

Combustion Technology Research And Development Issues

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(For The U.S. Department of Energy Combustion
Technology University Alliance Workshop)

Introduction

- Research project undertaken to provide additional information to DOE's fossil combustion program
- Results can be used to strategize the direction of future combustion research programs
- Project was an extension of the research presented at the 2002 Combustion Technology University Alliance Workshop
 - Focus of 2002 project was to identify continuing boiler operating and maintenance concern issues

Current Research Effort

- Data was collected from six groups using three combustion technologies (referred to as the combustion boiler system users group) [53 total plants were included in this part of the study]
 - Industrial users utilizing fluid bed combustion (FBC) technology
 - 16 responses were received from this group
 - Industrial users utilizing pulverized coal (PC) technology
 - 4 responses were received from this group
 - Industrial users utilizing conventional stoker-fired technology
 - 5 responses were received from this group
 - Utilities using fluid bed combustion technology
 - 11 responses were received from this group
 - Utilities using pulverized coal combustion technology
 - 15 responses were received from this group
 - Utilities using conventional stoker-fired technology
 - 2 responses were received from this group

Current Research Effort

- Data was also collected from thirty additional groups with either vendor or research knowledge of the various combustion technologies [129 total responses were included in this part of the study]
 - Technology vendors referencing industrial FBC plants
 - 10 responses were received from this group
 - Technology vendors referencing industrial PC plants
 - 8 responses were received from this group
 - Technology vendors referencing industrial stoker-fired plants
 - 4 responses were received from this group
 - Technology vendors referencing utility FBC plants
 - 10 responses were received from this group
 - Technology vendors referencing utility PC plants
 - 9 responses were received from this group
 - Technology vendors referencing utility stoker-fired plants
 - 2 responses were received from this group

Data Collection Results (continued)

- Association representatives referencing industrial FBC plants
 - 3 responses were received from this group
- Association representatives referencing industrial PC plants
 - 3 responses were received from this group
- Association representatives referencing industrial stoker plants
 - 3 responses were received from this group
- Association representatives referencing utility FBC plants
 - 3 responses were received from this group
- Association representatives referencing utility PC plants
 - 3 responses were received from this group
- Association representatives referencing utility stoker plants
 - 3 responses were received from this group
- Design and engineering firms referencing industrial FBC plants
 - 1 response was received from this group
- Design and engineering firms referencing industrial PC plants
 - 1 response was received from this group

Data Collection Results (continued)

- Design and engineering firms referencing industrial stoker plants
 - 0 responses were received from this group
- Design and engineering firms referencing utility FBC plants
 - 1 response was received from this group
- Design and engineering firms referencing utility PC plants
 - 1 response was received from this group
- Design and engineering firms referencing utility stoker plants
 - 0 responses were received from this group
- Research and development firms referencing industrial FBC plants
 - 5 responses were received from this group
- Research and development firms referencing industrial PC plants
 - 5 responses were received from this group
- Research and development firms referencing industrial stoker plants
 - 0 responses were received from this group
- Research and development firms referencing utility FBC plants
 - 6 responses were received from this group

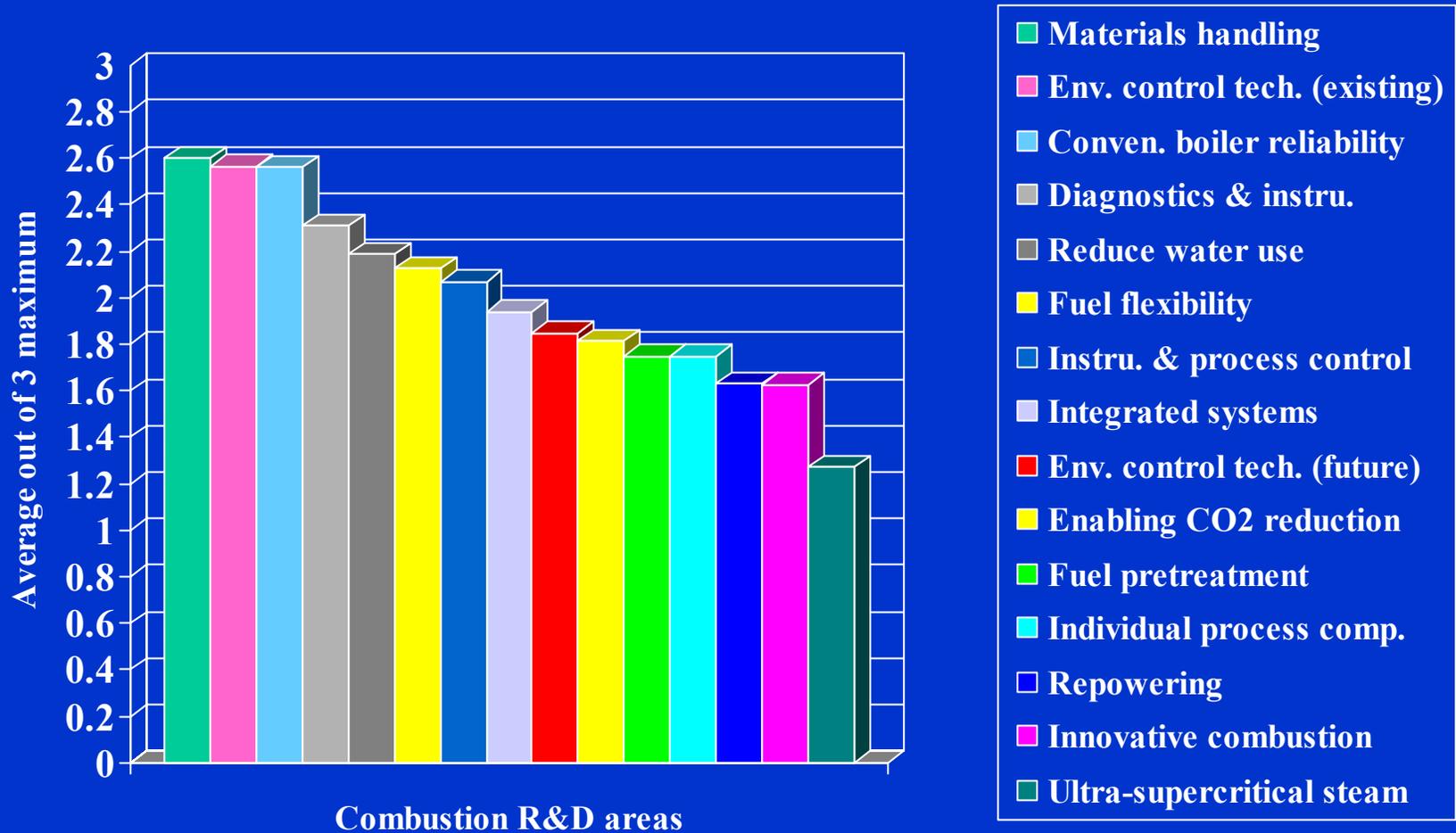
Data Collection Results (continued)

- Research and development firms referencing utility PC plants
 - 7 responses were received from this group
- Research and development firms referencing utility stoker plants
 - 1 response was received from this group
- University research centers referencing industrial FBC plants
 - 7 responses were received from this group
- University research centers referencing industrial PC plants
 - 8 responses were received from this group
- University research centers referencing industrial stoker plants
 - 4 responses were received from this group
- University research centers referencing utility FBC plants
 - 8 responses were received from this group
- University research centers referencing utility PC plants
 - 8 responses were received from this group
- University research centers referencing utility stoker plants
 - 5 responses were received from this group

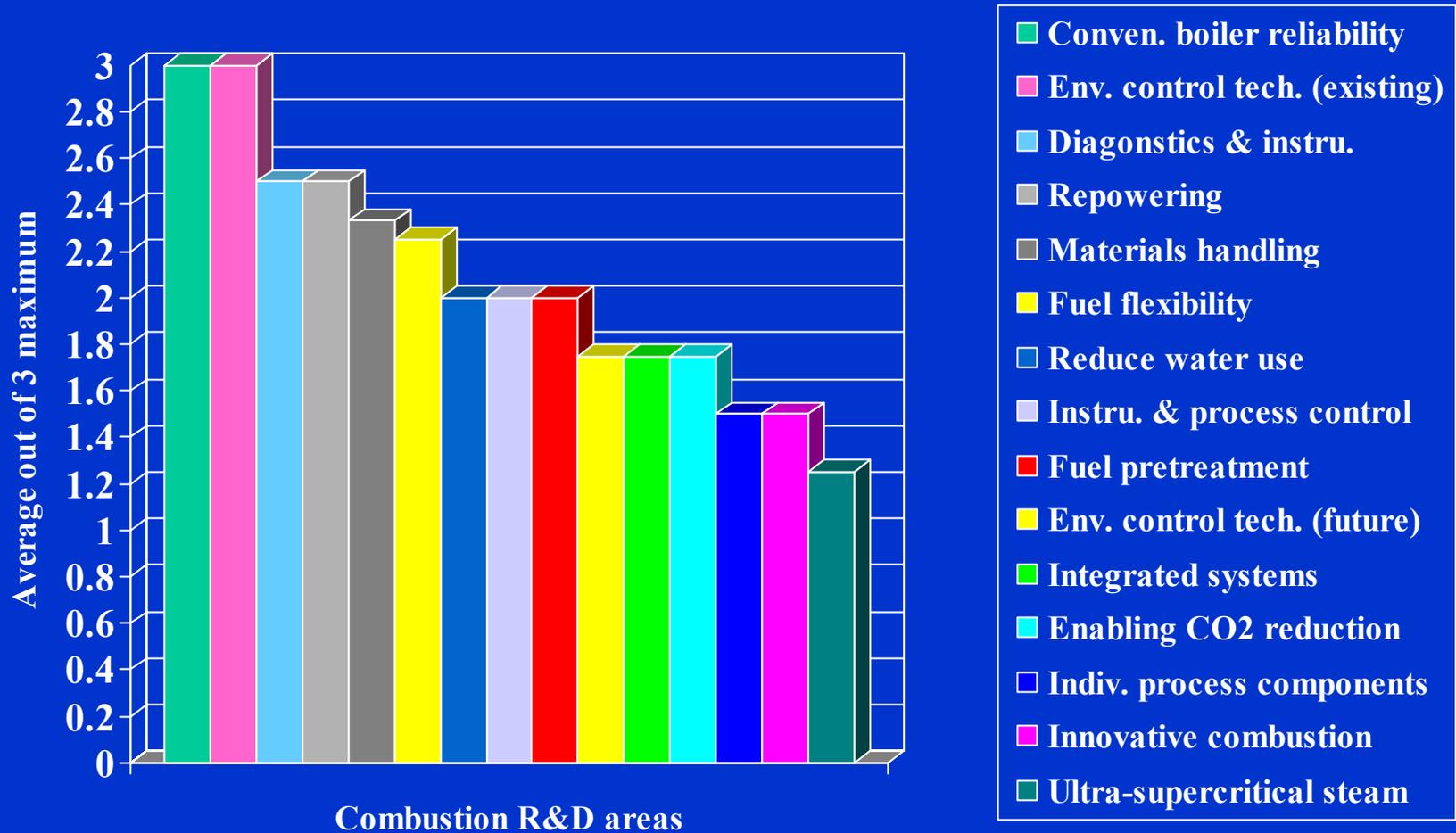
Data Collection Instrument

- Two separate data collection instruments were used
 - One for the first set of groups which are currently using one of the combustion technologies in their firm
 - These firms were asked to respond to a set of 15 combustion research issues as they would prioritize them in relation to the ongoing operation of their current plant
 - Possible responses included: very important, less important, very little (if any) importance
 - One for both the first set of groups and also for a second set of groups with knowledge of combustion technology issues
 - The second set included technology vendors, association representatives, design and engineering firms, research and development firms, and university research centers
 - Second survey included the same set of 15 questions, except that the perspective of the responder was how important the potential combustion technology research and development needs would be for the future use of coal as a fuel for combustion

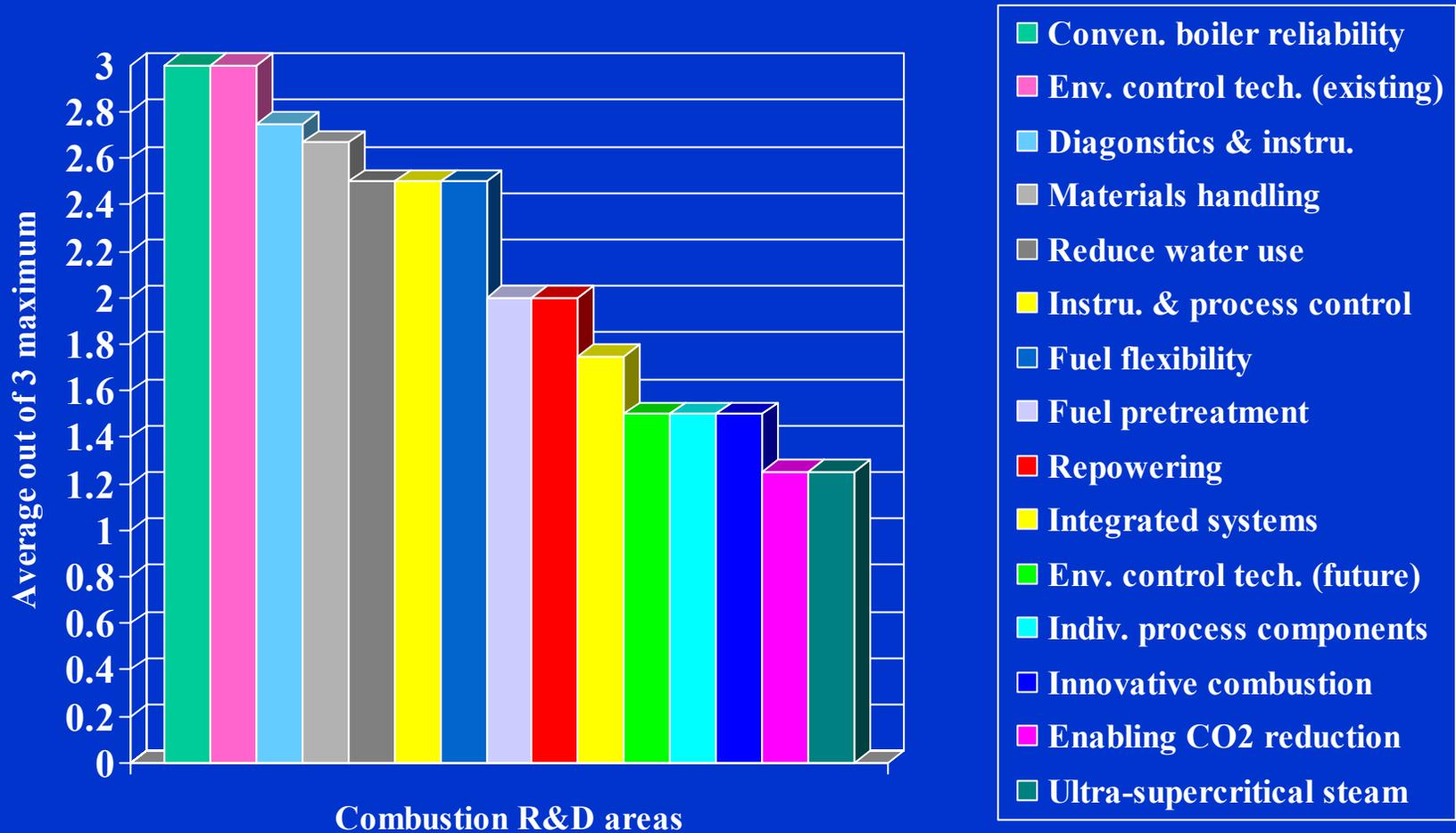
Industrial FBC Plant Owners and Operators



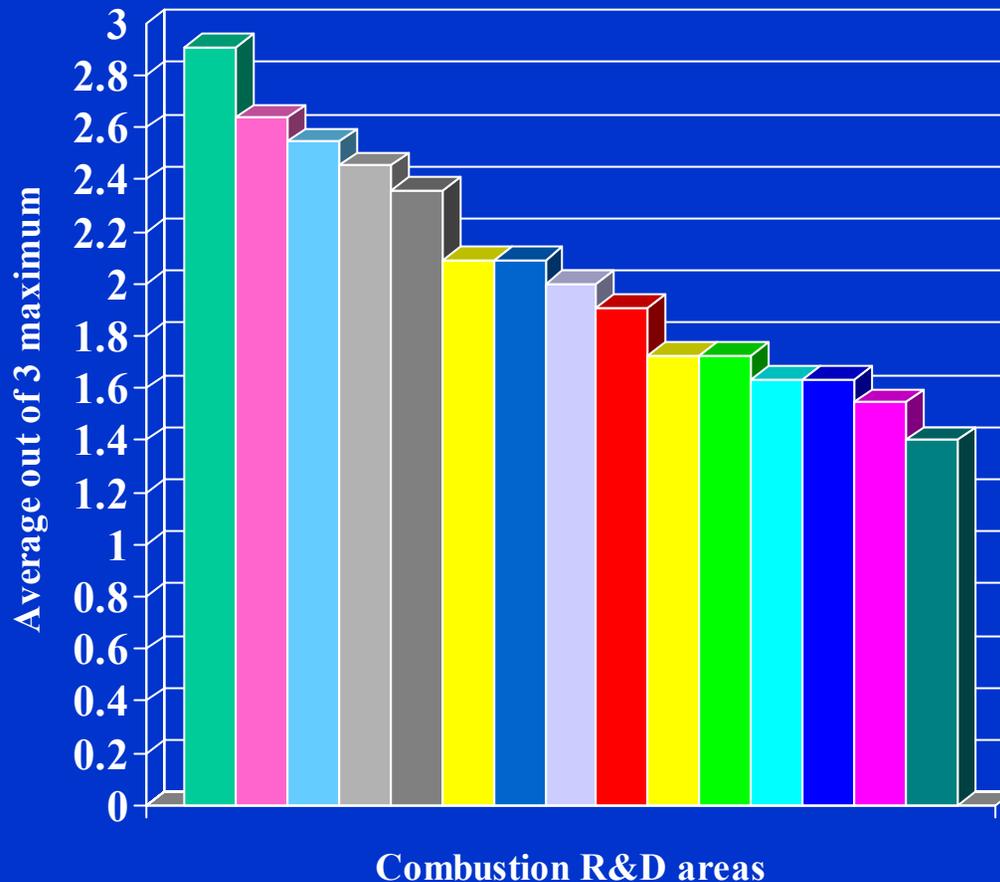
Industrial PC Plant Owners and Operators



Industrial Stoker-Fired Plant Owners and Operators

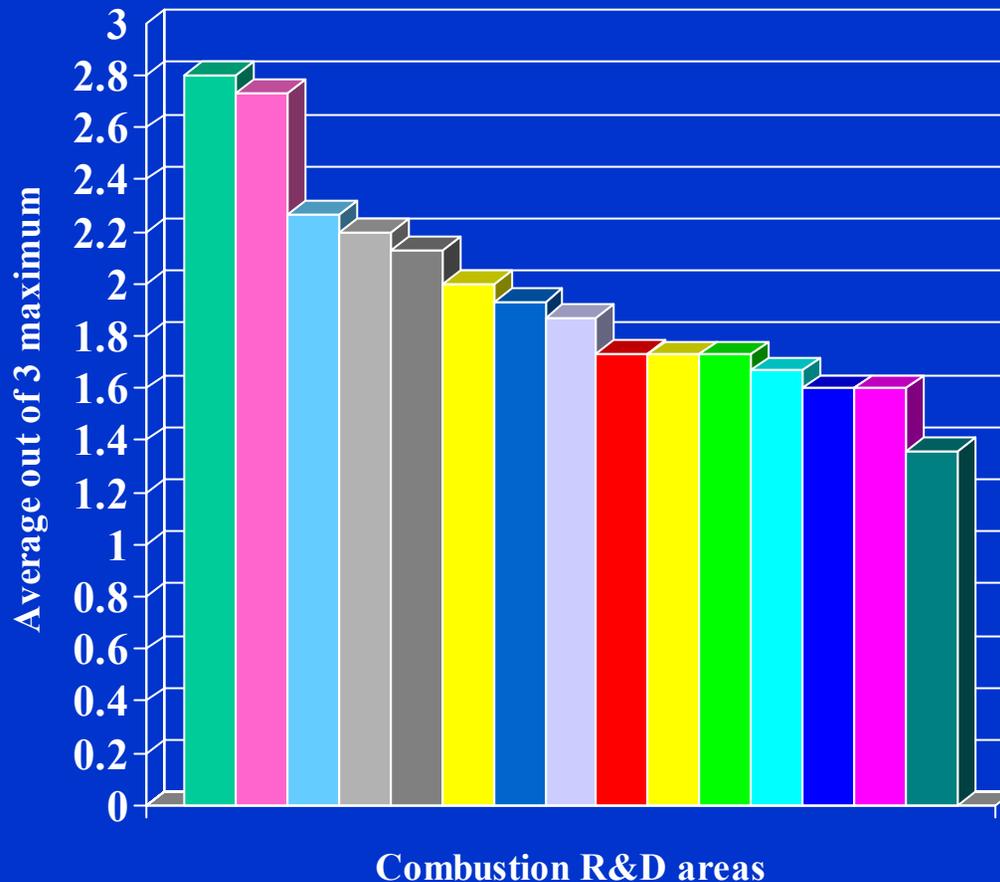


Utility FBC Plant Owners and Operators



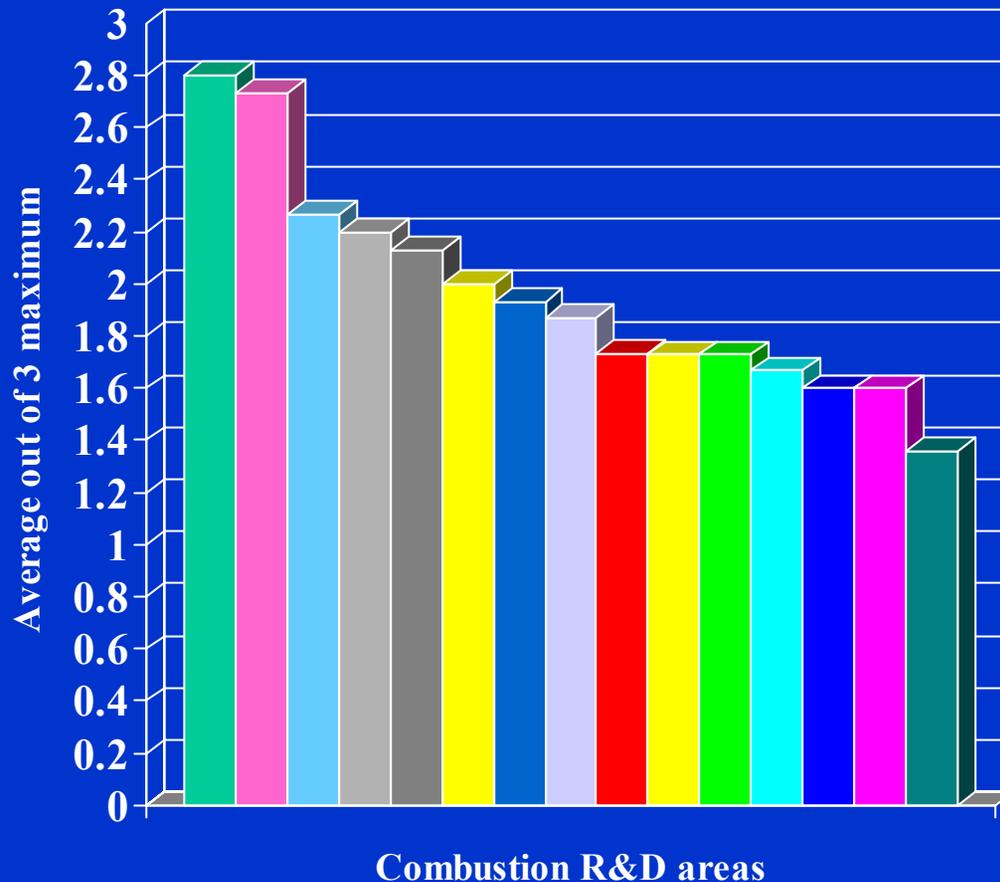
- Conven. boiler reliability
- Fuel flexibility
- Env. control tech. (existing)
- Materials handling
- Diagnostics & instru.
- Reduce water use
- Env. control tech. (future)
- Instru. & process control
- Repowering
- Integrated systems
- Individual process comp.
- Fuel pretreatment
- Enabling CO2 reduction
- Innovative combustion
- Ultra-supercritical steam

Utility PC Plant Owners and Operators



- Conven. boiler reliability
- Env. control tech. (existing)
- Fuel flexibility
- Materials handling
- Diagnostics & instru.
- Instru. & process control
- Env. control tech. (future)
- Repowering
- Reduce water use
- Fuel pretreatment
- Enabling CO2 reduction
- Individual process comp.
- Integrated systems
- Innovative combustion
- Ultra-supercritical steam

Utility Stoker-Fired Plant Owners and Operators



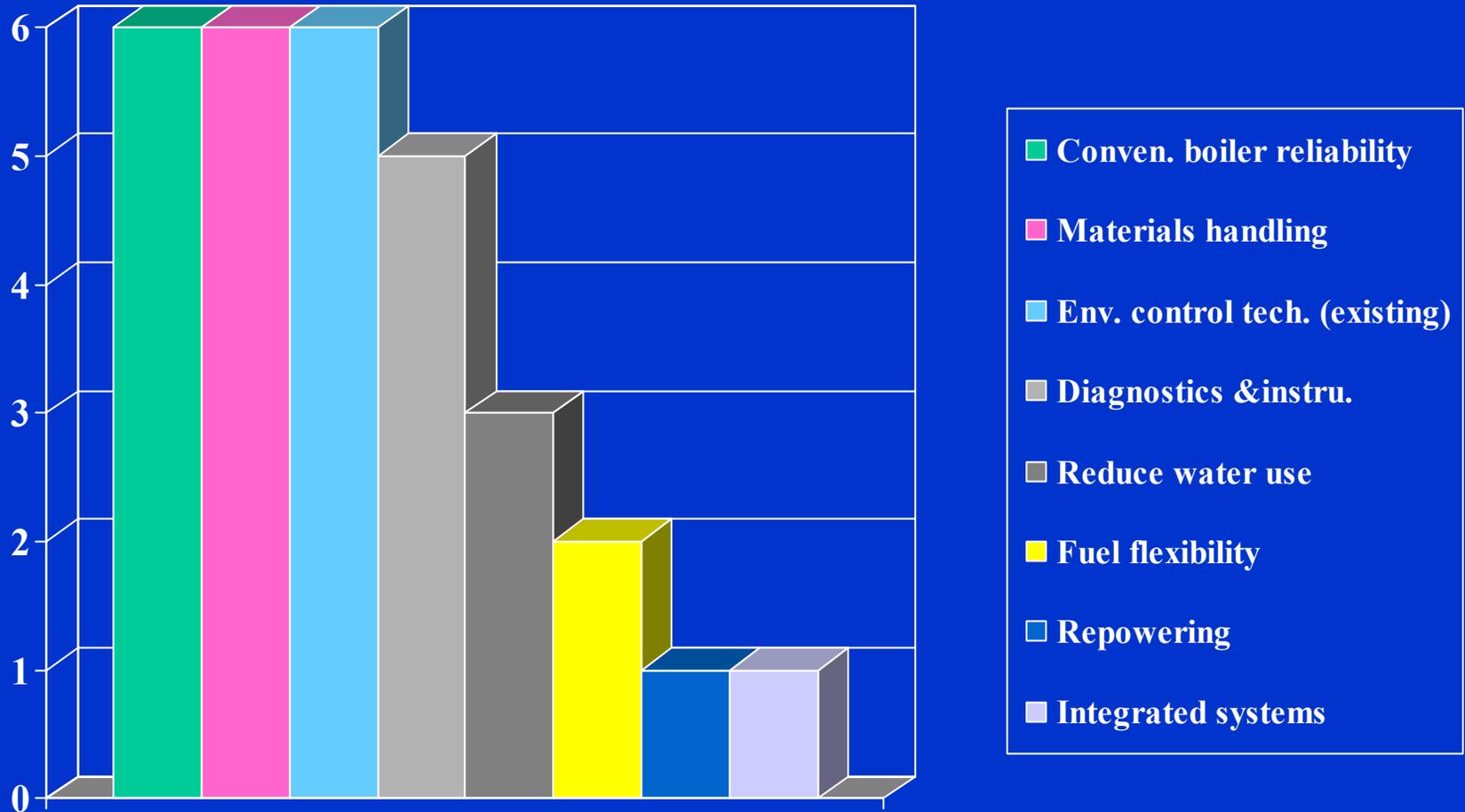
- Conven. boiler reliability
- Env. control tech. (existing)
- Fuel flexibility
- Materials handling
- Diagnostics & instru.
- Instru. & process control
- Env. control tech. (future)
- Repowering
- Reduce water use
- Fuel pretreatment
- Enabling CO2 reduction
- Individual process comp.
- Integrated systems
- Innovative combustion
- Ultra-supercritical steam

Comparison of Importance of Combustion Technology R & D Needs By Responding Group for Ongoing Operations of Current Plants

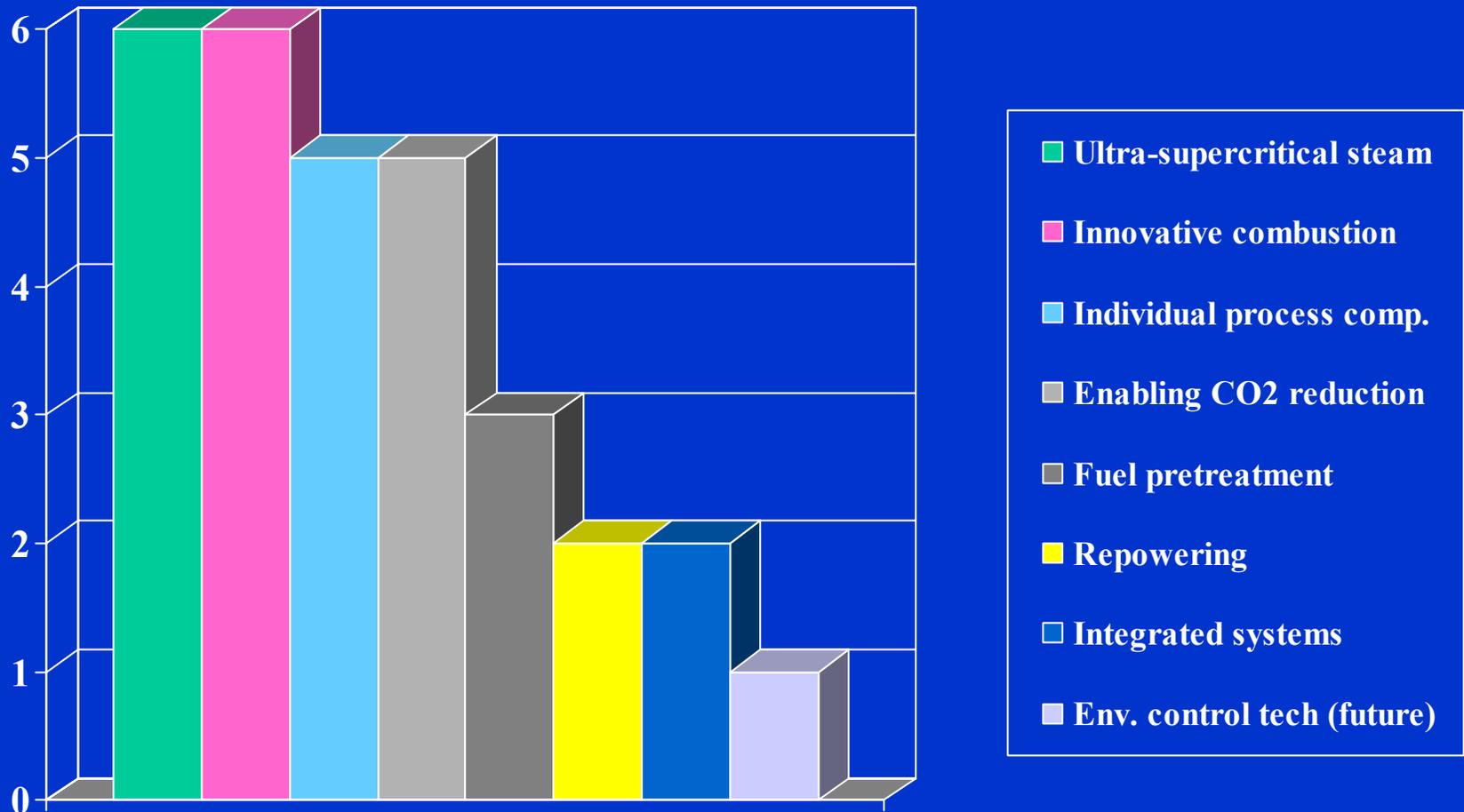
<u>Group</u>	<u>Top five</u>	<u>Middle five</u>	<u>Lowest five</u>
1	3,9,1,4,2	8,5,11,10,15	6,12,7,14,13
2	1,9,4,7,3	8,2,5,6,10	11,15,12,14,13
3	1,9,4,3,2	5,8,6,7,11	10,12,14,13,15
4	1,8,9,3,4	2,10,5,7,11	12,6,15,14,13
5	1,9,8,3,4	5,10,7,2,6	15,12,11,14,13
6	1,3,9,2,11	12,4,5,8,10	7,14,6,13,15

Note: Group 1 is industrial FBC owners and plant managers.
 Group 2 is industrial PC owners and plant managers.
 Group 3 is industrial stoker-fired owners and plant managers.
 Group 4 is utility FBC owners and plant managers.
 Group 5 is utility PC owners and plant managers.
 Group 6 is utility stoker-fired owners and plant managers.

Number Of Groups Out Of Six That Ranked This Item As One Of Their Top Five Combustion R&D Needs



Number Of Groups Out Of Six That Ranked This Item As One Of Their Lowest Five Combustion R&D Needs



Other Comments By Owners and Plant Managers Concerning Combustion Technology R&D Needs

- Ultra-low NO_x combustion (achieve NO_x < 0.05 # per mmBTU without chemical additives or catalysts)
- NO_x and mercury emissions reduction
- Methods to reduce NO_x and mercury
- Repair and maintenance of in-bed coil and metal coatings
- Environmental and regulatory case analysis (BACT analysis for existing and new plants). Goals to simplify permitting process or to identify areas where work is not considered a modification.
- Environmental emissions permits

Comment On Unconventional Fuels From Plant Manager

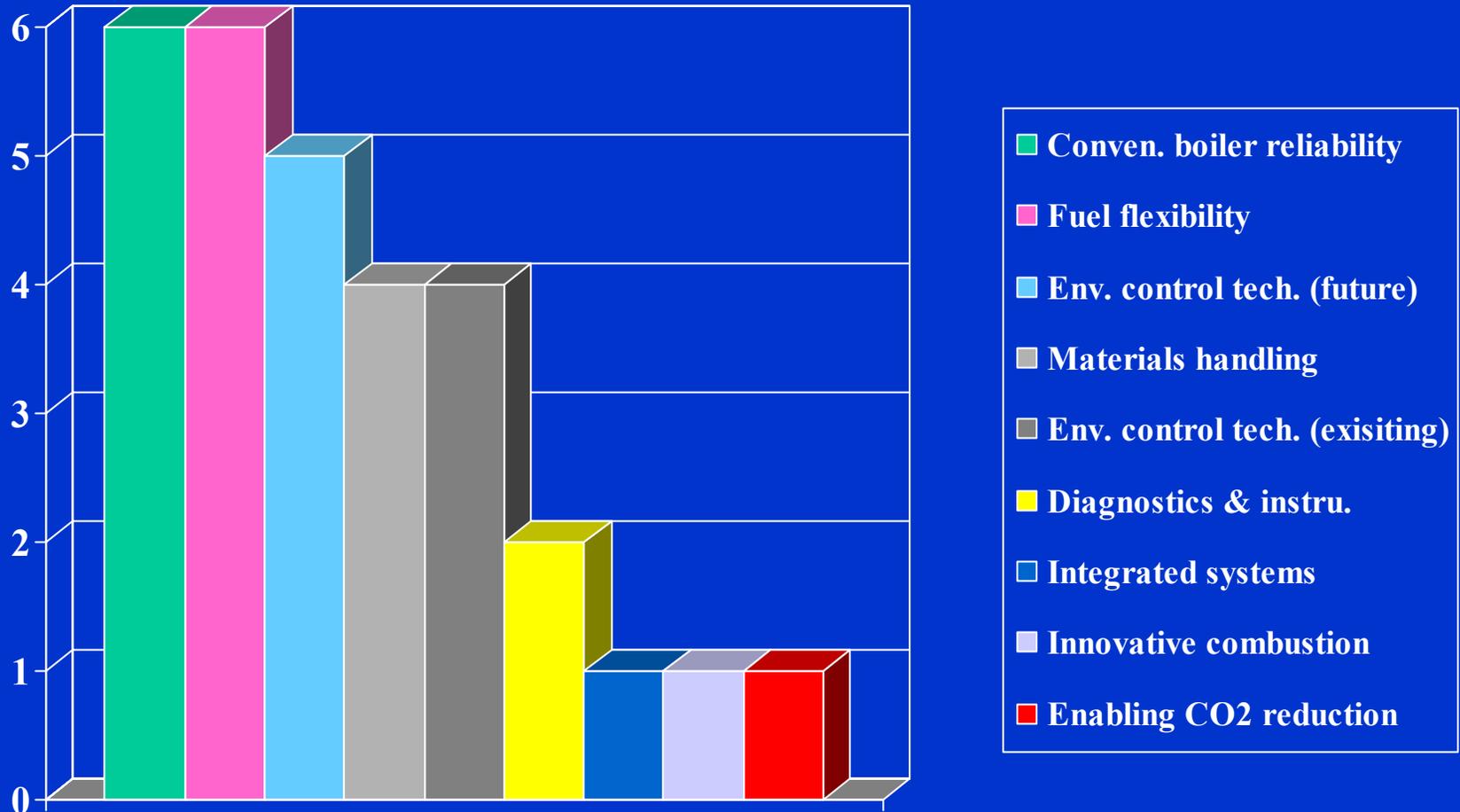
- Thoughts on how unconventional fuels can be transformed into fuels that can be burned in boilers already in operation:
 - They are working with a firm that will process rdf into a fuel with characteristics similar to coal that can be burned in their FBC and PC boilers while avoiding the incinerator regulations. The process involves pyrolysis of rdf. This enables them to get a cheap source of fuel, claim biomass credits, sell “green megawatts”, etc. More and more of their associates are turning to “processed engineered fuels”, which is coming up in the EPA agenda as well. The issue of how to make fuels that can be burned in existing boilers so we do not have to invest in massive capital projects is the “wave of the future”.

Comparison Of Importance of Combustion Technology R & D Needs For The Future Use Of Coal As A Fuel For Combustion By Responding Combustion Technology User Groups

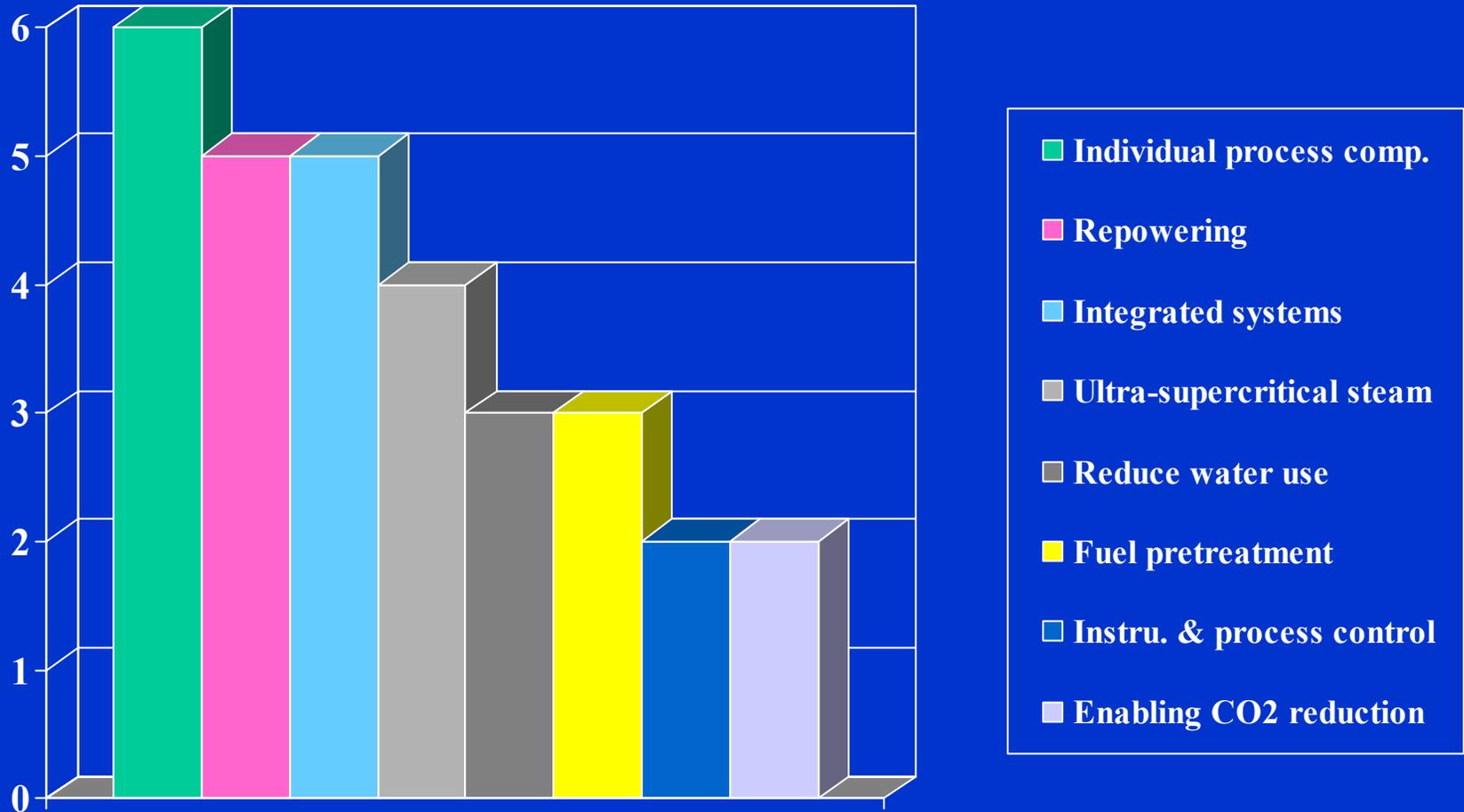
<u>Group</u>	<u>Top five</u>	<u>Middle five</u>	<u>Lowest five</u>
1	9,8,3,10,1	15,4,14,2,5	12,6,11,7,13
2	1,3,8,10,15	4,6,14,9,13	2,5,11,7,12
3	1,3,4,8,10	14,6,15,5,9	13,2,11,12,7
4	8,10,1,9,4	3,2,5,14,7	11,12,13,15,6
5	1,9,8,14,10	6,3,15,4,13	2,5,7,11,12
6	9,1,3,8,11	14,2,4,5,10	12,6,7,15,13

Note: Group 1 is industrial FBC owners and plant managers.
 Group 2 is industrial PC owners and plant managers.
 Group 3 is industrial stoker-fired owners and plant managers.
 Group 4 is utility FBC owners and plant managers.
 Group 5 is utility PC owners and plant managers.
 Group 6 is utility stoker fired owners and plant managers.

Number Of Groups Out Of Six That Ranked This Item As One Of The Top Five Combustion R&D Needs For The Future Use Of Coal As A Fuel For Combustion



Number Of Groups Out Of Six That Ranked This Item As One Of The Lowest Five Combustion R&D Needs For The Future Use Of Coal As A Fuel For Combustion



Comparison Of Importance of Combustion Technology R & D Needs for The Future Use Of Coal As A Fuel For Combustion By Non-Users

<u>Group</u>	<u>Top five</u>	<u>Middle five</u>	<u>Lowest five</u>
1	10,9,8,7,13	3,1,12,2,15	14,5,6,11,4
2	9,8,13,7,15	3,5,1,14,10	4,2,11,6,12
3	7,10,9,6,14	3,8,1,15,12	2,5,11,4,13
4	6,10,14,5,15	2,3,9,1,4	7,8,12,11,13
5	9,7,14,13,15	5,2,6,11,8	3,1,10,4,12
6	7,13,9,14,15	5,11,2,8,6	4,3,10,1,12

Note: Group 1 is technology vendors referencing industrial plants.

Group 2 is technology vendors referencing utilities.

Group 3 is association representatives referencing industrial plants.

Group 4 is association representatives referencing utilities.

Group 5 is design & engineering firms referencing industrial plants.

Group 6 is design & engineering firms referencing utilities.

Comparison Of Importance of Combustion Technology R & D Needs for The Future Use Of Coal As A Fuel For Combustion By Non-Users (continued)

<u>Group</u>	<u>Top five</u>	<u>Middle five</u>	<u>Lowest five</u>
7	9,2,11,8,7	12,13,10,14,15	1,5,4,3,6
8	7,9,2,13,8	3,5,1,10,12	1,6,11,4,15
9	10,9,13,14,4	15,1,5,11,8	7,3,12,2,6
10	13,10,14,4,8	9,5,7,11,15	1,12,2,6,3

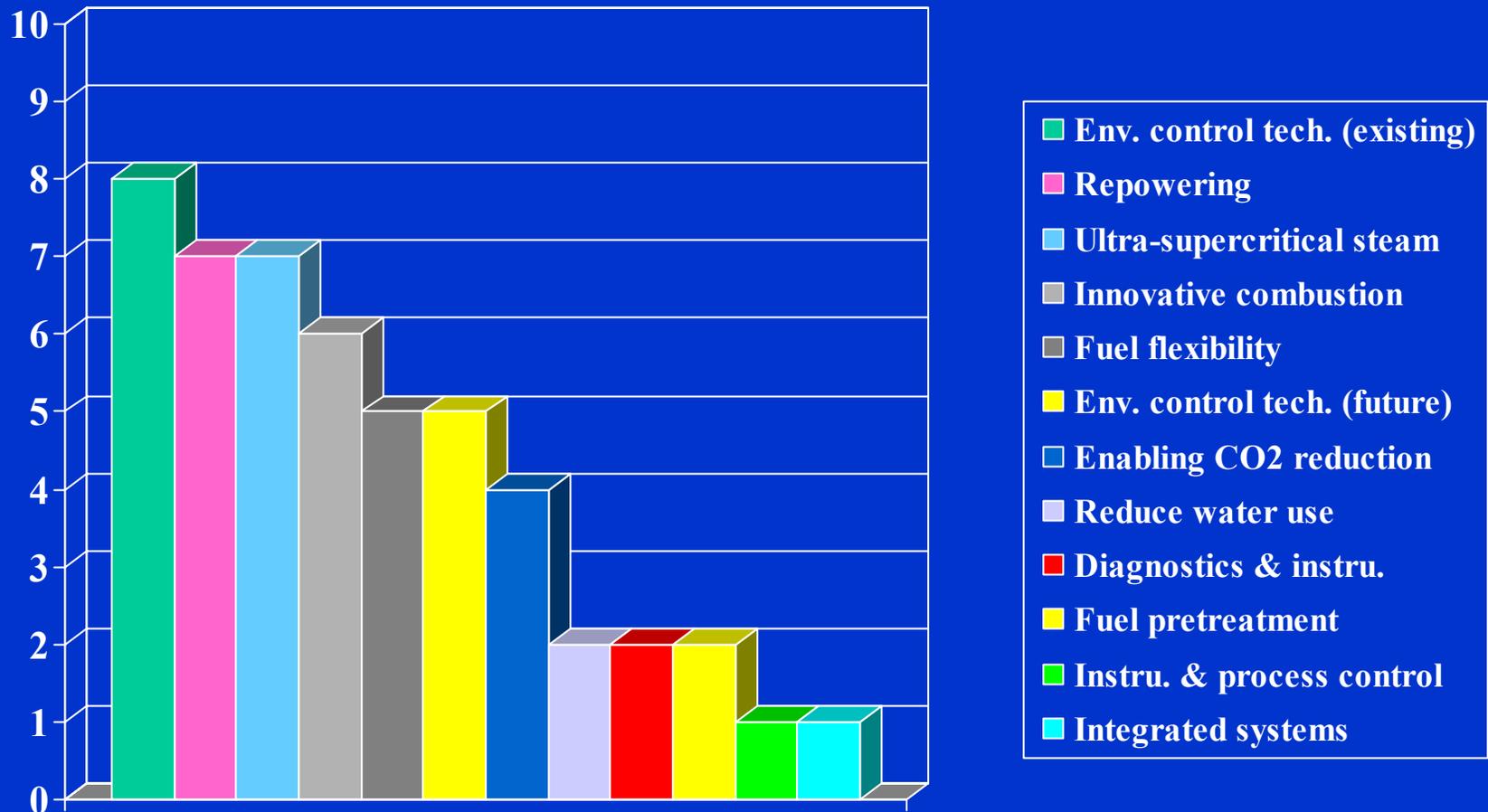
Note: Group 7 is R&D firms referencing industrial plants.

Group 8 is R&D firms referencing utilities.

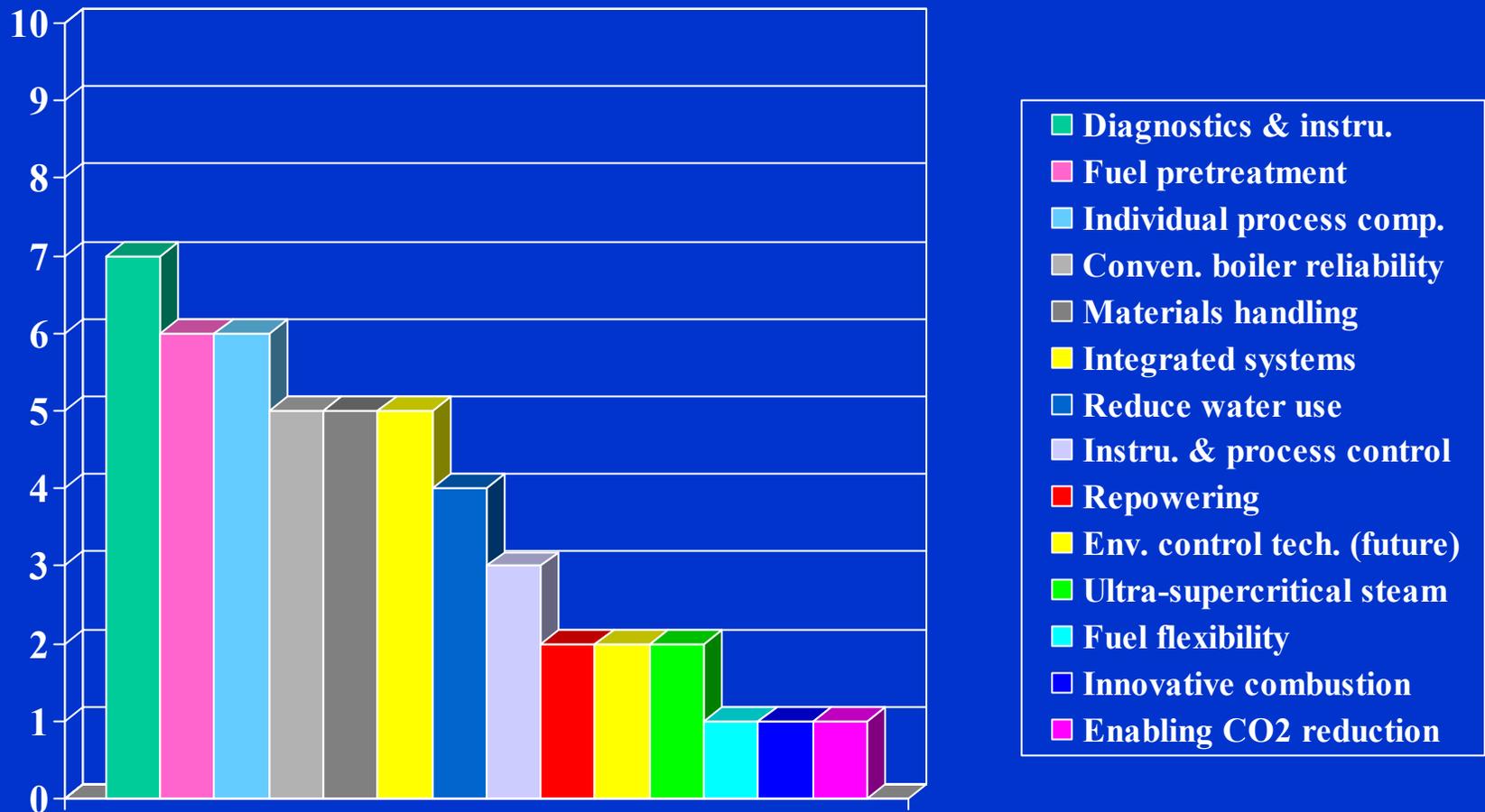
Group 9 is university research centers referencing industrial plants.

Group 10 is university research centers referencing utilities.

Number Of Groups Out Of Ten That Ranked This Item As One Of The Top Five Combustion R&D Needs For The Future Use Of Coal As A Fuel For Combustion



Number Of Groups Out Of Ten That Ranked This Item As One Of The Lowest Five Combustion R&D Needs For The Future Use Of Coal As A Fuel For Combustion



Overall Observations Considering Both Sets Of Groups (combustion technology users and non-users)

- A general observation was that there was not a lot of consistency between the combustion technology user groups and the non-user groups.
- Item 9 (Environmental control technology for existing plants) was shown to be a top five research need for 12 of the possible 16 groups (6 user groups and 10 non-user groups).
- Item 10 (Environmental control technology for future plants) was shown to be a top five research need for 10 of the possible 16 groups
- Item 12 (Design and operation of individual process components) was shown to be in the lowest five research needs for 12 of the possible 16 groups.
- Item 11 (Design and operation for integrated systems) was shown to be in the lowest five research needs for 10 of the possible 16 groups.
- Item 6 (Fuel pretreatment) was shown to be in the lowest five research needs for 9 of the possible 16 groups.
- Item 2 (Reduce water use) was shown to be in the lowest five research needs for 7 of the possible 16 groups.
- Item 3 (Materials handling and transport) seems to be of particular significance to combustion users and of little importance to non-user groups.

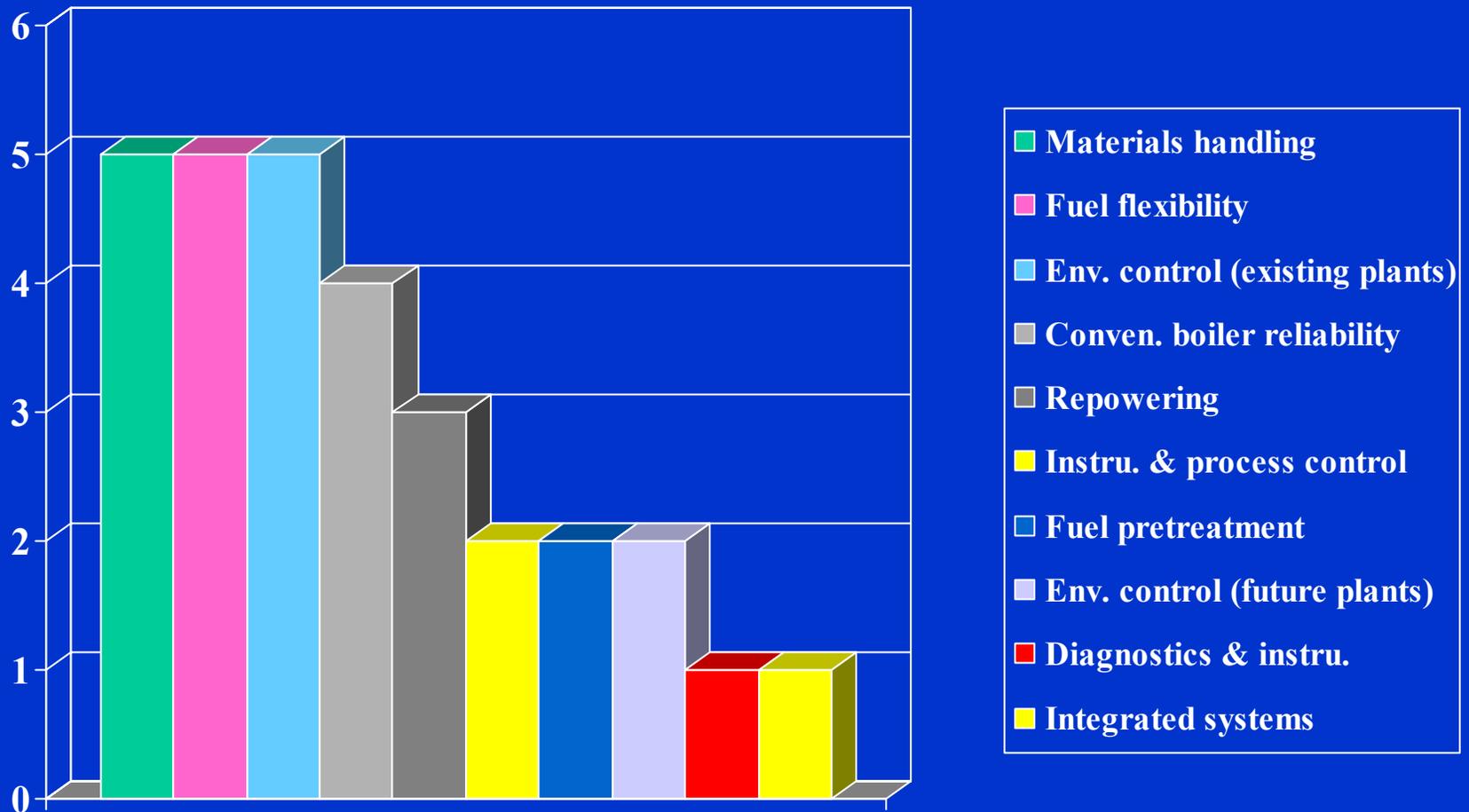
Extra Question 1: Which Potential Combustion R&D Areas Could Improve The Near-Term Cost Competitiveness Of Coal?

(responses from combustion technology user groups)

<u>Group</u>	<u>Top five</u>
all	8,9,1,3,6
1	8,3,7,9,10
2	8,7,6,1,3
3	8,3,6,7,9
4	1,8,9,5,10
5	1,9,8,5,3
6	9,1,3,4,11

Note: Group 1 is industrial FBC owners and plant managers.
Group 2 is industrial PC owners and plant managers.
Group 3 is industrial stoker-fired owners and plant managers.
Group 4 is utility FBC owners and plant managers.
Group 5 is utility PC owners and plant managers.
Group 6 is utility stoker fired owners and plant managers.

Number Of Groups Out Of Six That Ranked This Item As One Of The Top Five Combustion R&D Areas Which Could Improve The Near-Term Cost Competitiveness of Coal



Extra Question 1: Responses From Ten Non-User Groups

<u>Group</u>	<u>Top five</u>
all	9,7,1,13,14
1	9,13,1,7,8
2	9,1,13,14,7
3	7,14,8,9,15
4	7,14,9,3,15
5	7,6,9 (only three items had positive responses)
6	7,6,9 (only three items had positive responses)

Note: Group 1 is technology vendors referencing industrial plants.

Group 2 is technology vendors referencing utilities.

Group 3 is association representatives referencing industrial plants.

Group 4 is association representatives referencing utilities.

Group 5 is design & engineering firms referencing industrial plants.

Group 6 is design & engineering firms referencing utilities.

Extra Question 1: Responses From Non-User Groups (continued)

<u>Group</u>	<u>Top five</u>
7	9,1,7,8,4
8	9,1,7,8,10
9	13,9,14,1,7
10	9,13,1,8,14

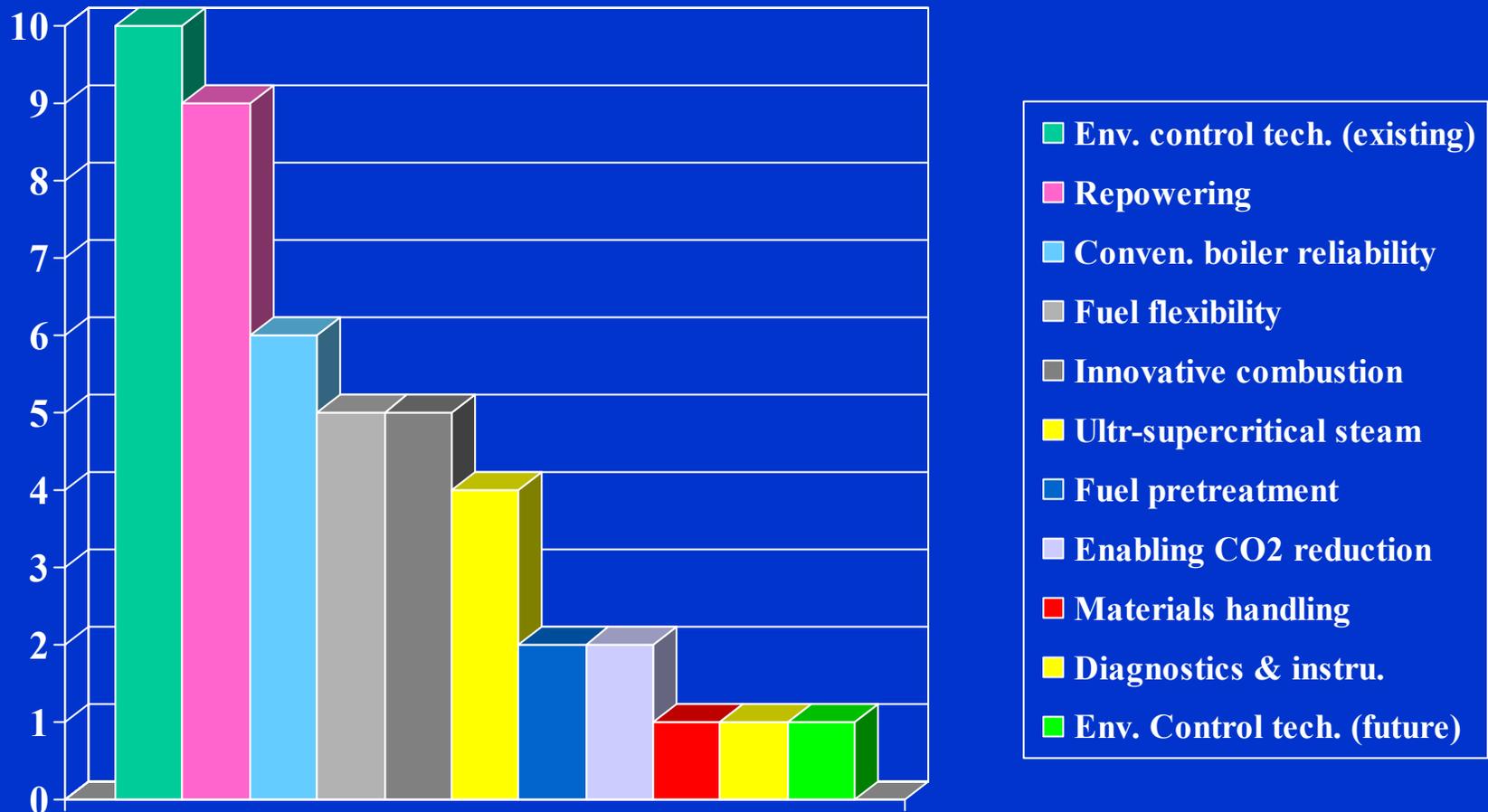
Note: Group 7 is R&D firms referencing industrial plants.

Group 8 is R&D firms referencing utilities.

Group 9 is university research centers referencing industrial plants.

Group 10 is university research centers referencing utilities.

Number Of Groups Out Of Ten That Ranked This Item As One Of The Top Five Combustion R&D Needs Which Could Improve The Near-Term Cost Competitiveness of Coal



Overall Observations Considering Both Sets Of Groups (combustion technology users and non-users) For Extra Question 1

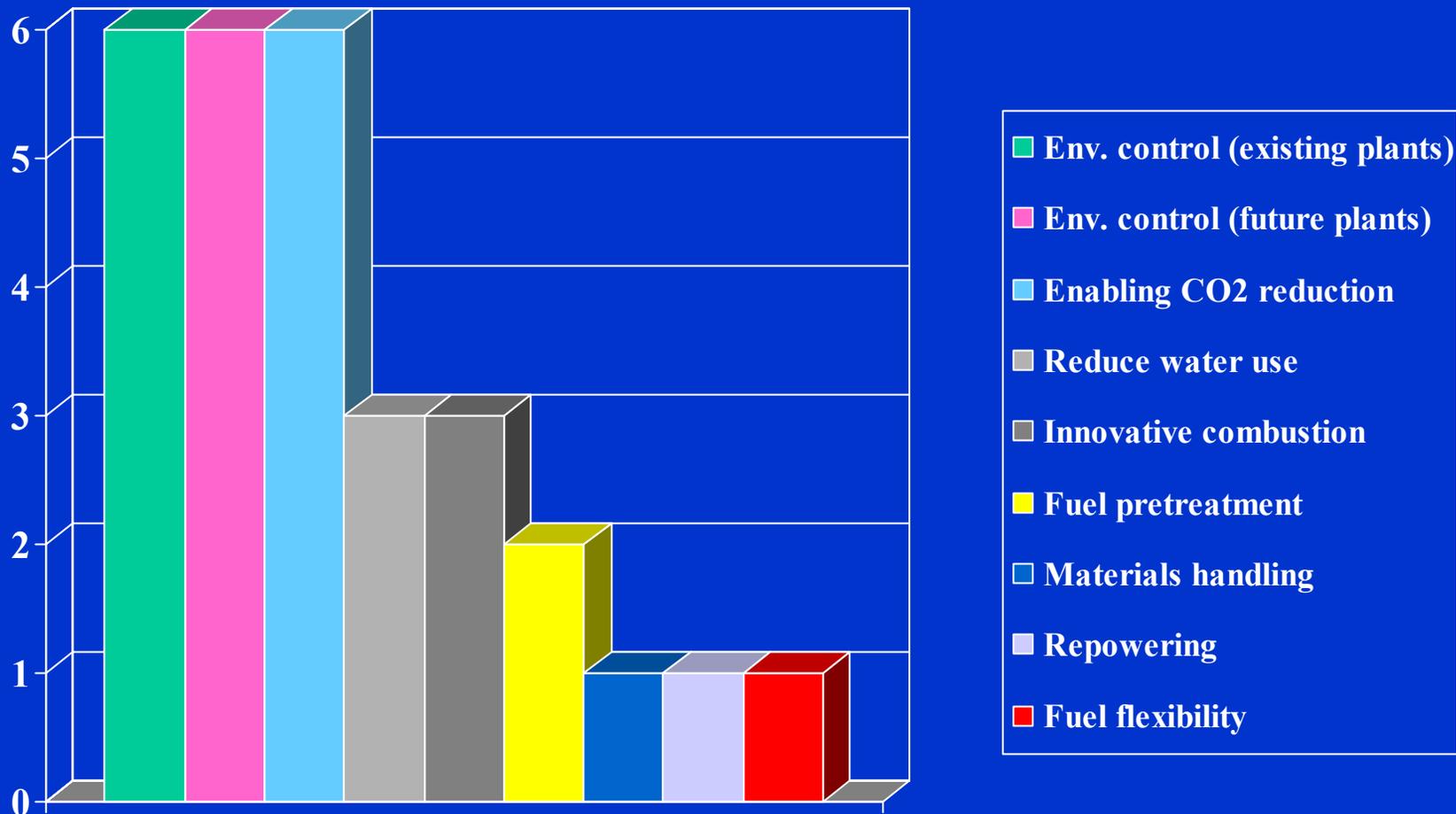
- Item 9 (Environmental control technology for existing plants) was shown to be a top five research need for 15 of the possible 16 groups (6 user groups and 10 non-user groups).
- Item 7 (Repowering) was shown to be a top five research need for 12 of the possible 16 groups
- Items 1 (Conventional boiler reliability) and 8 (Fuel flexibility) were shown to be a top five research need for 10 of the possible 16 groups.
- Item 3 (Materials handling and transport) was shown to be a top five research need for 6 of the possible 16 groups. (The materials handling and transport research item seems to be of particular importance to combustion users and of little importance to the non-user group.)

Extra Question 2: Which Potential Combustion R&D Areas Could Foster Long-Term Public Acceptance Of Coal Use? (responses from combustion technology user groups)

<u>Group</u>	<u>Top five</u>
all	9,10,15,14,2
1	15,9,10,7,14
2	15,9,2,10,6
3	15,10,2,9 (only 4 items had responses)
4	9,10,15,2,14
5	9,10,14,6,15
6	9,3,8,10,15

Note: Group 1 is industrial FBC owners and plant managers.
Group 2 is industrial PC owners and plant managers.
Group 3 is industrial stoker-fired owners and plant managers.
Group 4 is utility FBC owners and plant managers.
Group 5 is utility PC owners and plant managers.
Group 6 is utility stoker fired owners and plant managers.

Number Of Groups Out Of Six That Ranked This Item As One Of The Top Five Combustion R&D Areas Which Could Foster Long-Term Public Acceptance Of Coal



Extra Question 2: Responses From Ten Non-User Groups

<u>Group</u>	<u>Top five</u>
all	15,10,9,14,13
1	15,10,14,13,9
2	15,10,14,7,13
3	6,7,9,10,1
4	6,10,7,1,9
5	13,14,15 (only three items had positive responses)
6	13,14,15 (only three items had positive responses)

Note: Group 1 is technology vendors referencing industrial plants.

Group 2 is technology vendors referencing utilities.

Group 3 is association representatives referencing industrial plants.

Group 4 is association representatives referencing utilities.

Group 5 is design & engineering firms referencing industrial plants.

Group 6 is design & engineering firms referencing utilities.

Extra Question 2: Responses From Non-User Groups (continued)

<u>Group</u>	<u>Top five</u>
7	15,10,2,9,13
8	10,15,9,14,13
9	9,10,15,14,3
10	9,10,15,3,14

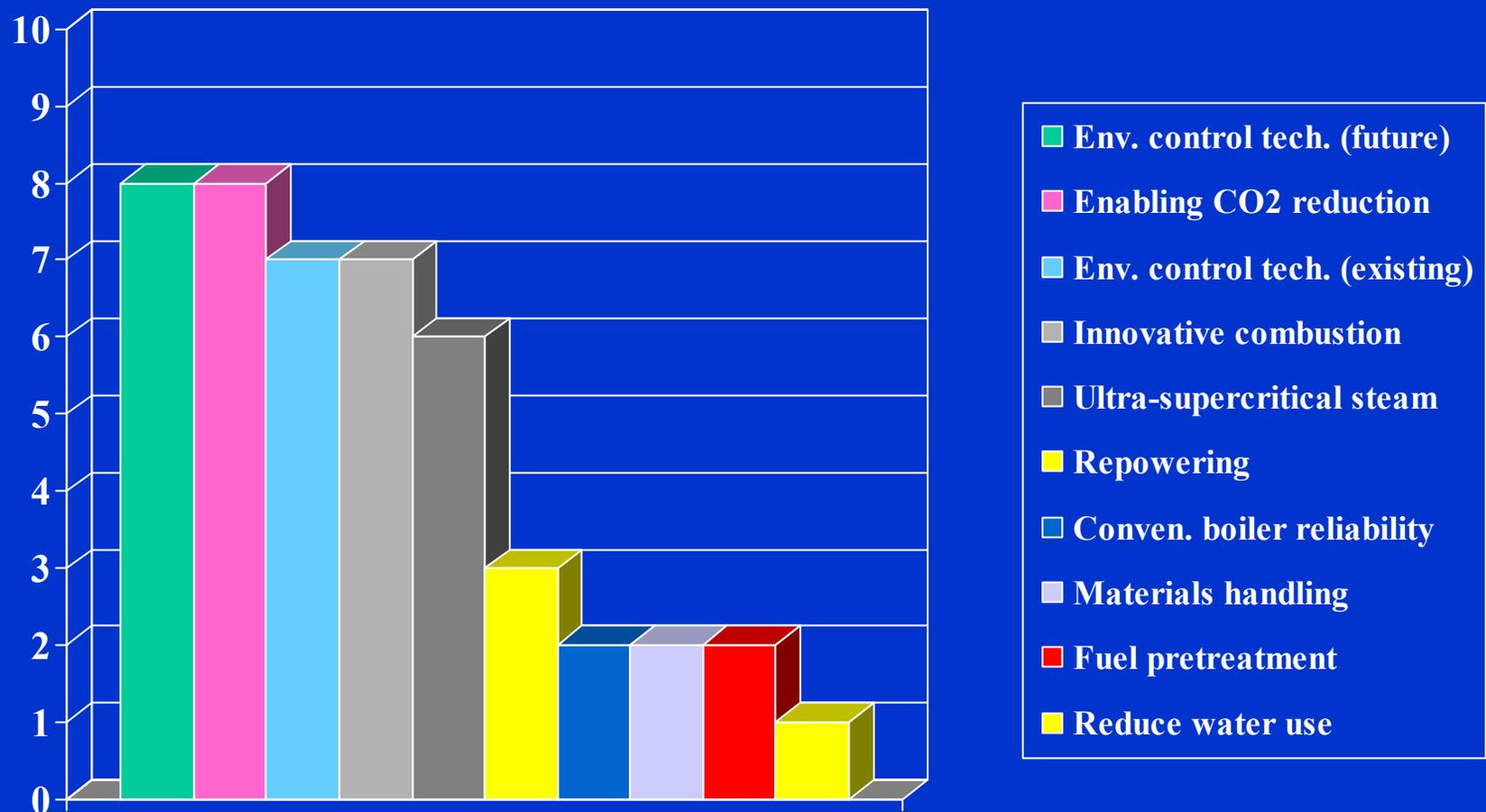
Note: Group 7 is R&D firms referencing industrial plants.

Group 8 is R&D firms referencing utilities.

Group 9 is university research centers referencing industrial plants.

Group 10 is university research centers referencing utilities.

Number Of Groups Out Of Ten That Ranked This Item As One Of The Top Five Combustion R&D Needs Which Could Foster Long-Term Public Acceptance Of Coal



Overall Observations Considering Both Sets Of Groups (combustion technology users and non-users) For Extra Question 2

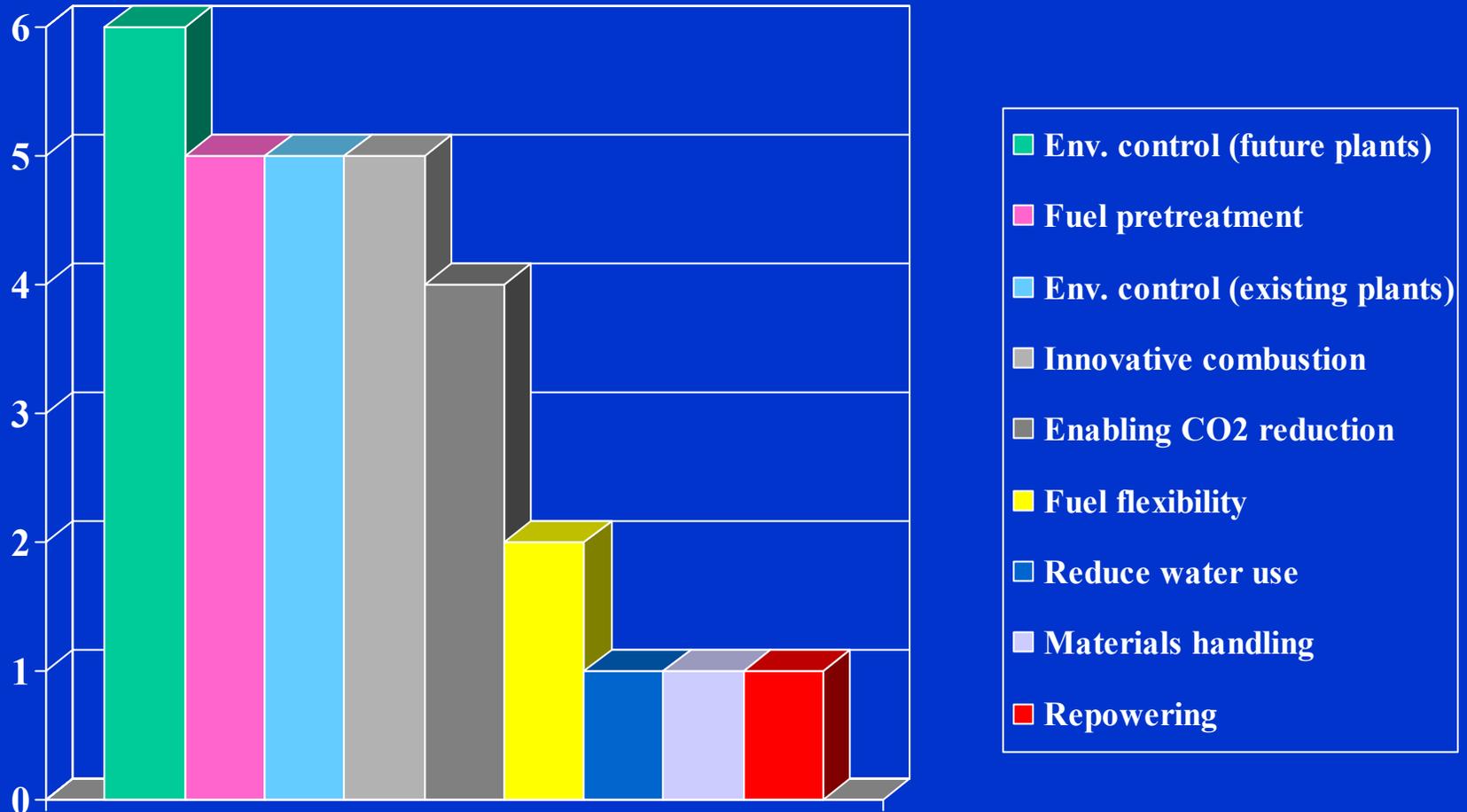
- Items 10 (Environmental control technology for future plants) and 15 (Enabling CO2 reduction) were shown to be a top five research need for 14 of the possible 16 groups (6 user groups and 10 non-user groups).
- Item 9 (Environmental control technology for existing plants) was shown to be a top five research need for 13 of the possible 16 groups
- Item 14 (Innovative combustion systems) was shown to be a top five research need for 10 of the possible 16 groups.
- Item 13 (Ultra-supercritical steam cycle) was shown to be a top five research need for 6 of the possible 16 groups.
- Item 13 (Ultra-supercritical steam cycle) seems to be of no importance on question 2 to the six combustion user groups but of some importance to the ten non-user groups.

Extra Question 3: Which Potential Combustion R&D Areas Would Be Most Appropriate For U.S. Government Support? (responses from combustion technology user groups)

<u>Group</u>	<u>Top five</u>
all	9,10,14,15,6
1	14,15,9,10,6
2	6,15,9,10,14
3	14,15,2,6,10
4	10,9,8,14,6
5	9,7,10,14,6
6	9,3,8,10,15

Note: Group 1 is industrial FBC owners and plant managers.
Group 2 is industrial PC owners and plant managers.
Group 3 is industrial stoker-fired owners and plant managers.
Group 4 is utility FBC owners and plant managers.
Group 5 is utility PC owners and plant managers.
Group 6 is utility stoker fired owners and plant managers.

Number Of Groups Out Of Six That Ranked This Item As One Of The Top Five Combustion R&D Areas Which Would Be Most Appropriate For U.S. Government Funding



Extra Question 3: Responses From Ten Non-User Groups

<u>Group</u>	<u>Top five</u>
all	14,15,10,9,13
1	14,15,9,10,13
2	14,15,10,9,13
3	14,2,7,15 (only four items had positive responses)
4	15,6,2,10,14
5	7,9,14 (only three items had positive responses)
6	7,9,14 (only three items had positive responses)

Note: Group 1 is technology vendors referencing industrial plants.

Group 2 is technology vendors referencing utilities.

Group 3 is association representatives referencing industrial plants.

Group 4 is association representatives referencing utilities.

Group 5 is design & engineering firms referencing industrial plants.

Group 6 is design & engineering firms referencing utilities.

Extra Question 3: Responses From Non-User Groups (continued)

<u>Group</u>	<u>Top five</u>
7	9,15,2,14,7
8	2,7,9,15,14
9	10,15,14,9,13
10	10,15,14,9,13

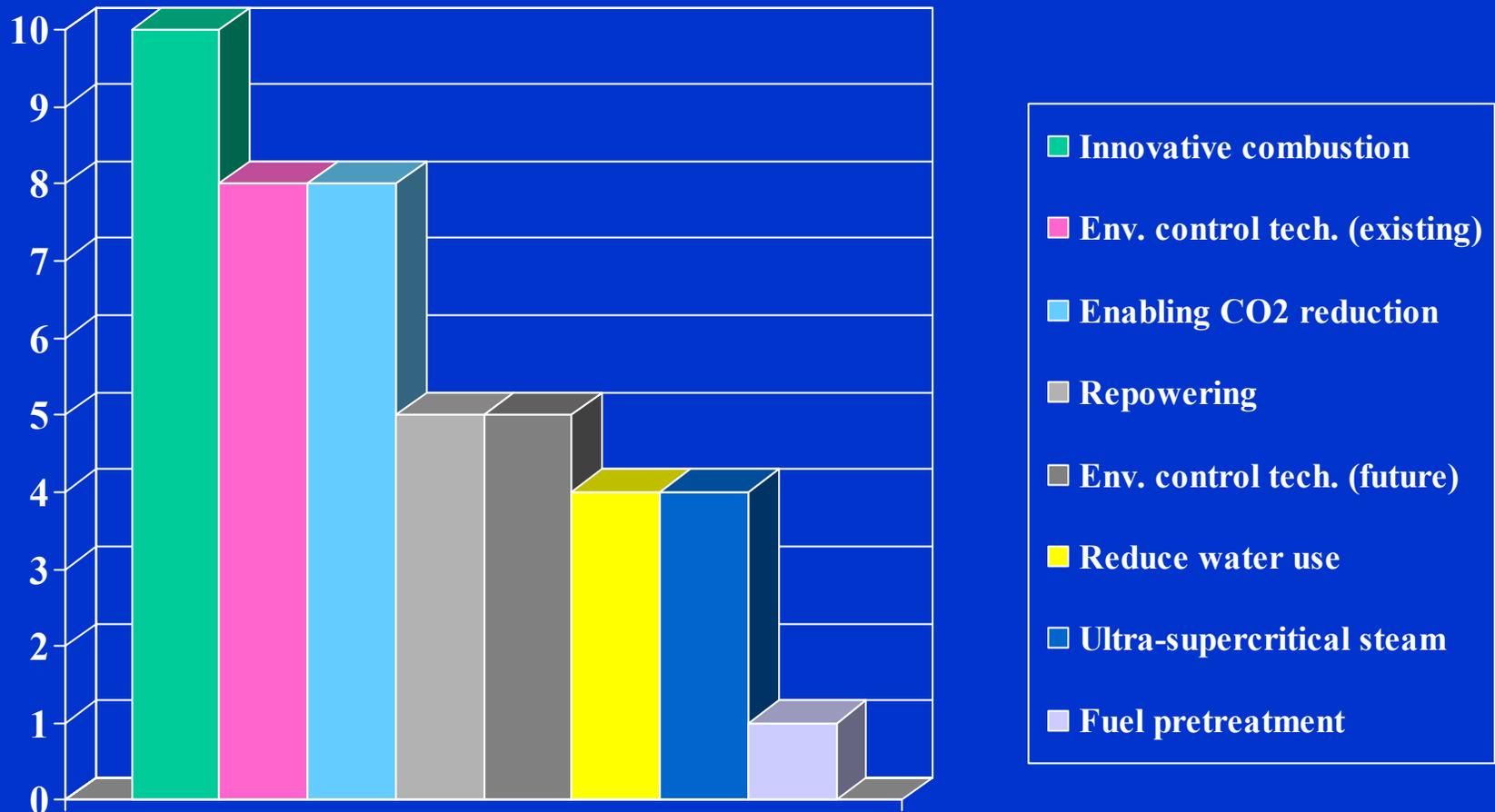
Note: Group 7 is R&D firms referencing industrial plants.

Group 8 is R&D firms referencing utilities.

Group 9 is university research centers referencing industrial plants.

Group 10 is university research centers referencing utilities.

Number Of Groups Out Of Ten That Ranked This Item As One Of The Top Five Combustion R&D Needs Which Would Be Most Appropriate For U.S. Government Support



Overall Observations Considering Both Sets Of Groups (combustion technology users and non-users) For Extra Question 3

- Item 14 (Innovative combustion systems) was shown to be a top five research need for 15 of the possible 16 groups (6 user groups and 10 non-user groups).
- Item 9 (Environmental control technology for existing plants) was shown to be a top five research need for 13 of the possible 16 groups
- Item 15 (Enabling CO₂ reduction) was shown to be a top five research need for 12 of the possible 16 groups.
- Item 10 (Environmental control technology for future plants) was shown to be a top five research need for 11 of the possible 16 groups.
- Item 6 (Fuel pretreatment) was shown to be a top research need for 6 of the possible 16 groups.
- Again, it was apparent that item 13 (Ultra-critical steam cycle) was of some importance to the ten non-user groups and of no importance for funding for the six combustion users groups.