

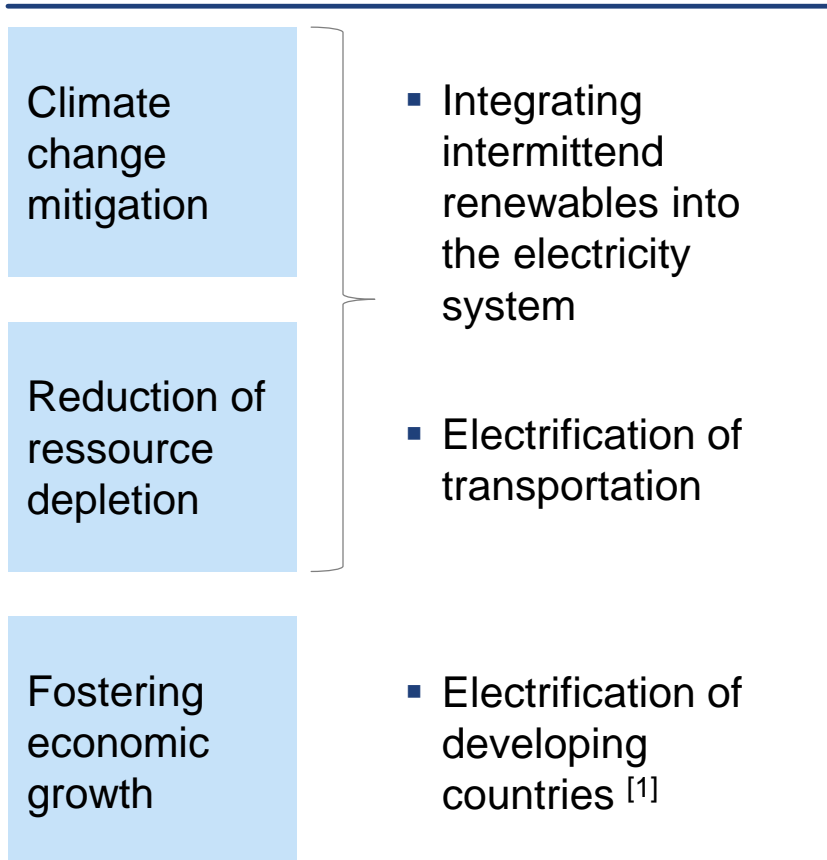


Knowledge creation across industry sectors in the field of lithium-ion batteries –
Who knows what, when and why?

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April, 14th, 2015

Lithium-ion batteries can play a key role in several means to cope with the world's key challenges



Lithium-ion batteries can play a key role in several means to cope with the world's key challenges

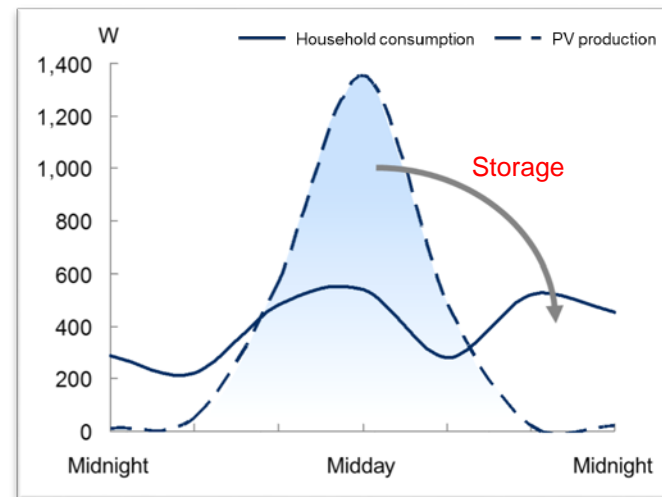
Climate change mitigation

Reduction of resource depletion

Fostering economic growth

- Integrating intermittend renewables into the electricity system
- Electrification of transportation
- Electrification of developing countries

Storage can shift electricity supply and demand



Lithium-ion batteries can play a key role in several means to cope with the world's key challenges

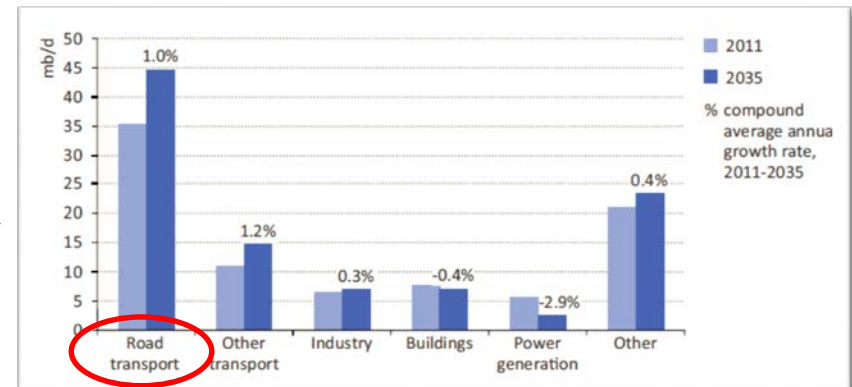
Climate change mitigation

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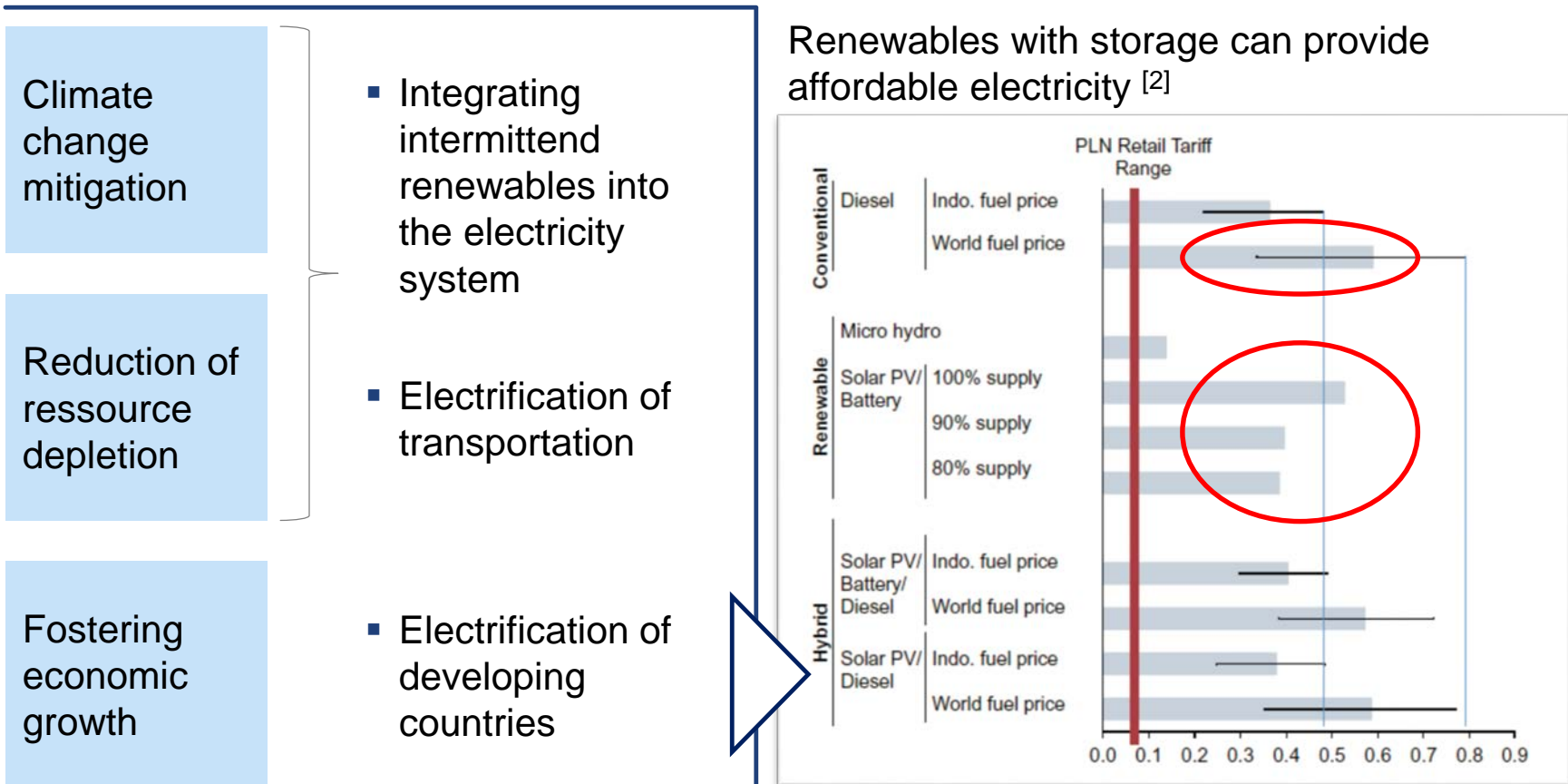
Fostering economic growth

- Integrating intermittent renewables into the electricity system
- Electrification of transportation [1]
- Electrification of developing countries

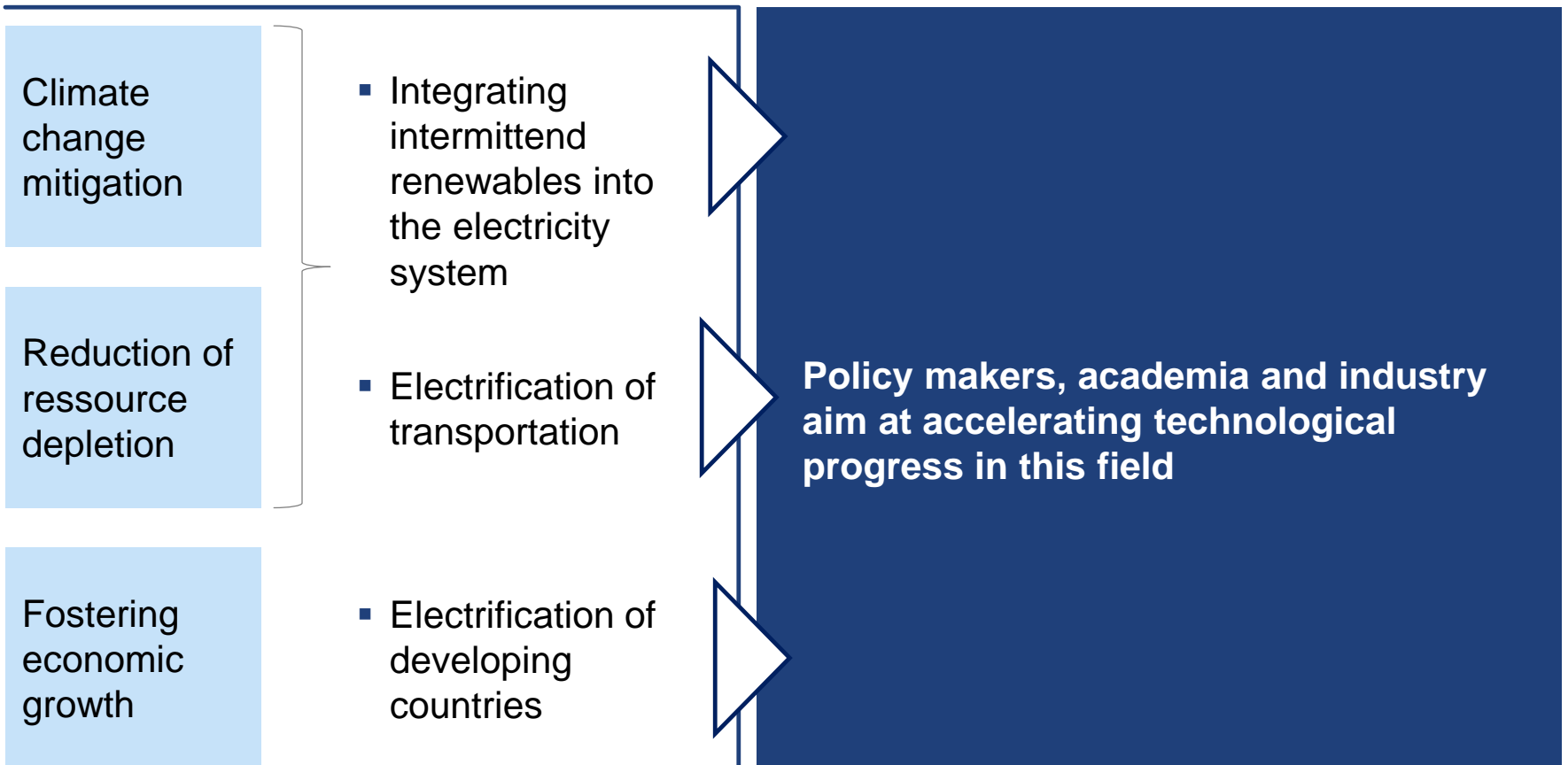
Highest world oil demand comes from the transportation sector [1], which can be reduced due to electric vehicles



Lithium-ion batteries can play a key role in several means to cope with the world's key challenges



Lithium-ion batteries can play a key role in several means to cope with the world's key challenges



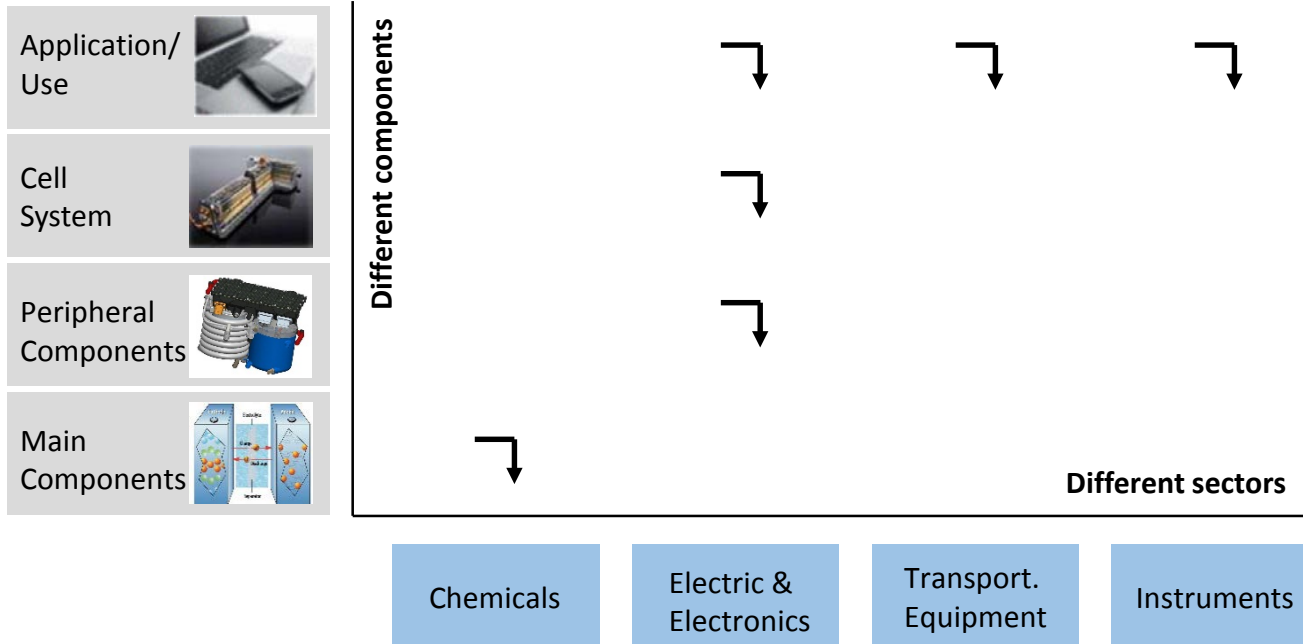
Lithium-ion battery technology is...

...important for the future energy system

→ Technological change is aimed by policy makers, academia and industry

↪ **Knowledge creation**

...a multi-component technology that is **produced** in **different sectors**



Which patterns of knowledge creation can be found across the different sectors of the lithium-ion battery technology?

Agenda

- Theoretical Embedding
- Data & Methodology
- Results & Discussion
- Implications & Further Research

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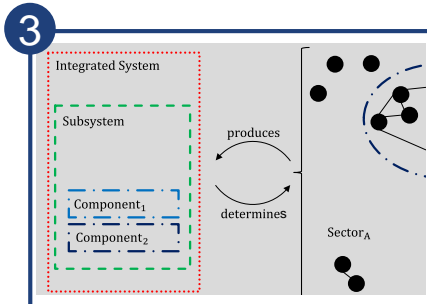
Literature gap

This study is a first attempt to investigate...

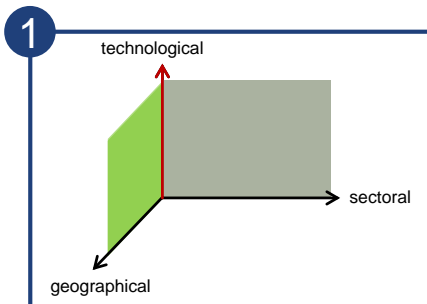
2

Dimensions ⁽¹⁾	Sectors' differences
Technological artifacts	<ul style="list-style-type: none"> Different outputs (according to definition)
Knowledge bases	<ul style="list-style-type: none"> Different product and process knowledge Center around/come from different scientific fields
Actors and networks	<ul style="list-style-type: none"> Different firms Sector-specific networks
Institutions	<ul style="list-style-type: none"> Different laws, norms, habits Different standardization bodies and processes Different labor markets and financial institutions

the sectoral dimension



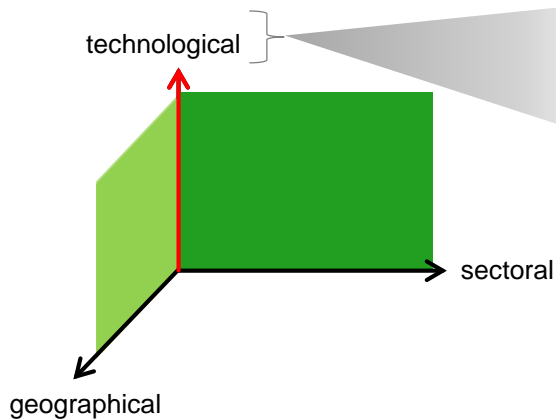
of a multi-component



technological innovation system (TIS)

1 The technological innovation system approach lacks a sectoral conceptualization...

Innovation System Approaches



Technological Innovation System

- **Aim:** Understanding mechanisms underlying the evolution of technologies to derive policy recommendations [3]
- **Systemic perspective** on a technology [4]
- **Knowledge development and diffusion** is one of the most important processes shaping TIS evolution [5],[6]
- TISs are affected (or constrained) by geographical and sectoral dimensions [4],[7]

BUT: Sectoral dimension has not been explicitly analyzed before

A sectoral conceptualization might help TIS scholars to develop an enhanced understanding of technological evolution

2 ...although sectors differ in their innovation behavior due to differences in certain dimensions

Sector = The aggregation of firms with **similar output** that are in **competition** with each other and that center around **similar production techniques**.

Dimensions^[8]

Sectors' differences

Technological artifacts

- Different outputs (according to definition)

Knowledge bases

- Different product and process knowledge
- Center around/come from different scientific fields

Actors and networks

- Different firms
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Institutions

- Different laws, norms, habits
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Different types of sectors in terms of innovation behavior ^{[9],[10],[11]}

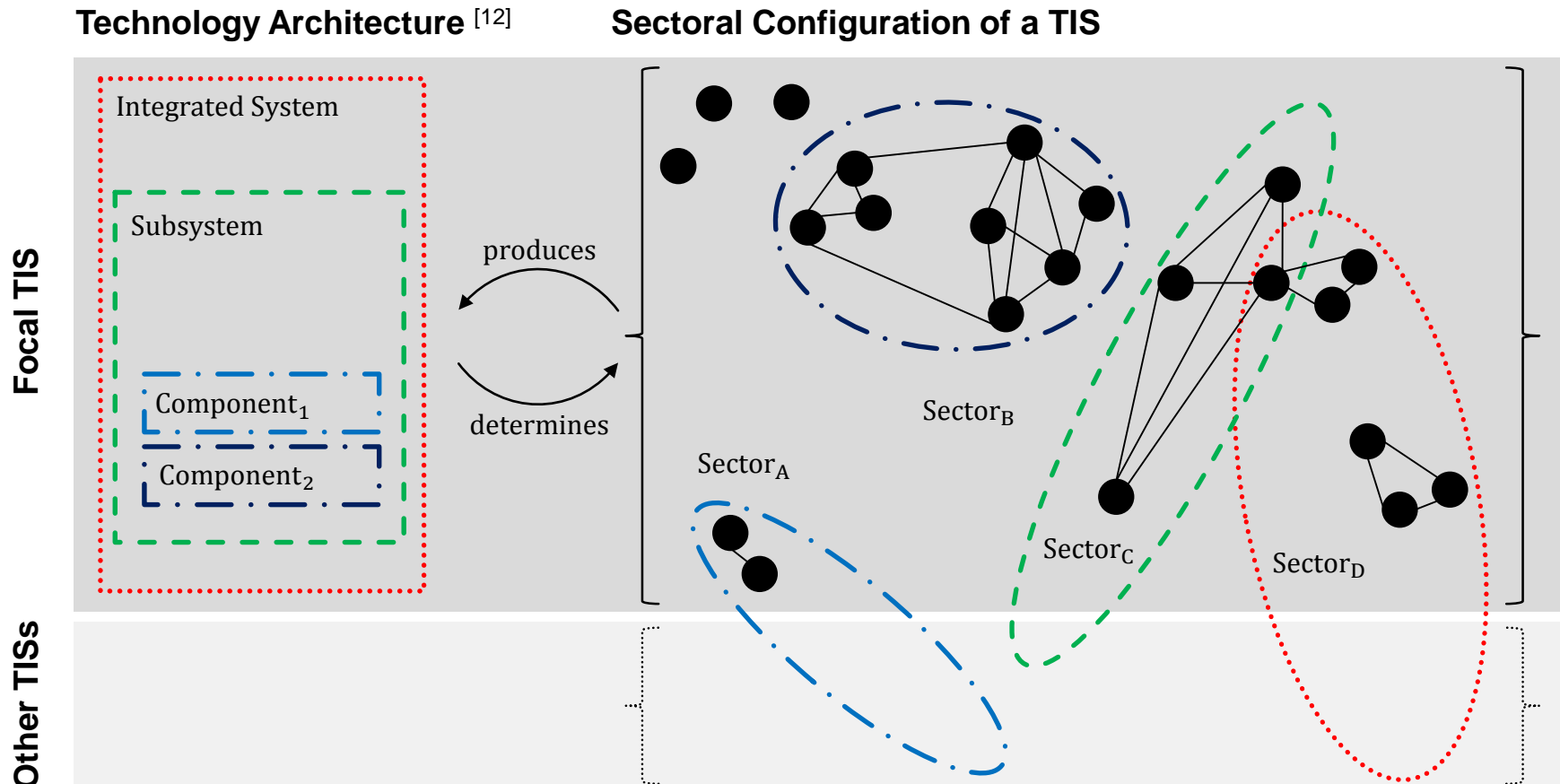
[8] Malerba (2004),

[9] Pavitt (1984), [10] Iammarino & McCann (2006), [11] Breschi & Malerba (1997) distinguish between different sector types based on different dimensions

3 ...and multi-component technologies cut across different sectors

- Actor
- Sector-specific network
- ▭ Technology artifact
- Sectoral boundary

Relationship between technology architecture and the sectoral configuration of a TIS



[12] Henderson & Clark (1990)

Explanations of the used terms

Terms	Explanations
Technological innovation system (TIS)	<ul style="list-style-type: none">• Encompasses all actors that interact "in a specific economic/industrial area under a particular institutional infrastructure and involved in the generation, diffusion, and utilization of technology" [4], p. 111
TIS function	<ul style="list-style-type: none">• Core process that shapes the evolution of a TIS [5],6]
Knowledge development and diffusion	<ul style="list-style-type: none">• "captures the breadth and depth of the current knowledge base of the TIS, and how that changes over time, including how knowledge is diffused and combined in the system" [6], p. 414
Technology architecture	<ul style="list-style-type: none">• the way how different components and subsystems are integrated and linked in one technology [12]
Sector	<ul style="list-style-type: none">• The aggregation of firms with similar output that are in competition with each other and that center around similar production techniques
Sectoral configuration	<ul style="list-style-type: none">• The number and kind of sectors

Literature gap and research questions

This study is a first attempt to investigate...

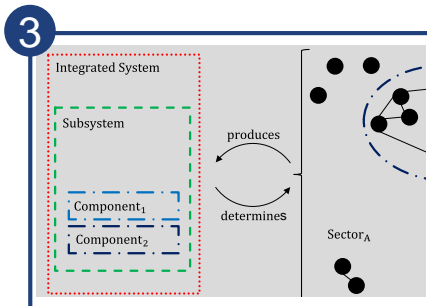


2

Dimensions ⁽¹⁾	Sectors' differences
Technological artifacts	• Different outputs (according to definition)
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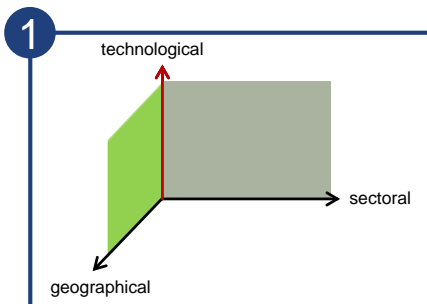
the sectoral dimension

How do different sectors affect the functional dynamics in technological innovation systems?



of a multi-component

Which patterns of knowledge creation can be found across the different sectors of the lithium-ion battery technology?



technological innovation system (TIS)

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The research question is investigated with a quantitative analysis of lithium-ion battery patent data in Japan

Reasoning

Li-ion battery technology

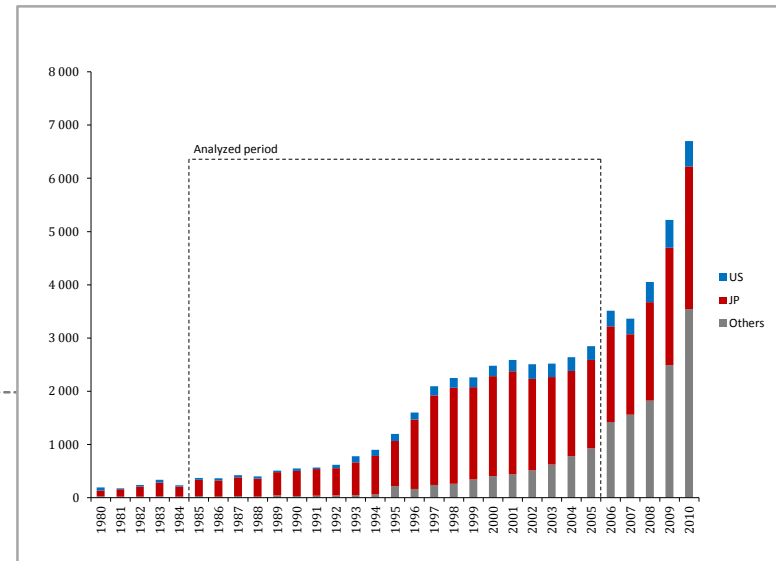
- ✓ Multi-component technology that is produced in different sectors
- ✓ Technological progress has occurred in the last 30 years
- ✓ Considered to play an important role in future energy and transportation systems

Japan

- ✓ Highest share of patents (73.5%) in the analyzed period

Patent data analysis

- ✓ TIS literature suggests patents as one measure for knowledge development and diffusion [5],[6]
- ✓ Wide use of patents as a measure for inventive activity and knowledge flows [13], [14]
- ! Patent data imply several limitations [15],[16],[17]



Operationalization

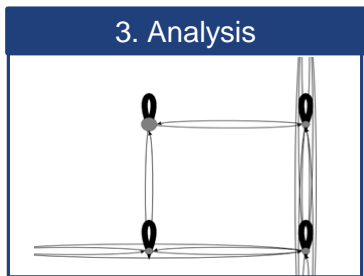
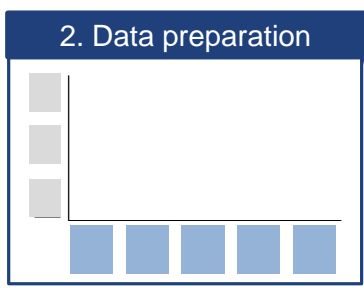
Knowledge development: Counts of patents

Knowledge diffusion: Counts of patents' forward citations

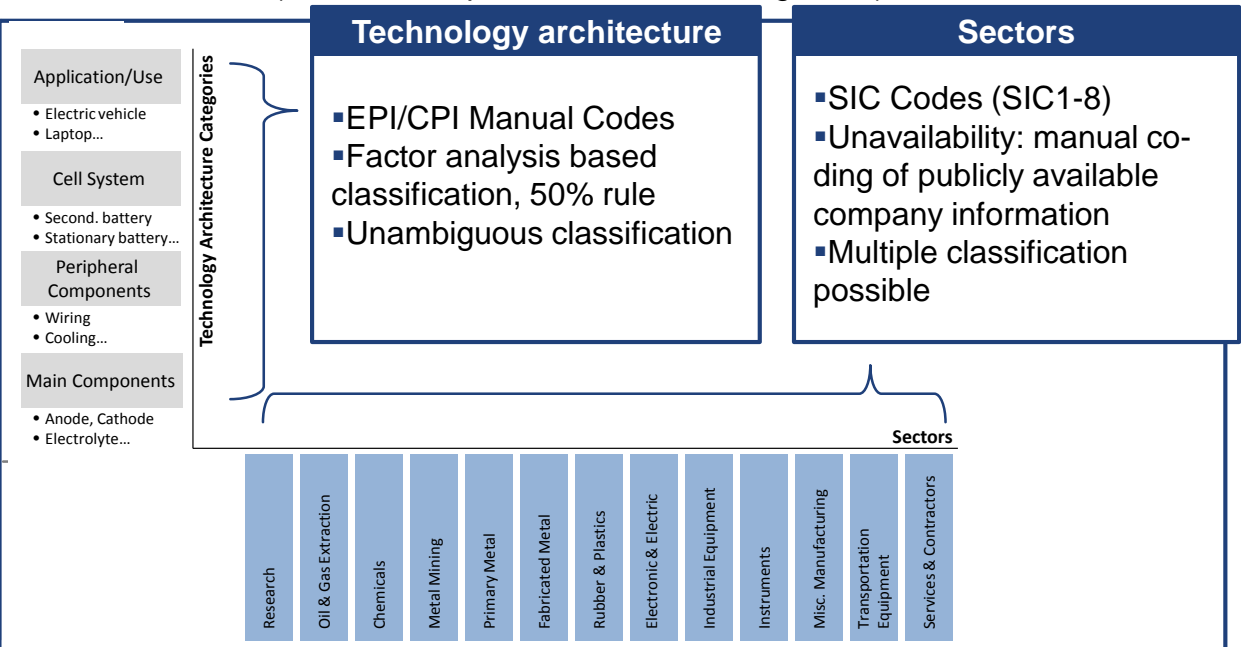
Data retrieval and processing

1. Data retrieval

Patent No.	IPC Class.	Pub. No.	Pub. Date	App. No.	App. Date	Inventor	Applicant	Abstract
12 2003042110	H01M 50/00	JP 2003-042110	2003.04.21	2002-10-10	2002.10.10	YOSHIDA, TOSIYUKI	DAIICHI KAGAKU KOGYO CO., LTD.	...



- Thomson Innovation Database
- Search: Keyword-based and classification based
- Several rounds (test for false positives and false negatives)



- Database: 13,090 patents from Japan¹
- Descriptive quantitative analysis with Pajek²

1 Country assignment via priority country

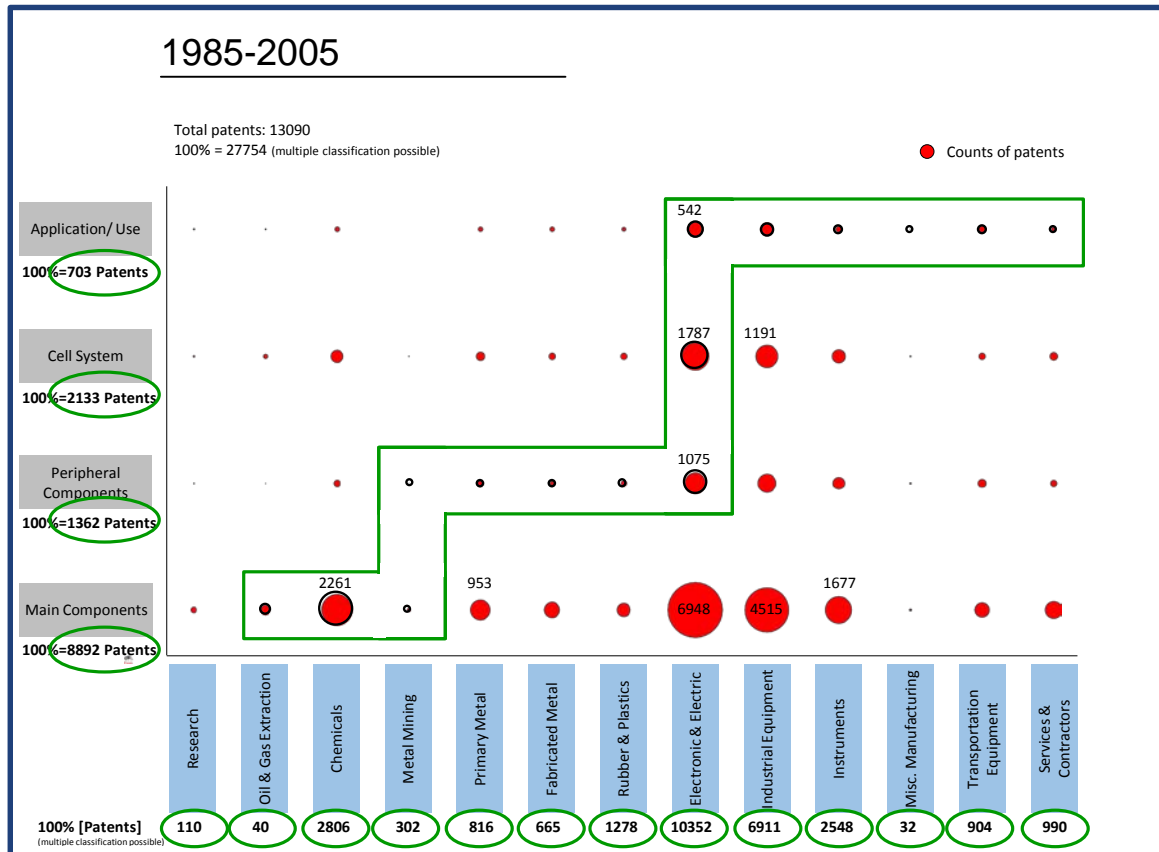
2 Software normally used for social network analysis

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Patterns of knowledge development (1/2)

PRELIMINARY



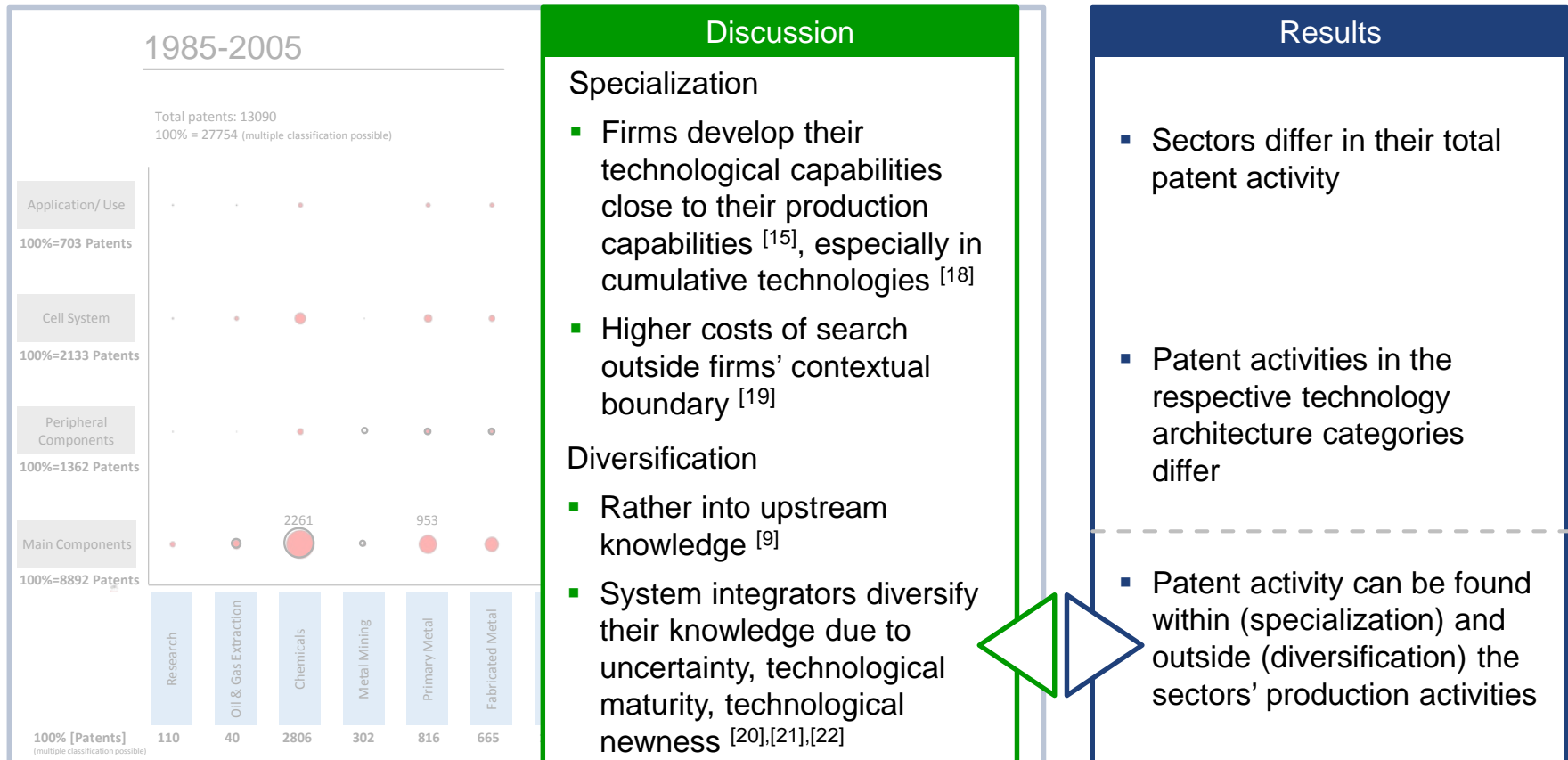
Within production activities

Results

- Sectors differ in their total patent activity
- Patent activities in the respective technology architecture categories differ
- Patent activity can be found within (specialization) and outside (diversification) the sectors' production activities

Patterns of knowledge development (2/2)

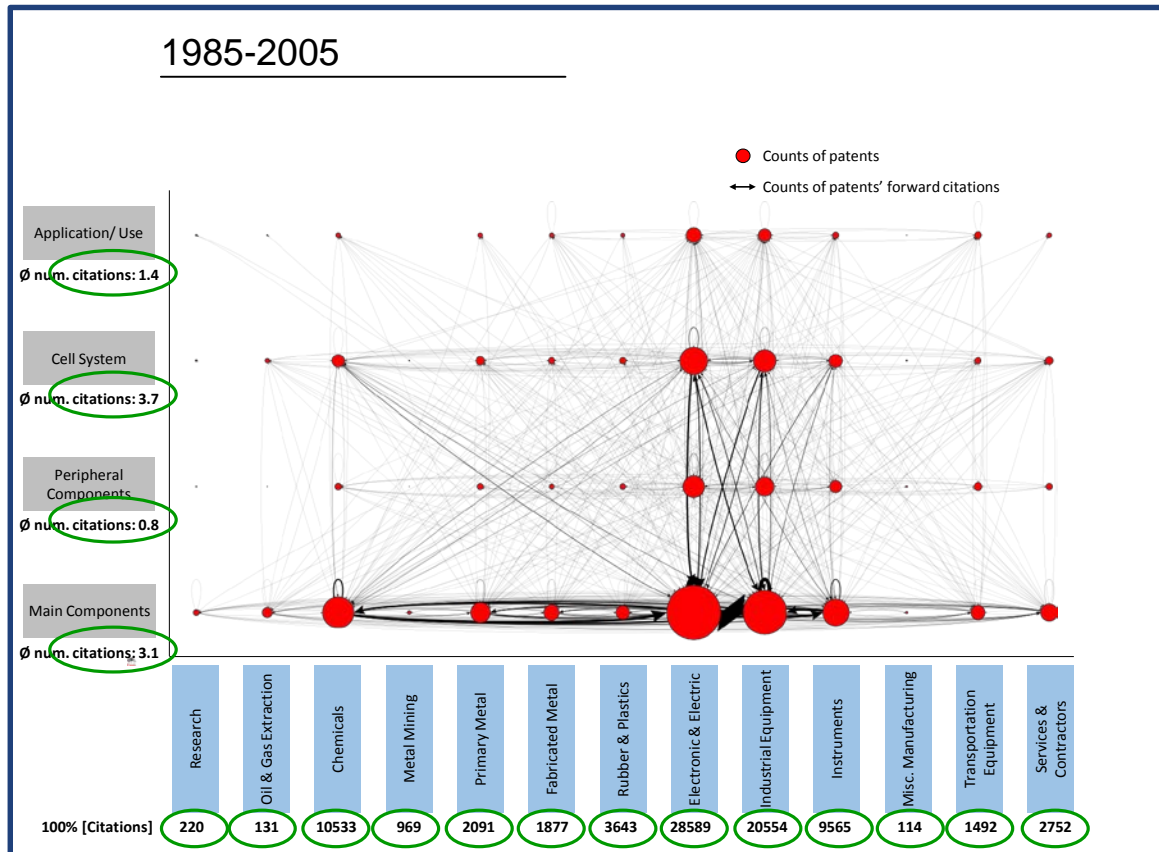
PRELIMINARY



Patterns of knowledge diffusion (1/2)

PRELIMINARY

- horizontal
- ↗ diagonal
- ↻ loop
- ↑ vertical

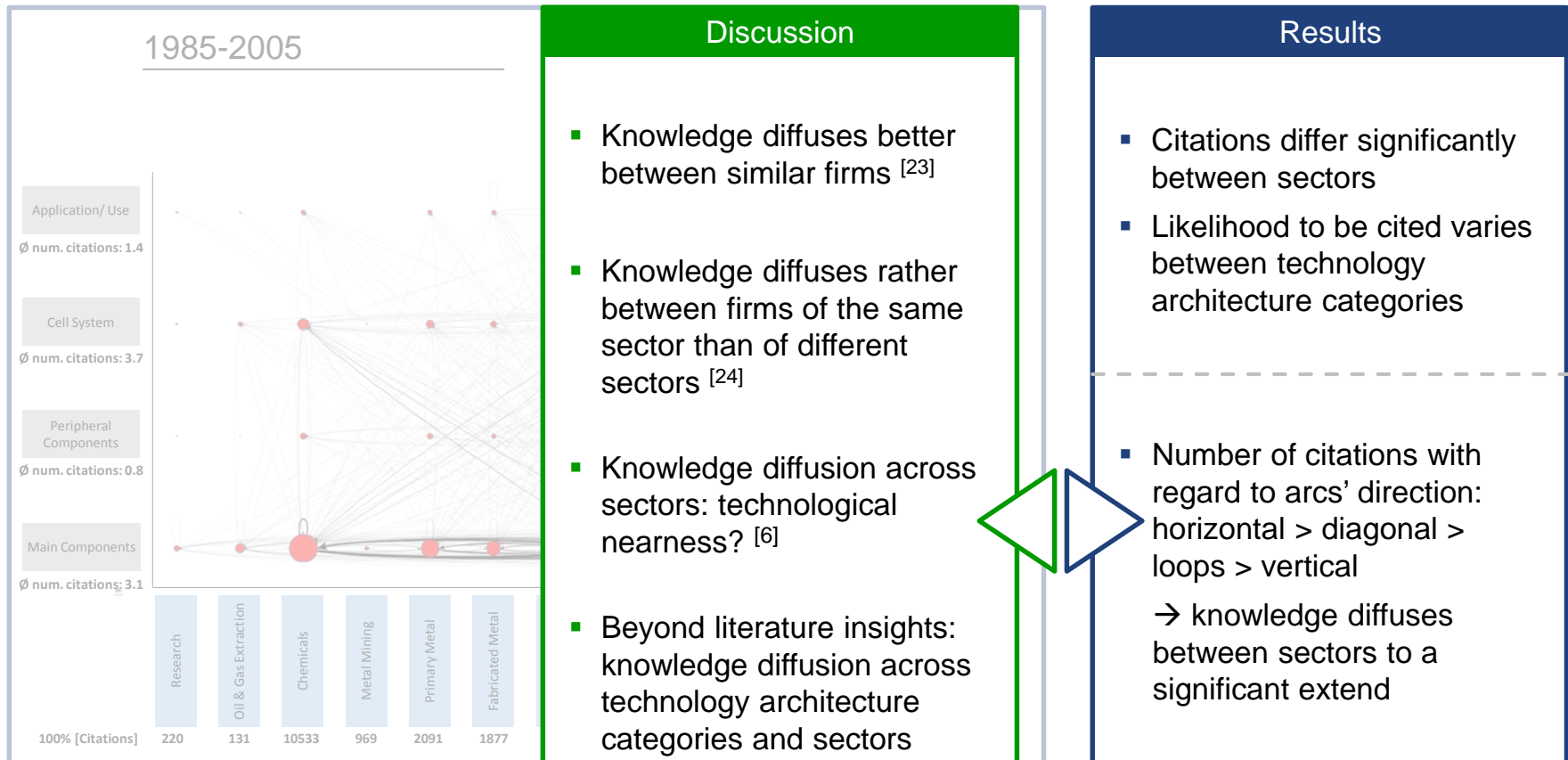


Results

- Citations differ significantly between sectors
- Likelihood to be cited varies between technology architecture categories
- Number of citations with regard to arcs' direction: horizontal > diagonal > loops > vertical

Patterns of knowledge diffusion (2/2)

PRELIMINARY

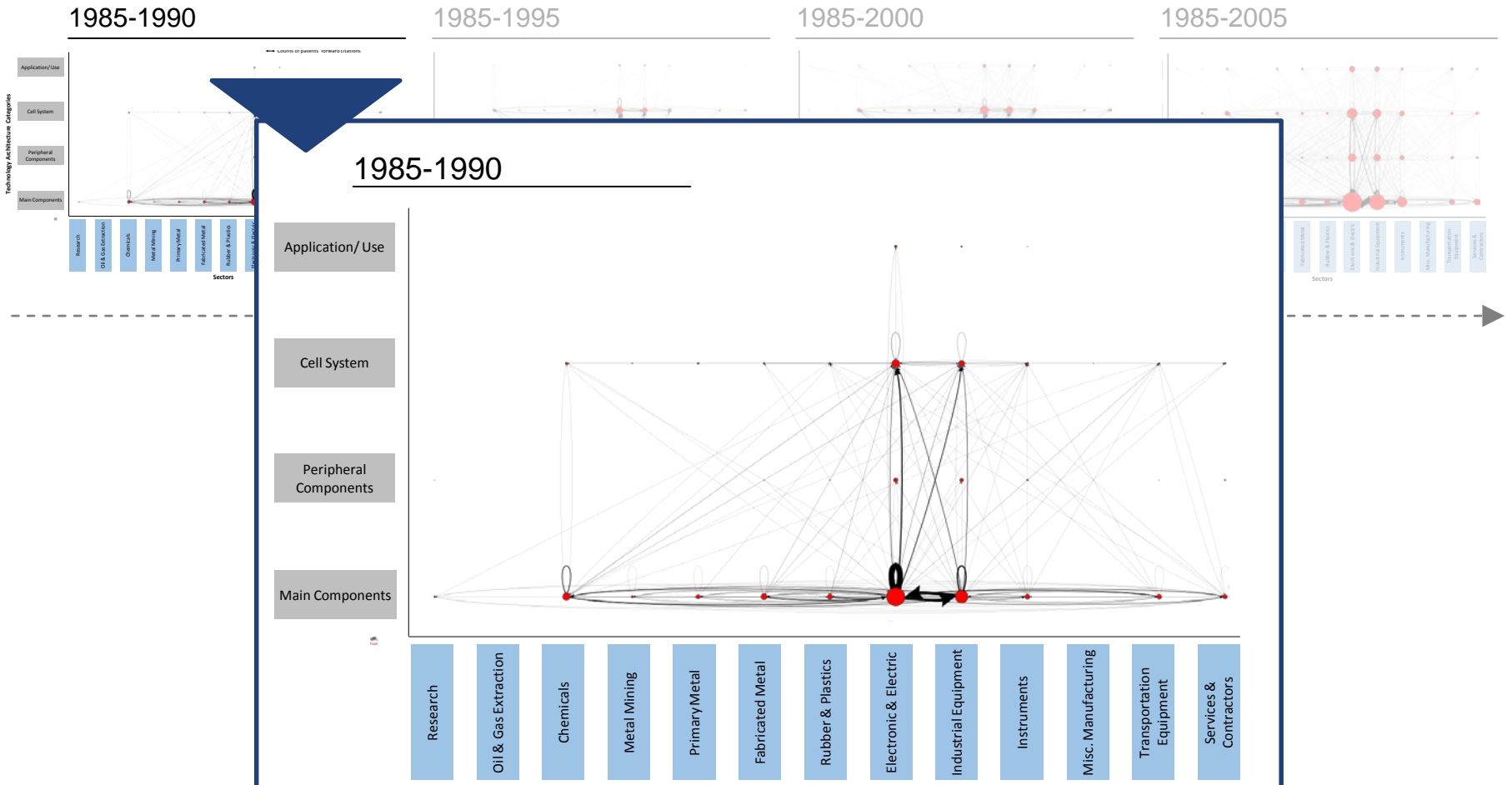


Evolution of knowledge development and diffusion (1/2)

PRELIMINARY

● Counts of patents

↔ Counts of forward citations

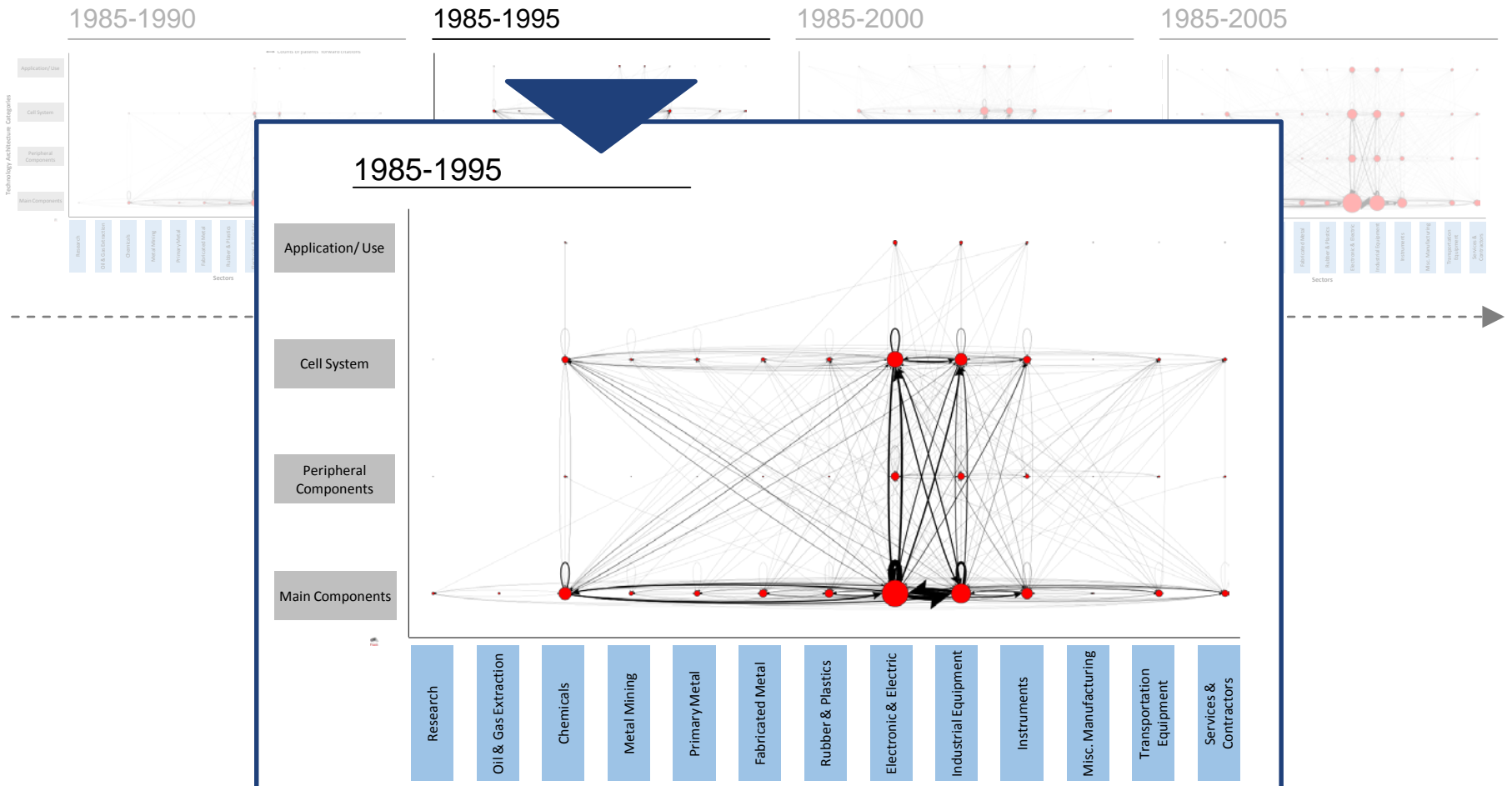


Evolution of knowledge development and diffusion (1/2)

PRELIMINARY

● Counts of patents

↔ Counts of forward citations

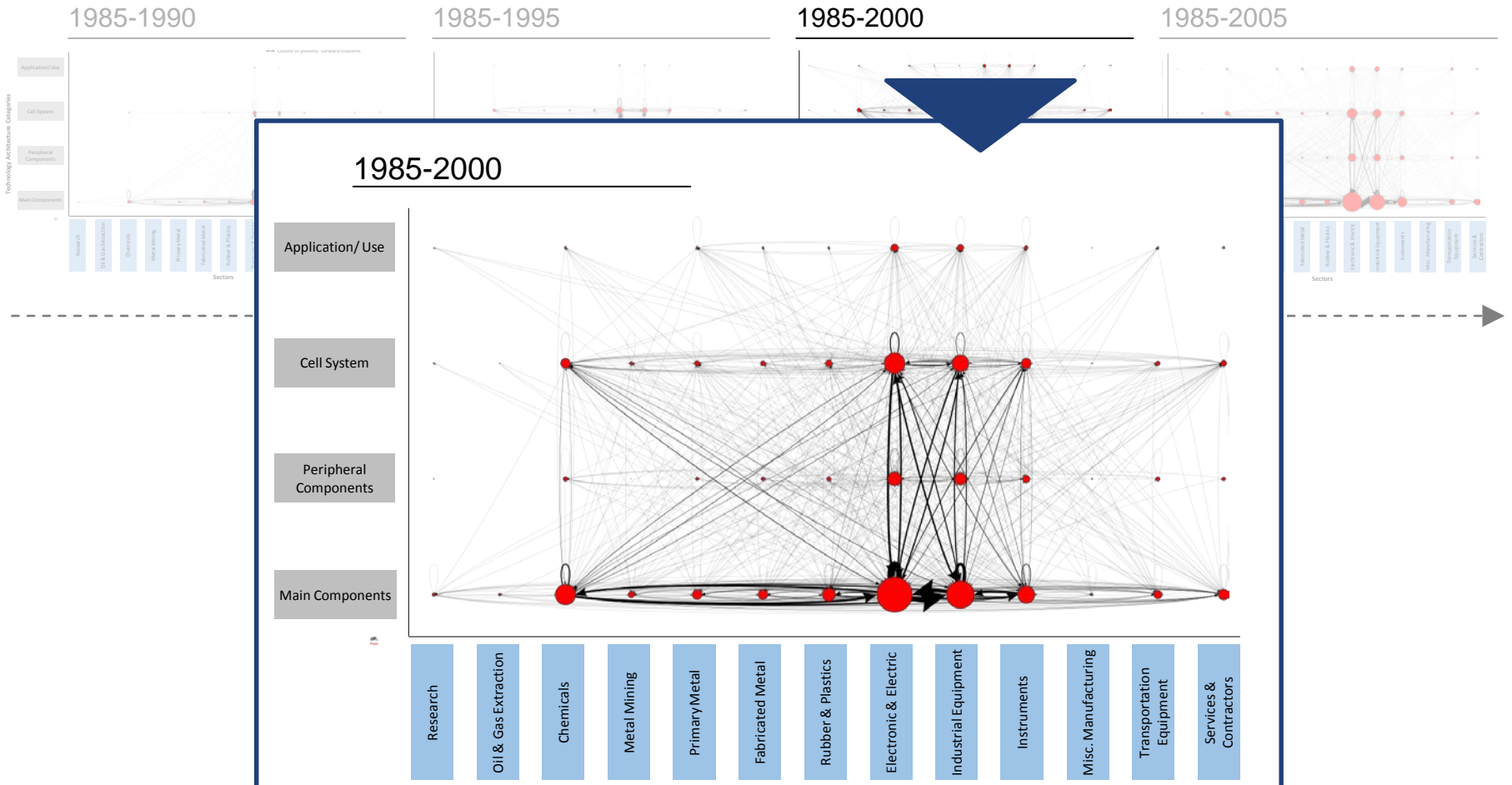


Evolution of knowledge development and diffusion (1/2)

PRELIMINARY

● Counts of patents

↔ Counts of forward citations

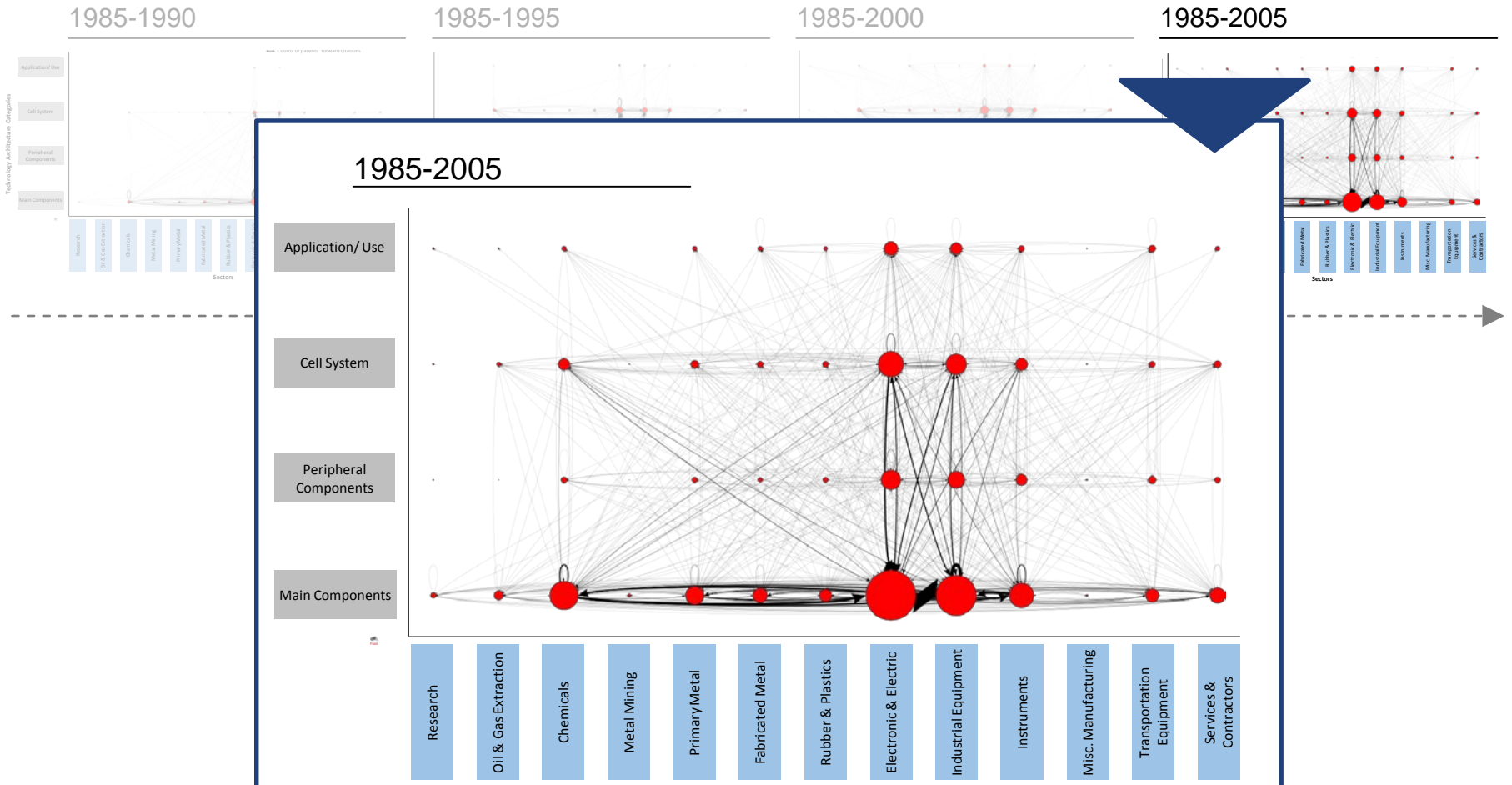


Evolution of knowledge development and diffusion (1/2)

PRELIMINARY

● Counts of patents

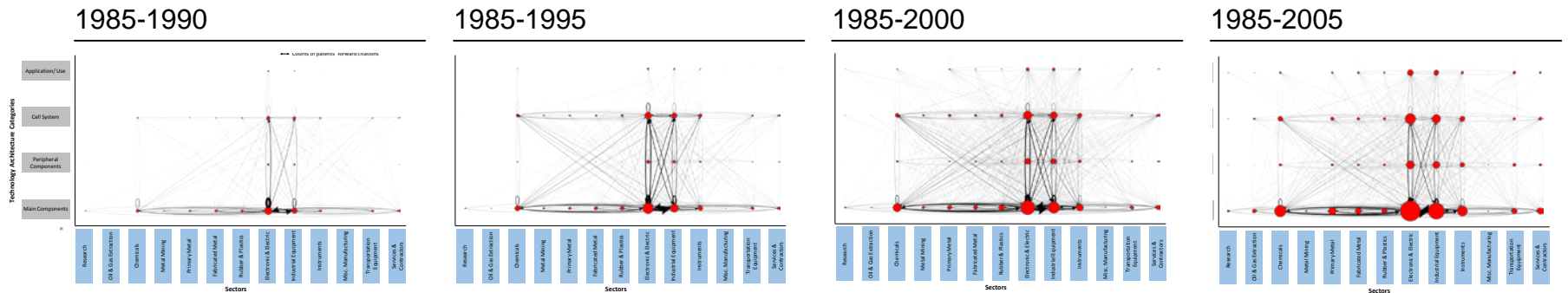
↔ Counts of forward citations



Evolution of knowledge development and diffusion (2/2)

PRELIMINARY

□ Detailed in following pages



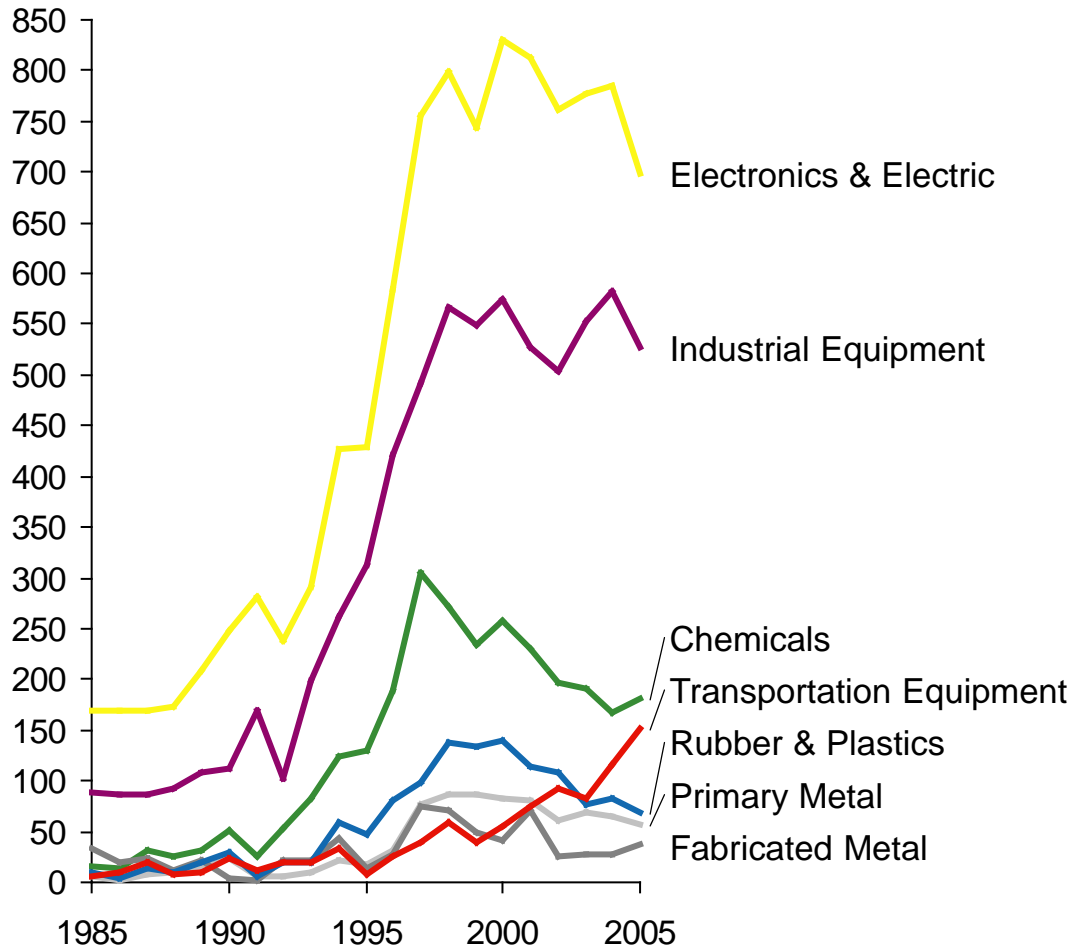
Results

- Knowledge development and diffusion started in some technology architecture categories and spread to other categories over time
- Sectors started patenting at different times

The role of different sectors varies over time

PRELIMINARY

Number of patents from selected sectors over time



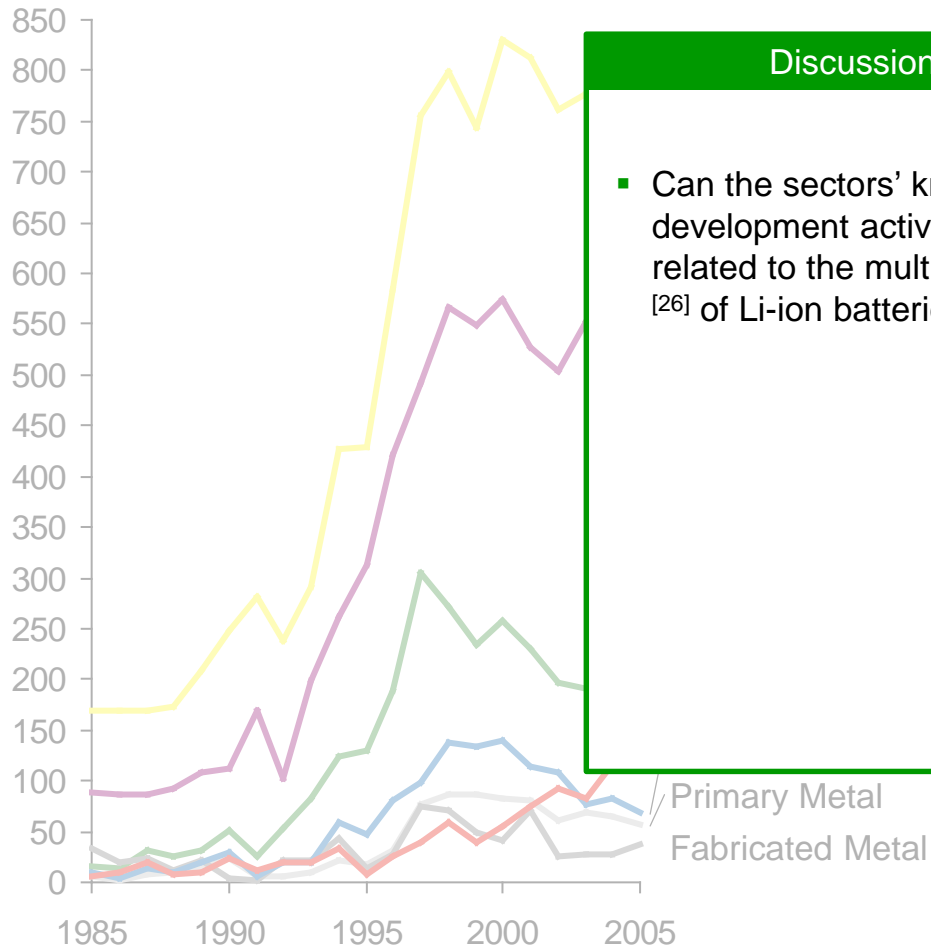
Results

- “Peak” activities vary between different sectors
- The share on patents of different sectors changes over time (e.g. transportation equipment)
- The importance of some sectors’ role (esp. “using” batteries) seems to increase continuously (e.g., transportation equipment)

The role of different sectors varies over time

PRELIMINARY

Number of patents from selected sectors over time



Discussion

- Can the sectors' knowledge development activities be related to the multi-purpose^[26] of Li-ion batteries?

Results

- “Peak” activities vary between different sectors
- The share on patents of different sectors changes over time (e.g. transportation equipment)
- The importance of some sectors' role (esp. “using” batteries) seems to increase continuously (e.g., transportation equipment)

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Theoretical and practical contribution

Contributions



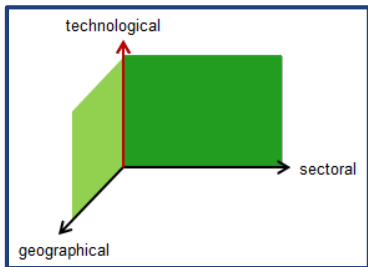
Specific knowledge patterns in the lithium-ion battery technology

Implications for policy makers

- Consider sector-specific knowledge patterns
- Consider multi-purpose character of batteries

Implications for (TIS) research

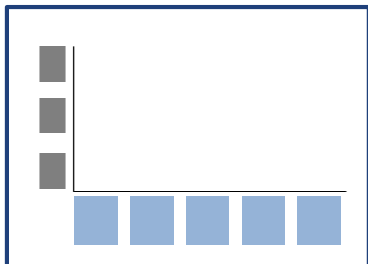
- Explore **unexpected patterns**
- Further explore the **direction** of knowledge diffusion



Sectoral dimension has to be included in TIS approach for multi-component technologies

- Consider sectoral availability and configuration and their changes over time

- Explore the role of **different types and configurations** of sectors
- Integrate **both spatial and sectoral dimension** simultaneously into TIS approach



Methodological approach

- Apply methodological approach to **other core processes** in a TIS → prove validity of conceptual suggestion

?!
Questions
Comments

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