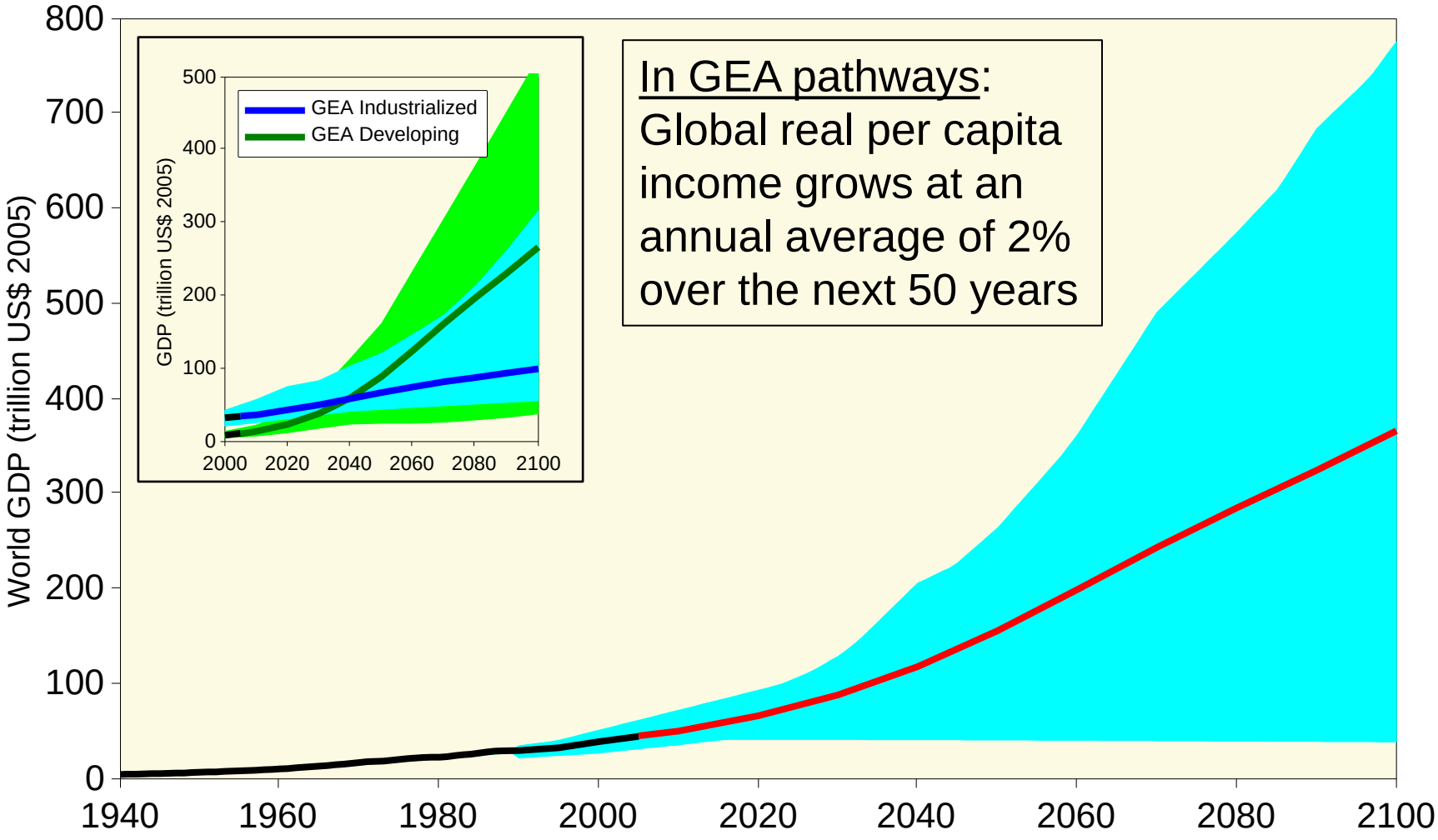
<u>Note</u>: In July 2012, the CO_2 price on the spot market was about 7 Euro per tonne CO_2.

Global population projections
(stabilization at about 9 billion in GEA)



Economic development projections

(In GEA: developing countries 3.5% a year, on average; developed countries 1.2% a year)



Branching points and GEA pathways

- **<u>Branching point 1</u>:**

What is level of energy demand?
(GEA-Efficiency; GEA-Supply; GEA-Mix - range reduction energy intensity: 1.5% - 2.2% a year).

- **<u>Branching point 2</u>:**

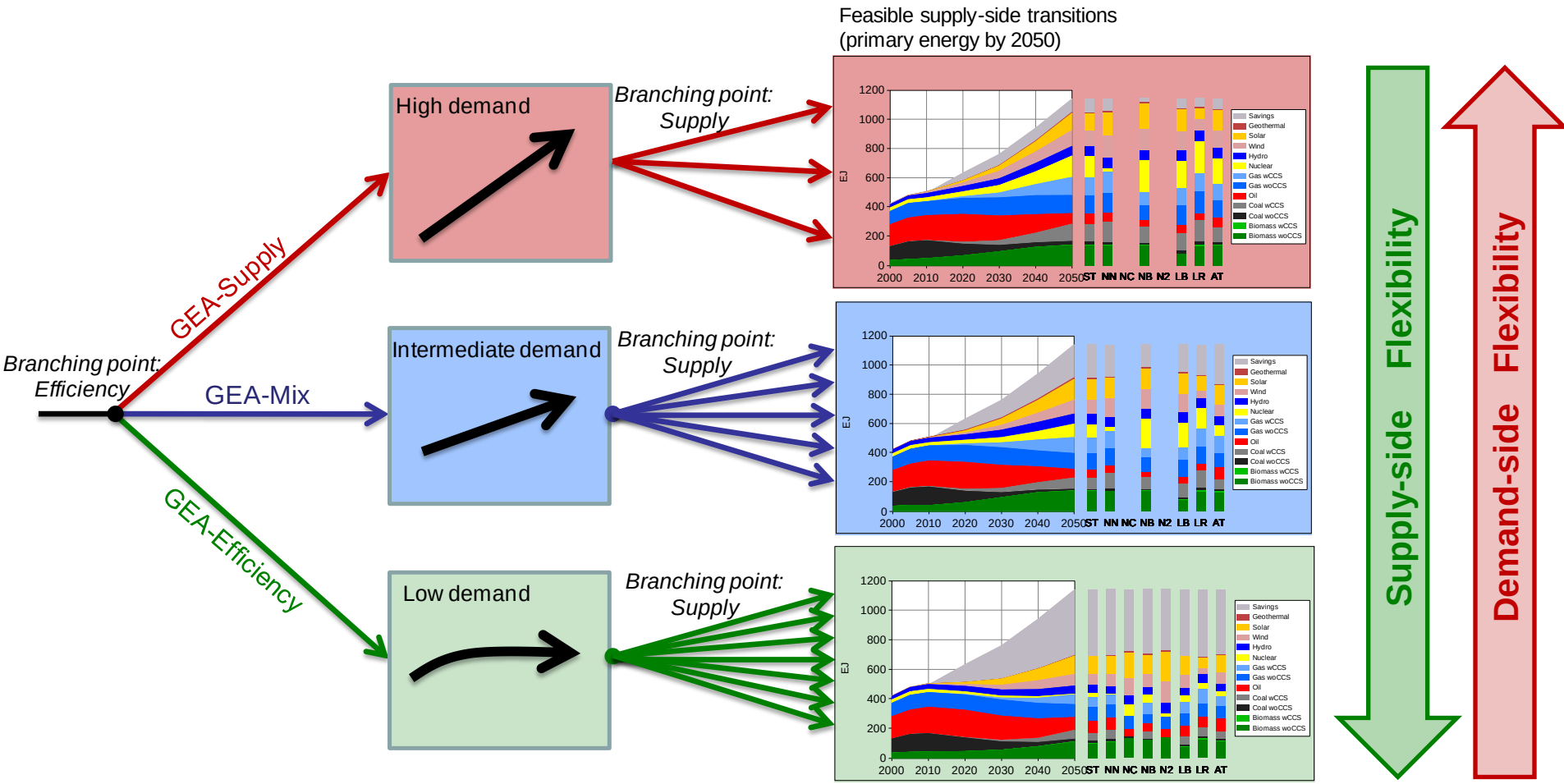
What are the dominant transportation fuels and technologies? (Conventional; Advanced).

- **<u>Branching point 3</u>:**

How divers is the portfolio of supply-side options?
(Full portfolio – all options available; Restricted portfolio – excludes or limits particular options).

Source: Keywan Riahi et al., 'Energy Pathways for Sustainable Development', GEA, 2012, p. 1205-1305.

Global Energy Assessment (GEA) Pathway Taxonomy

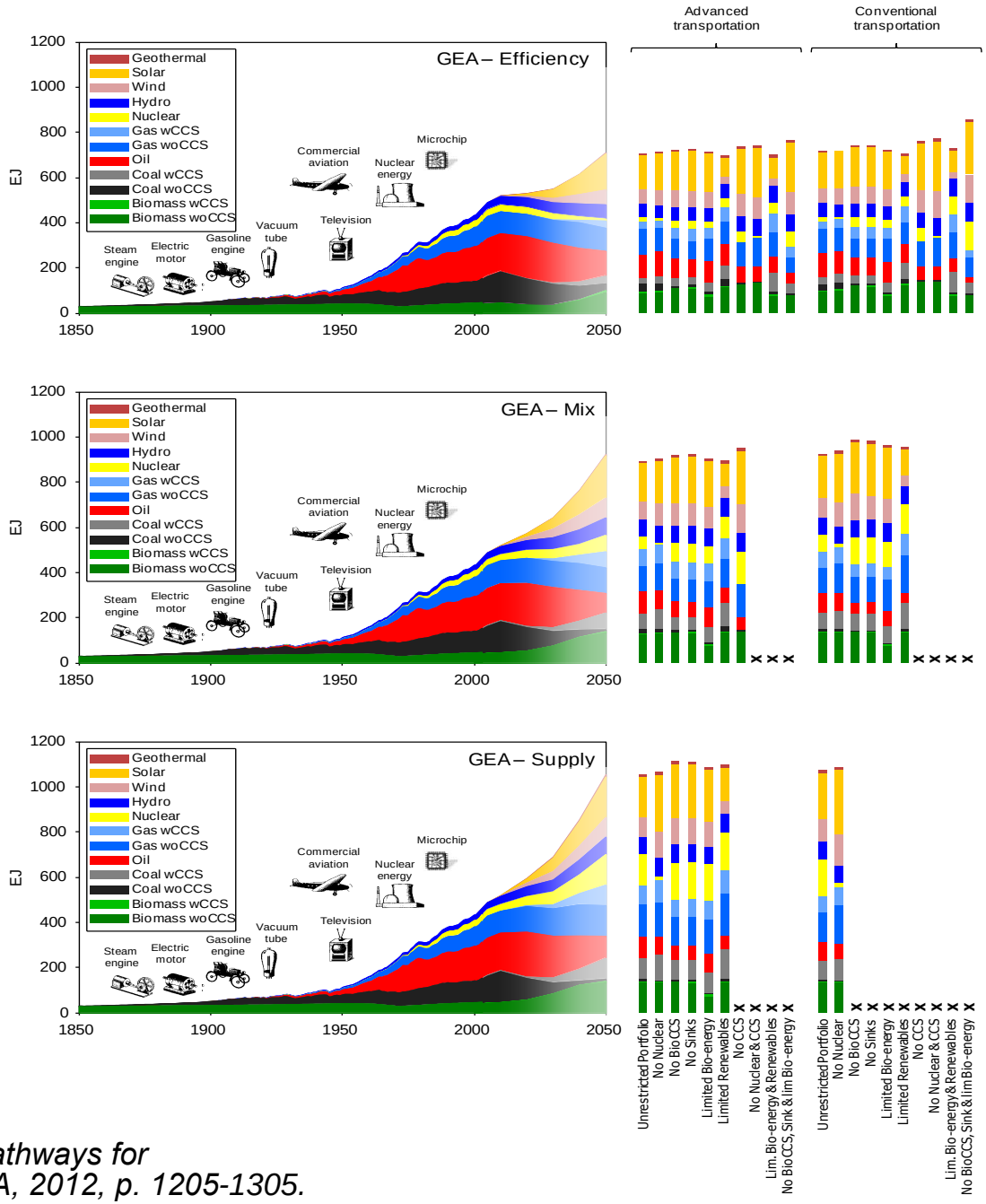


Source: Keywan Riahi et al., 'Energy Pathways for Sustainable Development', GEA, 2012, p. 1205-1305.

Development of Primary Energy in three sets of GEA pathways

(Three illustrative examples on the left, and all 60 pathways explored on the right)

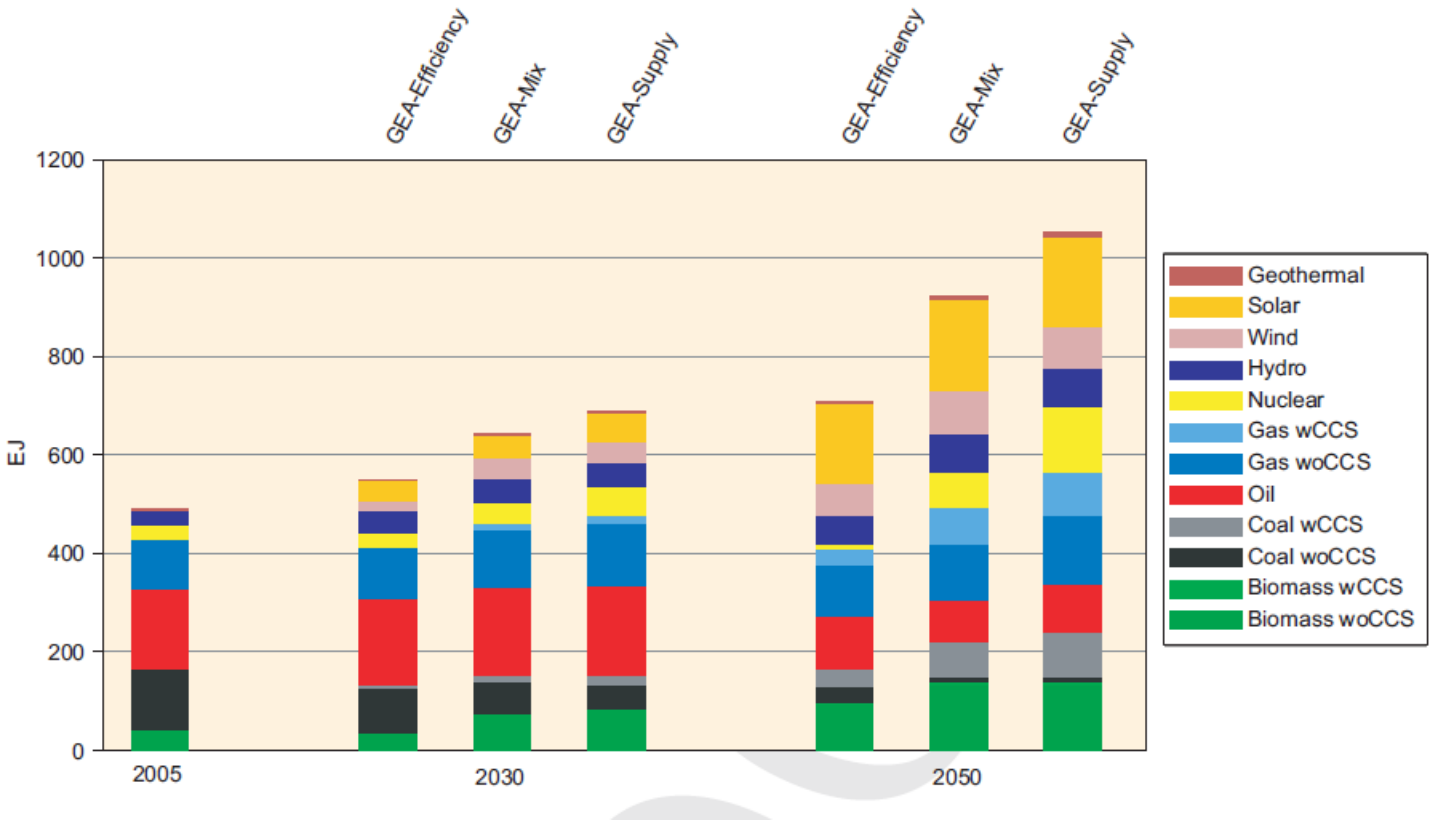
<u>Conclusion</u>: 41 out of the 60 pathways reach the GEA normative goals.



Source: Keywan Riahi et al., 'Energy Pathways for Sustainable Development', GEA, 2012, p. 1205-1305.

Composition of global primary energy supply in 2005, 2030 and 2050

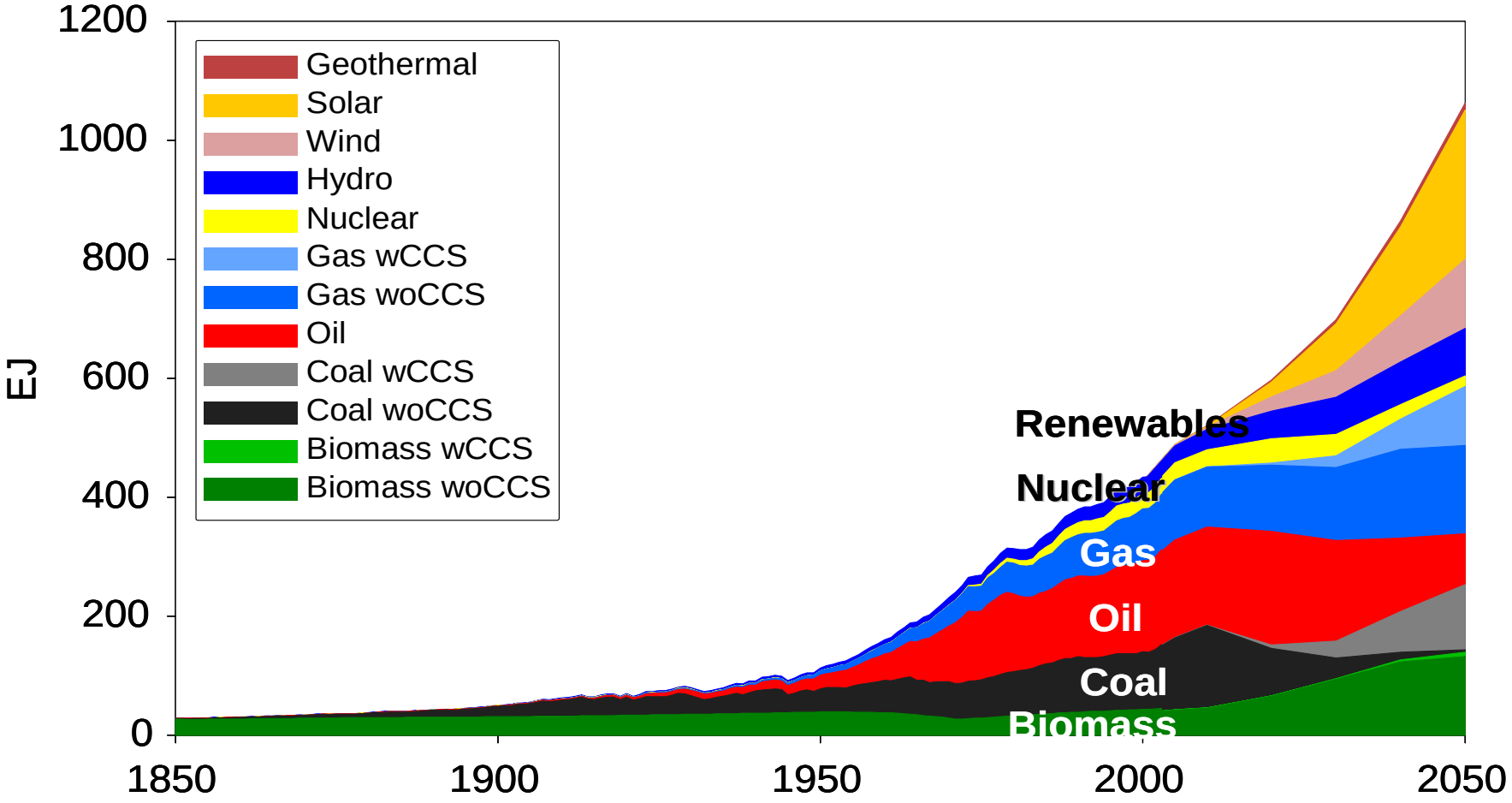
(across pathway groups, under unrestricted supply portfolio and Conventional Transportation set-up)



Source: Keywan Riahi et al., 'Energy Pathways for Sustainable Development', GEA, 2012, p. 1205-1305.

Development of primary energy

(In the GEA-Supply pathway, with a nuclear phaseout shortly after 2050)



Source: Keywan Riahi et al., 'Energy Pathways for Sustainable Development', GEA, 2012, p. 1205-1305.

Deployment of renewables in 2050, by region (in EJ)

region	bio-energy	hydro power	wind	solar	geo-thermal	all renew.		renew. % of total
Sub-Sahara African	9 - 41	2 - 6	0.5 - 20	1 - 26	0 – 0.3	11-91		31 - 94
Centrally Planned Asia and China	7 - 25	10	4 - 9	1 - 40	0 – 0.3	21 - 84		24 - 50
Eastern Europe	1 - 3	1	1 - 5	0.2 - 6	0 - 0.3	3 - 15		23 - 85
Former Soviet Union	3 - 10	3 -16	1 - 7	0.3 - 10	0 - 1	7 - 44		25 - 93
Latin America and Caribbean	11 - 23	11 - 18	4 - 12	0.5 - 22	0 - 2	25 - 76		40 - 100
Middle East and North Africa	1 - 5	1	1 - 9	0.5 - 16	0 – 0.3	4 - 31		17 - 40
North America	10 - 21	7 - 8	3 - 37	1 - 42	0 - 3	21 - 111		38 - 89
Pacific OECD	3 - 11	1 - 2	1 - 5	0.2 - 5	0.1 - 1	6 - 24		26 - 89
Pacific Asia	5 - 12	2 - 7	1 - 2	0.4 - 15	0.2 - 1	9 - 37		15 - 63
South Asia	5 - 21	4	1 - 7	1 - 79	0 – 0.2	11 - 111		21 - 65
Western Europe	4 - 11	6 - 8	3 - 30	0.7 - 29	0.1 - 2	13 - 80		34 - 83
WORLD	**78 - 139**	**50 - 80**	**29 - 134**	**7 - 285**	**1 - 12**	**164 - 651**		**28 - 74**

Source: Keywan Riahi et al., 'Energy Pathways for Sustainable Development', GEA, 2012, p. 1205-1305.

Energy investments needed to achieve GEA sustainability objectives (billions of US$/year)

Energy area	Investments in 2010	Investments per year in 2010-2050
Efficiency	(300)	290-800
Nuclear	5-40	15-210
Renewables	190	260-1010
CCS	<1	0-64
Infrastructure (grid, storage and back-up)	260	310-500
Energy access	n.a.	36-41
Total investments	**~ 1300**	**1700-2200 *)**

*) Continuing a business-as-usual (unsustainable) pathway, this figure might be ~ 1600 bln in 2050

Source: Keywan Riahi et al., 'Energy Pathways for Sustainable Development', GEA, 2012, p. 1205-1305.

Conclusions about a.o. the role of renewables in 2050 energy supplies

- At least the historical rate of improvement of the energy efficiency a year should be achieved, preferably more (decrease en. intens.: 1.5-2.2% a year).
- Low carbon energy shares in primary energy at least at 60-80% by 2050.
- Strong growth in renewable energy, beginning immediately and reaching 165-650 EJ a year by 2050 - about 30-75% of primary energy demand (and in some regions more than 90% of this demand in 2050).
- Increasing requirement for storage technologies, apart from other measures, to support system integration of intermittent renewable.
- Growth in bioenergy to 80-140 EJ a year by 2050. Strong growth of liquid biofuels in the short to medium term. Thereafter, the mix of liquid and gaseous fuels depends on transportation system choices.
- Nuclear energy may play an important role, but it is also possible to phase out nuclear, still meeting the GEA sustainability targets.
- Fossil CCS as an necessity or an optional bridge in the medium term; biomass plus CCS to achieve negative CO2 emission in longer term; cumulative storage of CO2 up to 250 GtCO2 by 2050.

6 essential technology-related requirements for radical energy transformation

GEA highlights the following *essential requirements*:

• Significantly larger investments in energy efficiency improvements, especially end-use, across all sectors;

• Rapid escalation of investments in renewable energies (hydropower, wind, solar energy, modern bioenergy, and geothermal) as well as the smart and super grids that enable renewable energies to become the dominant dpurces of energy;

• Reaching universal access to modern forms of energy and cleaner cooking through micro-financing and subsidies;

• Use of fossil fuels and bioenergy (with CCS) at the same facilities for efficient co-production of multiple energy carriers and chemicals;

• Full-scale deployment of CCS; and

• On one extreme nuclear energy could make a significant contribution to the global electricity, but in the other, it could be phased out.

Major challenges for renewables, both technical and economic

- Reducing costs through learning and scale-up;
- Creating a flexible (and predictable) investment environment that provides the basis for scale-up and diffusion;
- Integrating renewable energies into the energy system;
- Enhancing research and development to ensure technological advances; and
- Assuring the sustainability of the proposed renewable technologies.

Illustrative policy mechanisms for mobilizing financial resources

Energy area	Regulation, standards	Externality pricing	Carefully designed subsidies	Capacity building
Efficiency	Essential (elimination less efficient technology every few years)	Essential (prices should reflect full costs)	Complement (a basket of financing tools is needed)	Essential (expertise needed for new technologies)
Nuclear	Essential (for waste disposal and to prevent proliferation)	Uncertain (GHG pricing helps, but pricing nuclear risks would hurt)	Uncertain (with GHG pricing perhaps not needed)	Desired (need to correct loss of expertise in recent decades
Renewables	Complement (renew. port folio standards can complement GHG pricing)	Essential (GHG pricing is key to rapid development of renewables)	Complement (feed-in tariffs and tax credits can complement GHG pricing)	Essential (expertise needed for new technologies)
CCS	Essential (CCS requirement for all new coal plants and phase-in with existing)	Essential (GHG pricing is essential but prob. not enough in near term)	Complement (would help first plants while CHG pricing is still low)	Desired (expertise needed for new technologies)
Infrastructure (grid, storage and back-up)	Essential (security regulation critical for some aspects of reliability)	Uncertain (neutral effect)	Essential (customers must pay for reliability levels they value)	Essential (expertise needed for new technologies)

Thanks!

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For more information:

www.globalenergyassessment.org