Öko-Recherche

Büro für Umweltforschung und -beratung GmbH

Co-benefits of RAC sector transformation

Potential of alternative technologies substituting ODS and high-GWP HFCs

Bastian Zeiger, Öko-Recherche

New Delhi, 7 November 2014

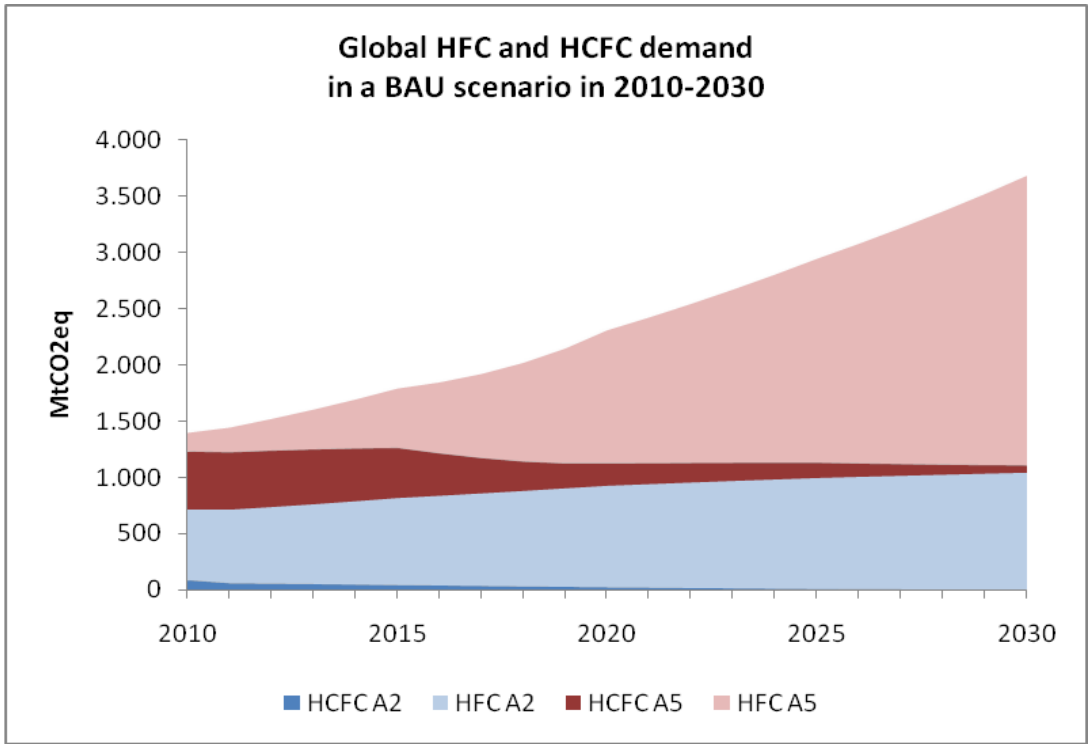
Content

- Post-ODS scenario
- Availability and experience with HFC alternatives
- Preparatory study for review of EU F-gas Regulation:
  - Market penetration of abatement options
  - Abatement technologies in stationary refrigeration and AC
  - Abatement costs and HFC demand reductions in 2030
- Closer look at unitary AC in India and energy efficiency at high ambient temperatures

Post-ODS scenarios in A5 and globally

- Increasing projected HFC demand and emissions especially in Article 5 (A5) countries
  - ODS phase-out related
  - Related to economic growth
- High-GWP HFCs and HFC blends often used as substitutes for HCFCs

HFC banks already there in A5 countries!



Source: Schwarz et al 2011

Increasing interest for alternatives to HFCs

- Research and development ongoing for many years and expanded to almost all applications
- 2014 TEAP Task Force Report: **Clear market signalling away from high-GWP options!**
- HFC regulations planned or in place in many countries:
  - EU F-gas Regulation No 517/2014
  - US President's Climate Action Plan
  - Japanese law amendments
- Long-term experience (e.g. domestic refrigeration)
- **"Window of opportunity"** for A5 countries:

Avoid HFC technology after ODS phase-out!

Experience with HFC alternatives in EU and globally

- Increasing use of **hydrocarbons** in different applications:
  - Domestic refrigeration, commercial stand-alone equipment, portable AC (< 5 kW), chillers (up to 150 kW), etc.
- Large scale experience with **ammonia** and **CO_2** technology
- Research and development concerning low-GWP HFC refrigerants:
  - **Unsaturated HFCs (HFOs): mobile AC**
  - **Low-GWP HFC/HFO blends** not yet commercially available

Preparatory study for the new EU F-gas Regulation

- 2.5 years in the making (2009-2011)
- International team
- Input and review from several technical and national experts
- Alternatives to HFCs not HCFCs!
- Content:
  - Effectiveness and implementation of previous F-gas Regulation
  - Cost-effectiveness
  - State and potential of alternative technology
  - Options for further international action on F-gases
  - Options for a revised EU F-gas Regulation

Today we will concentrate on available HFC alternatives!

Abatement options and cost

- **Abatement**: reduction of HFC use and emissions in a sector
- Identification of technically feasible and safe alternatives for each sector (**"abatement options"**) and comparison with conventional HFC technology
- Criteria for abatement options:
  - High demand and emission reduction potential
  - Cost effectiveness -> "**abatement costs"** (€/tCO_2 eq.)
  - Energy efficiency (avoidance of indirect emissions)
- Only technically feasible, cost-effective, low-GWP alternative options with at least the same energy efficiency as HFC options

The role of energy efficiency in the study

- Energy consumption of alternatives must be lower or at least the same as for HFC solutions to **avoid increase of the indirect CO_2 emissions**
- Less energy efficient alternative technologies not discarded if additional technical measures (e.g. larger heat exchangers) can be used to compensate for low efficiency → **increase in abatement cost**
- **But** exclusion of alternatives where additional technical measures are not sufficient (e.g. transcritical CO_2 technology in Southern climate)

Market penetration of abatement options

The maximum potential of each alternative to replace new equipment relying on HFCs in each sector based on technical feasibility.

Example: "Market penetration of 40% in 2030" means that 40% of new products or equipment in a sector can be replaced by that alternative technology in 2030.

Alternatives (abatement options) considered:

R-290/R-600a direct
R-290 indirect
R-744 (CO_2) (transcritical)
Unsaturated HFC direct
Unsaturated HFC indirect
R-717 (NH_3) (indirect)
HFC/unsaturated HFC blends

Various constraints to market penetration for each alternative might occur:
Safety, energy efficiency, higher costs (or investments), availability of materials, components and/ or substances etc.

→ Such constraints limit the market penetration of an alternative

Usually several abatement options will be required to reach maximum substitution of HFC technology per sector!

Market penetration of abatement options cont'd

Example for the combination of abatement options in a sector:

	Alternative A	Alternative B	Alternative C	Alternative D
Penetration rate in 2030 (%)	40	70	30	20
Costs (per unit)	10	17	5	38

The potential of all alternatives to replace HFC technology exceeds 100% !

Therefore, low cost alternatives are prioritized:

(30% C x 5) + (40% A x 10) + (30% B x 17) = 100 % at sector costs of 10.6

For its higher costs alternative D is no longer considered although technically feasible.

Mix of alternatives with different constraints to reach maximum emission reduction at minimum cost!

Abatement technologies by sectors: Refrigeration

Refrigeration		Key abatement options	Market penetration in 2030 (%)	
			A2	A5
Commercial refrigeration	Centralized systems	R290 indirect + CO_2 cascade	90	80
		R290 + CO_2 + CO_2 cascade	10	15
		Transcritical CO_2	0	5
	Condensing units	R290 direct	40	60
		R290 indirect	30	30
		Transcritical CO_2	30	10
	Stand-alone units	R290 direct	85	85
		Transcritical CO_2	15	15
Industrial refrigeration	Small equipment	NH_3	95	80
	Large equipment	NH_3	95	80

In most subsectors the penetration mix of abatement options is 100% in 2030 or before!

Abatement technologies by sectors: Refrigeration

Refrigeration		Key abatement options	Market penetration in 2030 (%)	
			A2	A5
Commercial refrigeration	Centralized systems	R290 indirect + CO_2 cascade	90	80
		R290 + CO_2 + CO_2 cascade	10	15
		Transcritical CO_2	0	5
	Condensing units	R290 direct	40	60
		R290 indirect	30	30
		Transcritical CO_2	30	10
	Stand-alone units	R290 direct	85	85
		Transcritical CO_2	15	15
Industrial refrigeration	Small equipment	NH_3	95	80
	Large equipment	NH_3	95	80

In most subsectors the penetration mix of abatement options is 100% in 2030 or before!

Abatement technologies by sectors: Stationary AC

Stationary AC	Key abatement options	Market penetration in 2030 (%)	
		A2	A5
Moveable AC	R290 direct	70	75
	R744 (CO_2)	20	15
	R1234yf	10	10
Single split AC	R290 direct	70	70
	R32 (later R32/HFO blends)	30	30
Multi split AC	R290 indirect	30	30
	R32 (later R32/HFO blends)	70	70
Small chillers	R290 direct	60	60
	R744 (CO_2)	20	20
	NH_3	20	20
Large chillers	R290 direct	15	15
	R744 (CO_2)	0	10
	NH_3	60	60
	R718	25	25
Centrifugal chillers	R290	20	20
	R1234ze	50	50
	R718	30	30

A5 countries include high ambient and moderate temperature areas!

Abatement technologies by sectors: Stationary AC

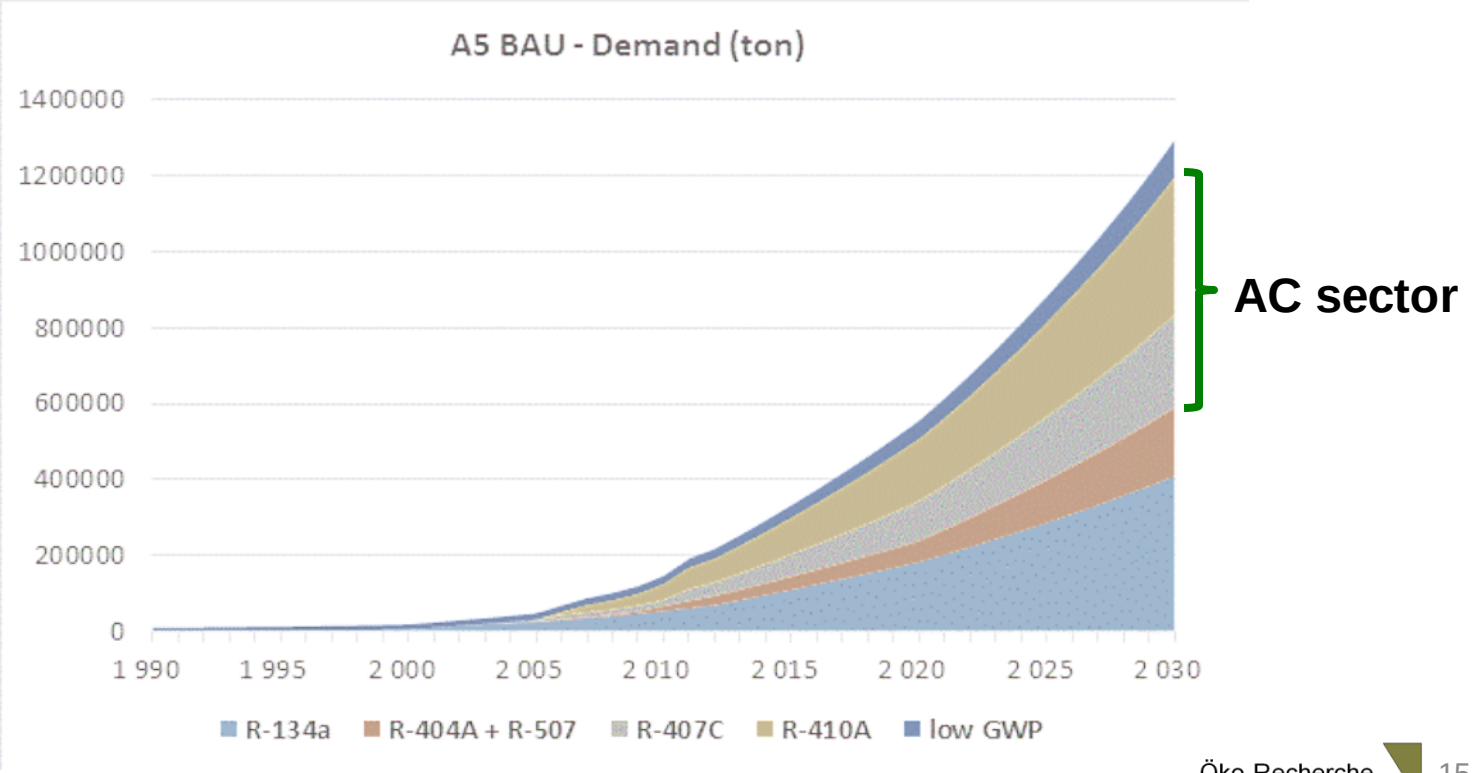
Stationary AC	Key abatement options	Market penetration in 2030 (%)	
		A2	A5
Moveable AC	R290 direct	70	75
	R744 (CO_2)	20	15
	R1234yf	10	10
Single split AC	R290 direct	70	70
	R32 (later R32/HFO blends)	30	30
Multi split AC	R290 indirect	30	30
	R32 (later R32/HFO blends)	70	70
Small chillers	R290 direct	60	60
	R744 (CO_2)	20	20
	NH_3	20	20
Large chillers	R290 direct	15	15
	R744 (CO_2)	0	10
	NH_3	60	60
	R718	25	25
Centrifugal chillers	R290	20	20
	R1234ze	50	50
	R718	30	30

A5 countries include high ambient and moderate temperature areas!

The situation in A5 countries

- ODS phase out creates demand for HFCs and alternatives
- Plus: Rapid expected growth especially in AC
- Unitary AC already largest sector
- Energy efficiency is an important factor

The technology choice is being made right now!

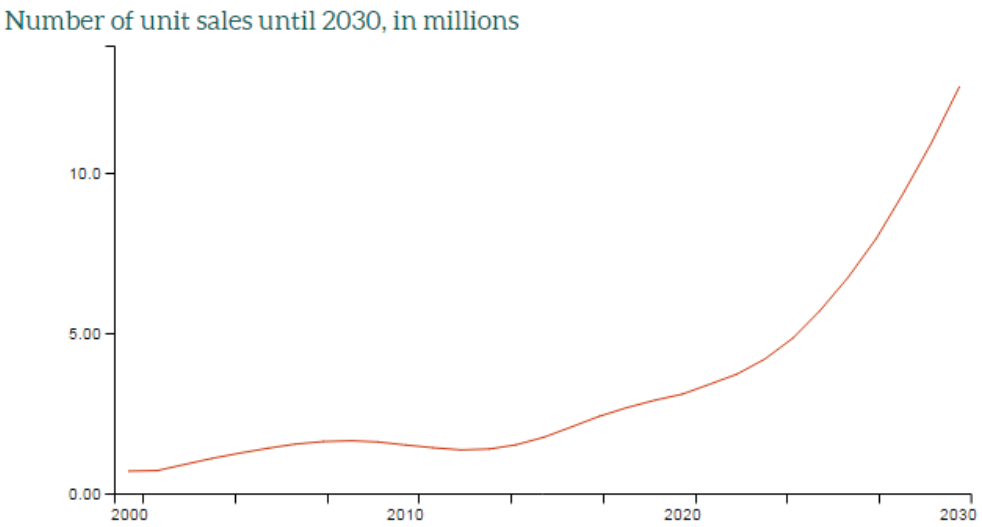


Source: 2014 TEAP Task Force Draft Report

Unitary AC in India

- Unitary AC most common systems in A5 incl. India
- Market saturation still moderate with large growth potential
- **Unit sales are projected to increase 8-fold!**
- > 80 % small units < 7 kW (relevant for charge limits)
- Small units account for ~ 50 % refrigerant weight in AC
- Phase down or freeze of GWP-weighted emissions not possible with high-GWP HFCs

Projected unitary AC unit sales in India:



Source: Green Cooling Initiative

Viable solutions for unitary split AC

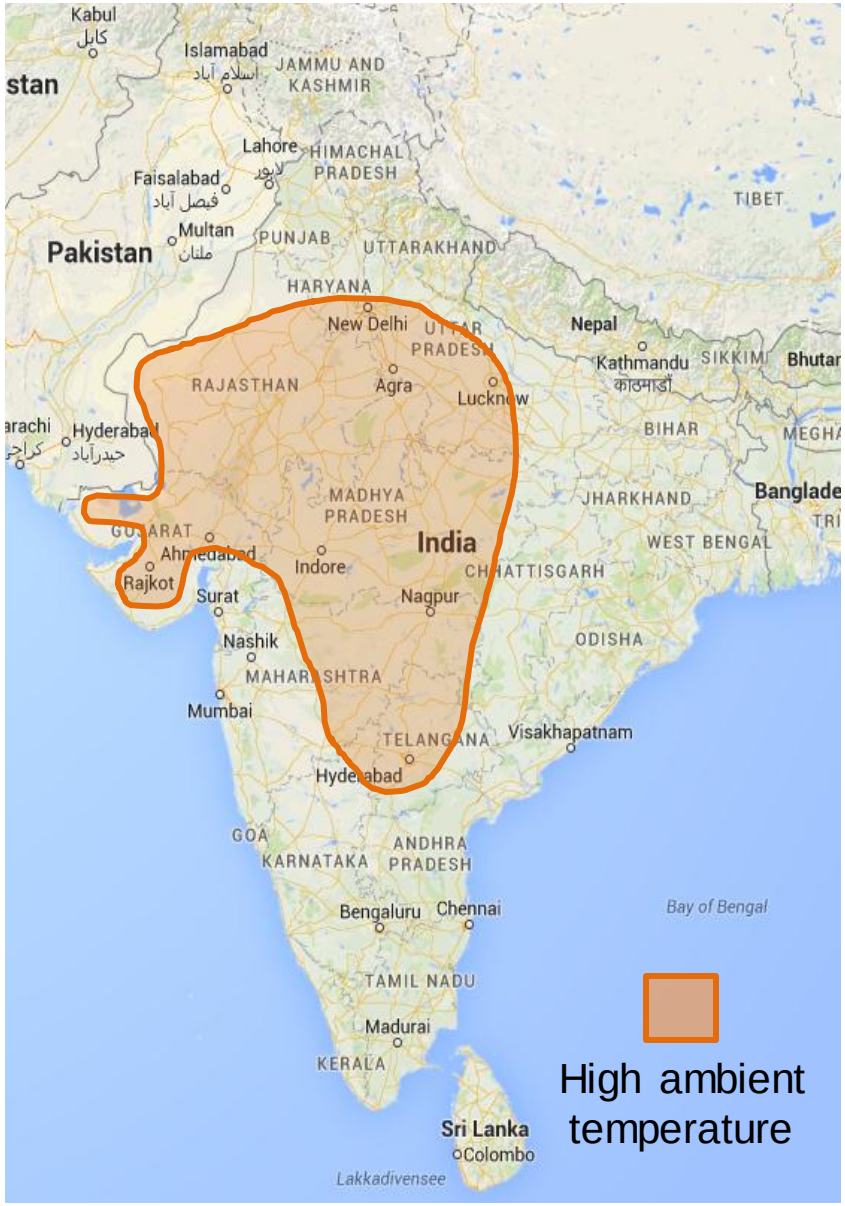
- R22 as benchmark, not high-GWP HFCs
- Hydrocarbons, HFOs, R32 and R32-HFO blends
- Requirement: Energy efficiency equal to R22 and at acceptable cost
- Constraints: Flammability -> charge limits
- 100% replacement possible in AC and 90% in all sectors

	Common gas	Cons. A5 2015	HC direct	HC in direct	HFO	R32	*R32-HFO blends*
GWP			3	3	< 10	675	*200-400*
Portable/Windows	R22	30 kt/y	🟢	🔴	🔴	🔴	🟡
Single Split < 7 kW	R22	90 kt/y	🟢	🔴	🔴	🔴	🟡
Split/Multi. >7 kW	R22	80 kt/y	🔴	🔴	🔴	🟢	🟡

🔴 Efficiency too low or cost too high compared to other alternatives
🟡 Efficient. Safe. But costly and no short term availability
🟢 Efficiency high. No or acceptable additional cost. Short term availability

HC (smaller units) and R32 (larger units) combination enable significant reduction!

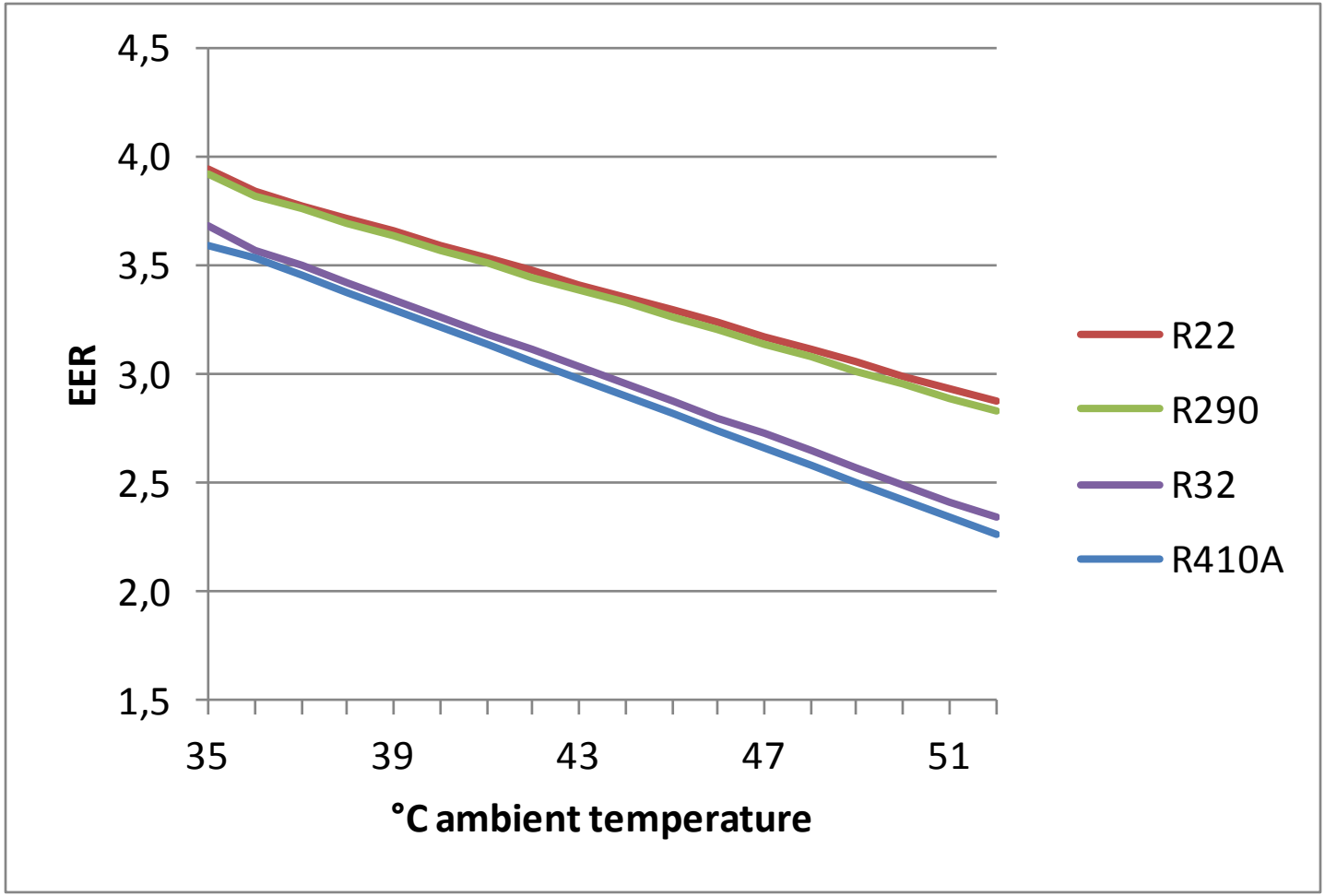
High ambient temperatures: Indian example



- High ambient temp: Mean max daily temps of >40°C in May
- ~ 1/2 of India affected by HAT
- New Delhi: 355 h/a 40°C or above

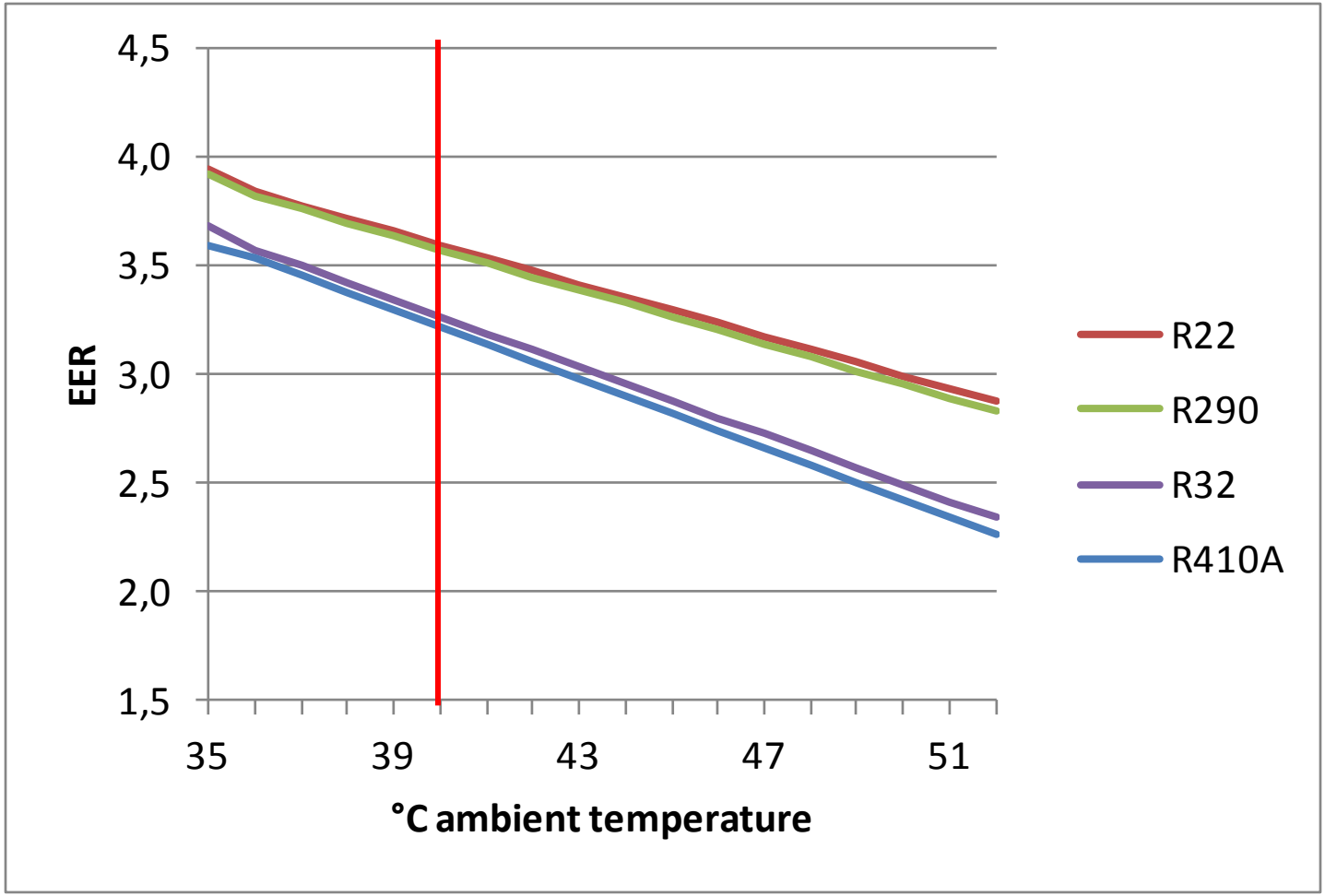
Energy efficiency under HAT conditions

- R22 currently most energy efficient solution at HAT
- R290 most comparable low-GWP alternative, R32 next best (later R32-HFO blends?), R410A much worse



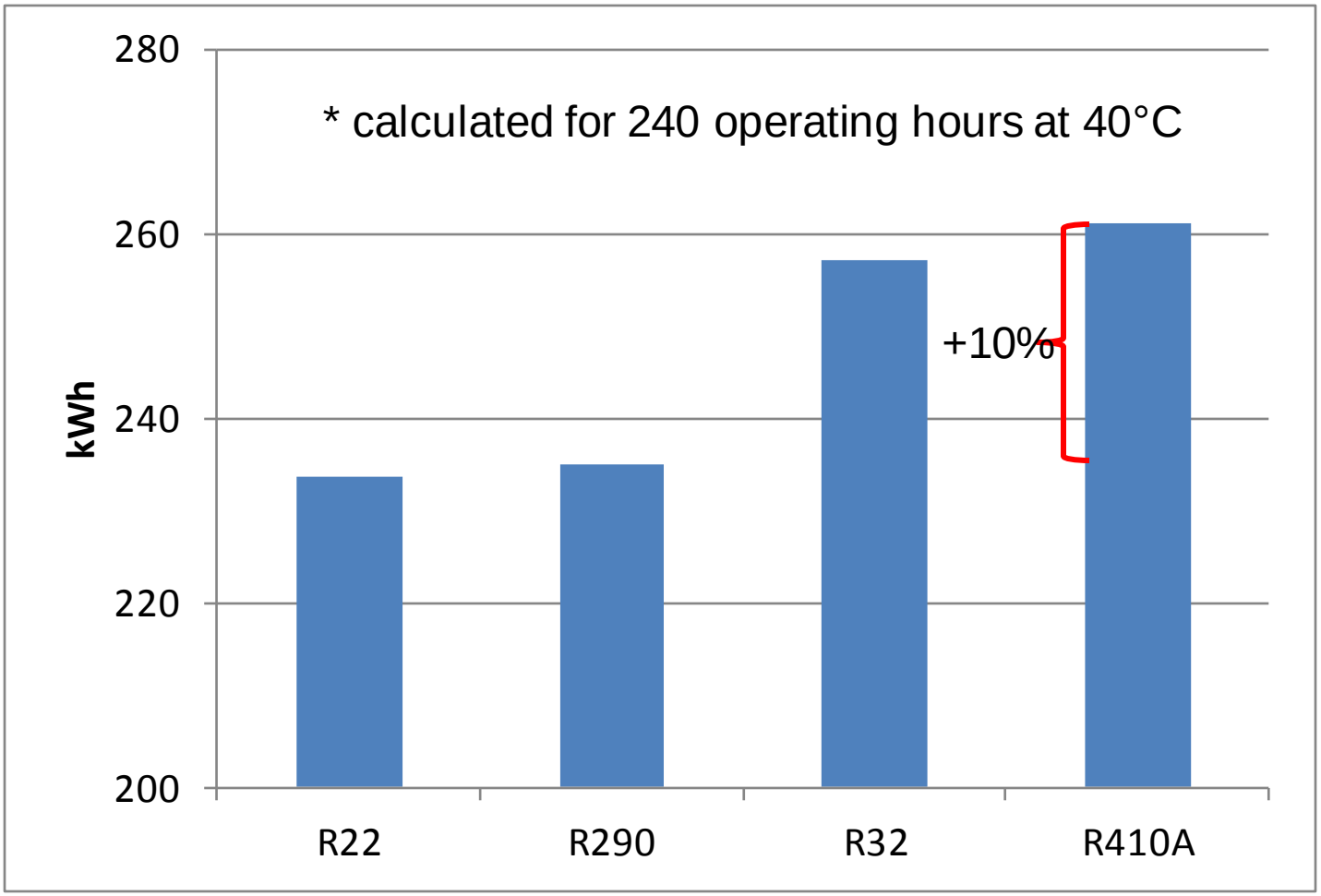
Energy efficiency under HAT conditions

- R22 currently most energy efficient solution at HAT
- R290 most comparable low-GWP alternative, R32 next best (later R32-HFO blends?), R410A much worse

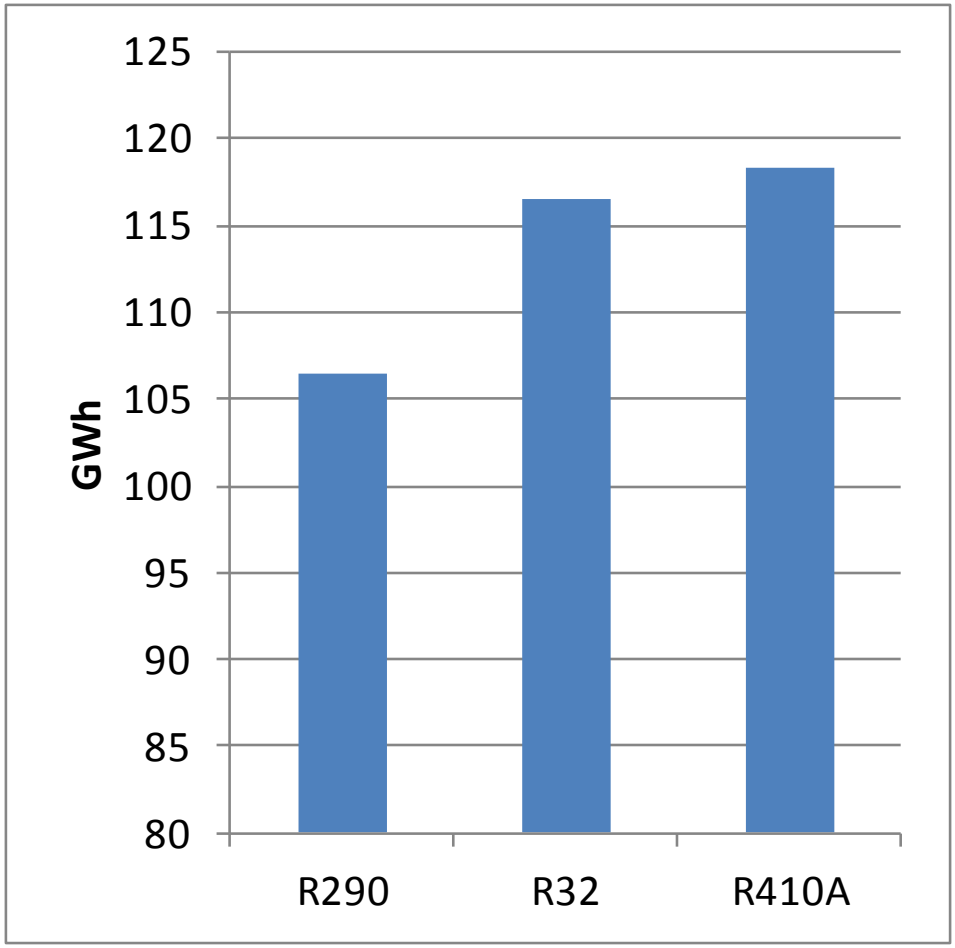


Energy consumption under HAT

Energy Consumption of one unitary (split) AC unit (3,5 kW) for one month at high ambient temperature*



Energy consumption under HAT cont'd



- Projected unitary AC unit sales in 2015 in India: 906.163 units
- Half of them operating under HAT for one month

Reduction Potential:

- R290 over R410A: 11.9 GWh reduction per month
- Cost reduction for energy per month: Over R410A: 59mio INR
- Indirect emission reduction per month: 13.6 Mt CO_2eq

HC and R32 are viable combination under HAT

- Lower EER of R32 equipment can be alleviated -> But: higher abatement costs!
- Charge limits still apply: HC the better solution for small charges, R32 for larger
- Both is possible: reductions in
  - HFC demand and
  - energy consumption

Even under HAT significant reduction possible via HC and R32!

Thank you for your attention!

Download of the EU study and its annexes:
http://ec.europa.eu/clima/policies/f-gas/docs/2011_study_en.pdf

Download of the study on alternatives for high ambient temperatures and technical annex:
http://ec.europa.eu/clima/policies/f-gas/legislation/docs/alternatives_high_gwp_en.pdf

Questions…???

b.zeiger@oekorecherche.de