COPA
Cutting refrigerant emissions

DEMONSTRATION REPORT ON REFRIGERANT RECYCLING IN CHINA'S AUTOMOTIVE MAINTENANCE INDUSTRY

Climate and Ozone Protection Alliance (COPA)

October 2024

CATALOGUE

LIST OF ABBREVIATIONS

4S	SALES, SERVICE, SPARE PARTS, SURVEY
AV	Autonomous Vehicle
BL	Baseline
BAU	Business as Usual
CATARC	China Automotive Technology Research Center
CO_{2EQ}	Carbon Dioxide Equivalent
COPA	Climate and Ozone Protection Alliance
EOL	End of Life
EV	Electric Vehicle
GIZ	Deutsche Gesellschaft für Internationale Zusammenarbeit GmbH
GWP	Global Warming Potential
HFC	Hydrofluorocarbon
IAM	Independent Aftermarket
IC	Initial Refrigerant Charge
IKI	Internationale Klimaschutzinitiative
MAC	Mobile Air Conditioning
MIT	Mitigation Scenario
NDCS	Nationally Determined Contributions
ODS	Ozone Depleting Substances
OEM	Original Equipment Manufacturer
PICC	People's Insurance Company of China
PRR	Potential Refrigerant to be Recycled
RAC	Refrigeration and Air Conditioning
SAIC GROUP	Shanghai Automotive Industry Corporation Group
TEAP	The Technology and Economic Assessment Panel
VR	Virgin Refrigerant
WS1	Workshop Scenario 1
WS2	Workshop Scenario 2

1. PREFACE/INTRODUCTION

As the world's largest producer, consumer, and exporter of refrigerants, China faces significant challenges in refrigerant recovery and reuse. The automotive repair industry is a key area for the use and recycling of refrigerants, but the recycling condition in this sector segment is currently not optimal in China. Developing, implementing, and validating standardized refrigerant recovery processes is crucial for improving the environment and enhancing resource utilization efficiency.

Many refrigeration and air conditioning appliances, and foam products contain refrigerants and blowing agents respectively with high global warming potential as well as ozone depleting potential. The Technology and Economic Assessment Panel (TEAP) of the Montreal Protocol estimates the global warming potential of these old stocks at 16-18 billion tonnes of CO_2-eq or annual emissions from them at over 1.5 billion tonnes CO_2eq. Application of available technologies and management practices for these chemicals to eliminate their use and capture them for destruction at end of life (EOL) is seen as one of the most cost-effective means of slowing and arresting global temperature rise between now and 2050. However, the capture and destruction of refrigerants at the cooling appliances end-of-life (EOL) have not yet been widely practiced. Therefore, if these gases are not properly recovered and destroyed, their release will have a significant negative impact on the global climate and may potentially control the global temperature rise at a reversible level.

This report introduces the reduction of emissions of ozone depleting substances (ODS) and hydrofluorocarbons (HFC) from Air Conditioners in the automotive industry within the scope of the GIZ IKI-project " Climate and Ozone Protection Alliance (COPA)" COPA aims to promote international dialogue on greenhouse gas mitigation actions through the management of ODS and HFC banks, empower key actors to take action, assist partner countries in raising funds to implement comprehensive mitigation actions, position the theme at the international level as cost-effective and effective measures that contribute to achieving national climate goals (Nationally Determined Contributions, NDCs), and design specific mitigation measures.

China is the world's largest producer, consumer, and exporter of refrigerants. From the perspective of refrigerant usage, the automotive industry is one of the key areas of refrigerant usage in China. Since 2018, passenger cars, trucks, and buses sold in China mainly use HFC-134a as a refrigerant, with a global warming potential of up to 1430. With the rapid development of the automotive air conditioning industry, hydrofluorocarbon/HFCs have become the fastest-growing greenhouse gas in recent years, accelerating the process of global warming. The refrigerant recovery efforts in the automotive maintenance industry are still in their early stages, with challenges such as an incomplete top-level system design, an underdeveloped technical standard system, and a lack of responsibility awareness among recycling enterprises, hindering the establishment of a sustainable refrigerant recovery industry chain. In the context of promoting ecological civilization, actively addressing climate change, and fully implementing sustainable development strategies, advancing the recycling and reuse of refrigerants in the automotive dismantling industry could contribute to China's carbon peak and carbon neutrality goals in compliance with the United Nations Framework Convention on Climate Change. In this process, realizing the refrigerants recovery potential in the automotive repair chain is one of the main points.

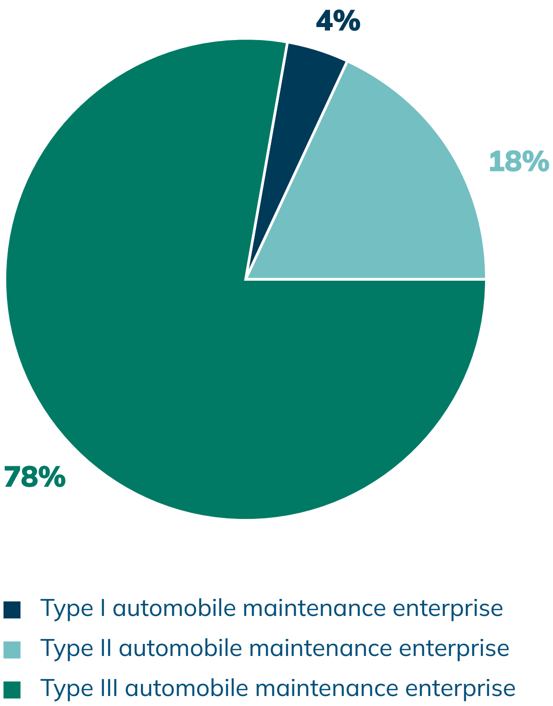
According to a report by the Ministry of Transport of China in 2022, there are about 386000 automobile repair companies in China (data from the Ministry of Transport), most of which have not successfully recovered refrigerants. Due to various subjective and objective reasons such as inadequate equipment, unproper technology, no capacity, and management systems, the maintenance process of air conditioning systems are not standardized, leading to the direct release of unrecovered refrigerants into the atmosphere. Overall, the state of refrigerant recovery remains unsatisfactory.

The general goal of this COPA activity is to develop, pilot, and test standardized processes for workshops to carry out the recovery of refrigerants during automotive air conditioning maintenance. The potential impact of the development process will be assessed by comparing the data from pilot and testing (demonstrations) with the baseline. The findings will be summarized to provide corresponding recommendations. This report begins with an overview of China's Automotive Maintenance Industry, highlighting typical enterprises in this sector in *chapter 2*. *Chapter 3* examines the current condition and challenges for refrigerant recovery from air conditioning in China's automotive industry. *Chapter 4* provides a detailed description of the pilot project, starting with an overview and introducing the pilot enterprise partner Harson along with the various project activities such as developing and testing a survey and training components for the technicians. This *Chapter 5* explains the Methodology used for the baseline calculations with data from the pilot. *Chapter 6* presents the analysis and assessment results of the collected data, along with lessons learned from the pilot experience. *Chapter 7* offer recommendations based on the pilot data and assessment along with an outlook to potential new pilot projects aimed at enhancing mitigation efforts in the automotive industry. Finally, *chapter 8* conclude the report, summarizing the next steps for developing a proposal for standard specifications for refrigerant recovery processes in the automotive industry in China on national level.

2. CHINA'S AUTOMOTIVE MAINTENANCE INDUSTRY

The automotive repair industry in China is extensive and varied in scale. According to data from the Ministry of Transport, the number of automobile repair enterprises in China has reached 386.000 in the year 2022, including 15.500 (4%) first-class repair enterprises, 70.400 (18%) second-class repair enterprises, and 300.100 (78%) third-class repair enterprises.

Figure 1. *Distribution and Proportion of National Automotive Maintenance Enterprises.*

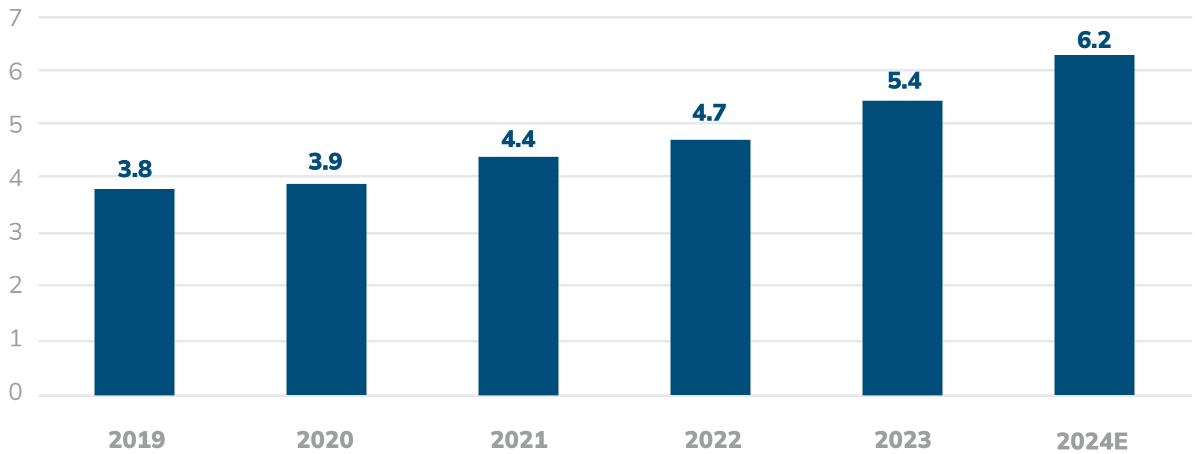


In China's automotive maintenance industry, enterprises are classified into 3 categories. Type I enterprises possess the highest level of technical expertise and state-of-the-art equipment, allowing them to manage a wide range of complex repairs. These enterprises primarily serve large corporate fleets and high-end clients. Type II enterprises offer a comprehensive range of services and can handle most standard repairs; however, they may lack the advanced capabilities required for more complex tasks, making them more suited for small to medium-sized businesses and general private customers. Type III enterprises are smaller, with basic technology and equipment, focusing mainly on routine maintenance and minor repairs for local customers. The distinctions among these categories are primarily based on the scope of services, technical proficiency, and equipment sophistication, tailored to meet the diverse needs of various customer segments.

From the perspective of industry structure, the automotive after-sales service market is diversified. Among various players, 4S stores (Type I) hold an important position, capturing about 60% of the market share. These stores are usually authorized by car manufacturers to provide brand specific repair services with high quality service quality and reliable component, at relatively high prices. In contrast, independent repair shops and chain repair shops (Type II and Type III) also play crucial roles in the market. Independent repair shops are usually smaller, offering flexible services at lower prices, though the quality of parts and service can vary widely. Chain repair shops provide standardized services through unified management and standards, with prices that fall between 4S stores and independent repair shops.

In 2023, the size of China's automotive aftermarket[1] continued to expand, reaching a volume of approximately 5.4 trillion yuan, reflecting a strong growth trend. The number of passenger cars in China reached 336 million in 2023, driving the growth of the aftermarket. It is expected that this market will grow at a compound annual growth rate of 9.2% in the coming years. The China Academy of Commerce predicts that the market size of China's automotive aftermarket industry will reach 6.2 trillion yuan by 2024.

Figure 2. *Market Size Forecast Trend of China's Automotive Aftermarket Industry from 2019 to 2024 (Unit: Trillion Yuan).*



Data source: China Passenger Car Market Information Joint Meeting, compiled by China Business Industry Research Institute

China's Automotive after-sales maintenance market is composed of three major stakeholder groups: manufacturers, category/channel providers, and independent service providers. The independent after-sales market (IAM) is rapidly expanding, while service channels authorized by original equipment manufacturers (OEM) are facing new challenges. At the same time, the rising of electric vehicles (EVs) and autonomous vehicle (AVs) is driving technological advancements and shifts in business models, injecting vitality and growth into the market.

The market is diverse, with participants including traditional warehousing distributors, wholesalers, auto parts repair chains, roadside stores, brand chain stores, and multi-functional Internet and system platforms. For example, Internet platforms such as Tuhu Car Care, Tmall Car Care (Xinkangzhong) and Jingche Car Care draw the support of the Internet to enter the automotive after-sales market and providing customers with convenient booking and maintenance services.

China's automotive repair industry is constantly developing and improving, providing consumers with a wide range of choices and high-quality services through various types of repair enterprises that cater to different needs of the market. According to data from the China National Bureau of Statistics, as of the end of 2023, there were about 238 cars per thousand people, in China compared to 500-850

1 The automotive aftermarket refers to various service areas surrounding the use of a vehicle after its sale, including maintenance, repairs, and more.

cars per thousand people in developed countries. This indicates significant growth in China's car ownership in the future. In addition, Chinese passenger cars travel an average of 20.000 to 30.000 kilometers per year, surpassing the 19.000 kilometers averaged by passenger cars in the United States. The high kilometer per car combined with the rapidly growing used-cars fleet, is expected to further drive the development of the automotive repair market.

2.1. CHINAS' MARKET OF MAINTENANCE ENTERPRISES

Chinese automobile repair enterprises market can be categorized based on enterprises' main characteristics including market positioning, service goals, and business models. Totally, eight categories of maintenance enterprises have been identified within the Chinese automotive repair market, as listed below.

The following section provides detailed descriptions of each category's characteristics, along with typical examples of existing maintenance enterprises from each category.

Table 1. *Comparison of Different Types of Enterprises*

Nr	Classification Enterprise type	Main representative enterprises	Service features
1	Traditional car dealerships	zhongsheng group	AdhereAdhering to traditional service models and provideproviding stable and reliable services
2	Traditional third-party service providers	Harson Auto Repair Group	Focusing on high-end vehicle maintenance and repair, providing andproviding more professional services
3	Traditional car companies	SAIC Group	ExtendExtending the industrial chain, enterentering the maintenance market, and provideproviding integrated after-sales services
4	Traditional accessory manufacturers	Michelin	ExpandExpanding retail channels, extend to end customers, and provideproviding high-quality accessories and services
5	Internet ecological giant	Alibaba Group, JD.com	Utilizing online platforms and logistics networks to provide convenient appointment and repair services, changingtransforming traditional models
6	New forces of the Internet	Batulu, Tuhu Car Care, Lechibang	Innovating business models to attract young consumers, by providing online and offline integrated services, transparent priceing, and convenient services options.
7	insurance company	PICC	Directly participating in maintenance and repair toreduce payout ratios, ensuring repair quality and component reliability
8	Other types of enterprises		Focusing on controlling maintenance costs and quality from the perspective of insurance claims

2.1.1. Traditional car dealer - Zhongsheng Group

Traditional car dealers are mainly positioned as traditional service providers, adhering to established service models and providing stable and reliable services to customers.

Zhongsheng Group is one of the leading automobile dealer groups in China with annual revenue of RMB 179.857 billion in 2023, representing a year-on-year increase of 2.7%. Zhongsheng Group focuses on the sales and after-sales service of high-end and luxury brand cars, possessing an extensive distribution network and high-quality services. By providing comprehensive after-sales service, Zhongsheng Group has achieved significant results in improving customer satisfaction and brand loyalty.

2.1.2. Traditional third-party service provider - Harson Auto Repair Group

Traditional third-party service providers are also positioned as traditional service providers specialize in the maintenance and repair of high-end vehicles, offering more professional services.

Harson Auto Maintenance Group focuses on the maintenance and repair of high-end vehicles, delivering professional and high-quality services. The group mainly serves luxury brand car owners, providing a variety of services including regular maintenance, accident repairs, and spare parts replacement. In 2024, Harson Auto Repair Group opened over 200 chain stores nationwide, achieving significant growth in revenue.

2.1.3. Traditional car company - SAIC Group

Traditional car companies such as SAIC Motor have gradually entered the automotive repair and maintenance market by extending their industrial chain, providing integrated after-sales services to enhance customer experience and brand loyalty.

SAIC Group has gradually extended its industrial chain into the automotive repair and maintenance sector. In 2023, SAIC Group achieved total vehicle sales of 5.021 million units, maintaining the first place in China for the 18th consecutive year. SAIC Group provides integrated after-sales services by leveraging its technological advantages and brand resources in the automotive manufacturing field, that enhance customer experience and brand loyalty. SAIC Group's strong focus on after-sales service helps to consolidate its leading position in the market.

2.1.4. Traditional parts manufacturer - Michelin

Traditional accessory manufacturers such as Michelin, are expanding their business to end customers by exploring retail channels and providing high-quality automotive accessories and related services.

Michelin, as a globally renowned tire manufacturer, has extended its business to end customers by exploring retail channels. Michelin not only sells high-quality tires in the Chinese market, but also provides a range of automotive parts and services. In 2023, Michelin achieved a 15% increase in sales within China. By ongoing expansion of its retail network, Michelin has significantly enhanced its market influence.

2.1.5. Internet ecological giants - Alibaba and JD

As new entrants, Internet eco giants such as Alibaba and JD have leveraged their powerful online platforms and logistics networks to provide convenient reservation and maintenance services, changing the traditional vehicle maintenance model.

Alibaba as one internet ecological giant, has swiftly occupied a place in the automobile maintenance market. Through its Tmall Auto and Cainiao networks, Alibaba provides convenient online scheduling and offline repair services. In 2023, Alibaba's revenue from its automotive after-sales service sector increased by over 20% year-on-year, driven by its extensive user base and efficient service system. JD.com has utilized its powerful logistics network and e-commerce platform to deliver efficient car repair solutions. As of 2023, JD Auto Care has opened over 1400 high-standard stores in more than 163 cities across China and has partnered with 30000 third-party directly connected cooperative stores to provide professional maintenance services, By integrating online and offline channels, JD.com has significantly advanced the real economy and demonstrated its strong growth in the market.

2.1.6. New Internet forces - Baturu, Tuhu Yangche, Lechebang

New Internet-driven companies have quickly attracted a number of young consumers through innovative business models and service concepts, providing online and offline integration services with transparent pricing and convenient services, which greatly enhanced customer satisfaction.

Batulu, Tuhu Yangche, and Lechibang are examples of such new internet enterprises. In 2023, Tuhu Auto achieved a revenue of 13.601 billion yuan, representing a year-on-year increase of 17.6%, and achieved full year profitability for the first time. This success demonstrates the sustainability and effectiveness of its business model.

2.1.7. Insurance company - PICC

Insurance companies through direct participating in vehicle repair and maintenance, aim to reduce the insurance payout rate, ensure the quality of repair and reliability of parts, and thus reduce accidents and claims. This approach contrasts sharply with other enterprises, focusing more on controlling maintenance costs and quality from an insurance claims perspective.

PICC exemplifies this strategy by entering the automobile maintenance market to lower its insurance payout ratio. By directly participating in vehicle repair and maintenance, PICC ensures the quality of repair and reliability of parts, which helps reduce accidents and claims. In 2023, PICC's business in the automotive after-sales service market led to significant growth with annual motor vehicle insurance premium income reaching 285.626 billion yuan, a 5.3% increase year on year.

2.1.8. Other types of enterprise

In addition to the typical categories of enterprises mentioned above, there are also some excellent enterprises in the automotive repair sector.

Linglong Tire, a leading tire manufacturer, has secured a significant position with its extensive product range and market penetration. Tuhu Car Maintenance has earned the trust of many car owners through its innovative online-to-offline service model, becoming a well-known brand in the car maintenance market. Tmall Car Maintenance, leveraging Alibaba's powerful e-commerce platform, has rapidly expanded its market influence by offering convenient and high-quality car care services. Chia Tai Group, a professional automotive repair chain, has steadily grown in the market with its reliable service quality and a broad network of outlets. These companies represent the diverse range of enterprises in the automotive repair sector. Each has carved out a significant role in the competitive market by leveraging its unique strengths. Below are the details of these representative companies and their repair scale data.

These typical maintenance enterprises are crucial to their respective fields, injecting new vitality into China's automotive maintenance industry and driving the healthy development through continuous innovation and improvement of service quality.

Table 2. *Ranking of Specific Representative Enterprises and Their Maintenance Scale Data*

Ranking	Brand Name	2021 sales scale (in billions of yuan)	Total number of stores in 2021 (units)	Number of franchise stores in 2021 (units)
1	Linglong Tire	185.79	34290	34280
2	Tuhu Car Maintenance	117.24	3853	3658
3	Tmall Car Maintenance	98.04	3014w	1945
4	Chijia	55	1672	1667
5	Quick and Accurate Car Service	36	1816	309
6	little finger	26.45	1227	1224
7	Unified lubricating oil	21.88	34542	34540
8	superhuman powers	19	2600	2451
9	Bosch Car Service	17.2	515	513
10	Zhongce Car Space	12.03	602	598
11	Harson	11.02	242	44
12	Jiashi Batong Tire	7	7500	3880
13	Love and Righteousness	4	185	66

*The ranking is based on sales scale.

2.2. INTRODUCTION TO HARSON

Since its establishment in 1998, Guangzhou Harson Group has gradually developed into a leading national auto repair service provider, integrating auto repair, auto parts, and software data services. Headquartered in Guangzhou, Harson boasts over 20 years of industry expertise and innovation, consistently providing excellent car repair and maintenance experiences. Especially in the field of automotive air conditioning and refrigerant maintenance and recycling, Harson adheres to standardized and scientific practices to ensure high-quality service to every car owner.

Founded in Guangdong, China in 1998, Harson operates across four major business segments: auto repair, auto parts, new energy vehicle services, and software data services. It is a leading enterprise in China that manages the entire auto repair value chain and continues to achieve profitability.

3. CHINA'S AUTOMOTIVE AIR CONDITIONING REFRIGERANT RECOVERY INDUSTRY

In recent years, China's automobile industry has developed rapidly. By the end of 2023, the total number of automobiles in China reached 336 million, accounting for 77.24% of all motor vehicles. This marks an increase of 17.52 million or 5.21% compared to 2022. Since 2002, HFC-134a has been the standard air-conditioning refrigerant for all newly produced passenger cars in China. This refrigerant is also used in some passenger cars and all trucks in commercial vehicles. Statistics indicate that approximately 22,000 tons of hydrofluorocarbons (HFCs) are used as air conditioning refrigerants in China's automotive industry.

3.1. OPERATIONAL CHALLENGES IN REFRIGERANT RECYCLING IN CHINA

Currently the air conditioning refrigerant recovery system in the automotive maintenance industry is not fully developed, especially in small and medium-sized maintenance enterprises, where equipment and technical levels vary resulting in low recovery efficiency.

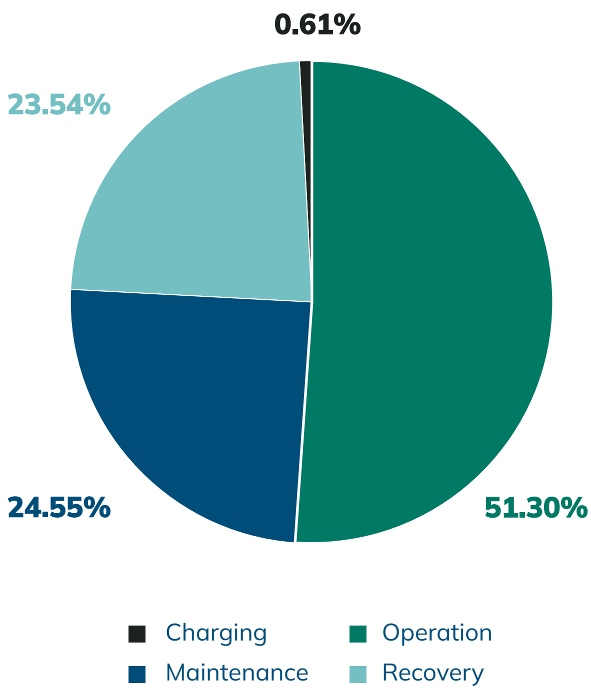
There are generally two ways to handle recovered refrigerants:

1. **Recycling and reuse**: This is to separate and purify the recovered refrigerant. Once it meets relevant standards, it can be reused;
2. **Destruction:** This is to use a rotary furnace for high-temperature decomposition and equip it with exhaust gas treatment equipment.

In practice, refrigerant recovery during automotive air conditioning maintenance faces several challenges. These challenges which hinder an efficient operation of refrigerant recovery, grouped into four areas, detailed further in the next sections.

According to a survey conducted by the China Automotive Technology Research Center, direct emissions from fuel vehicle maintenance account for 24.55% of the total emissions over their entire lifecycle.

Figure 3. *Proportion of Direct Emissions from Various Stages of Air Conditioning Refrigerant in Fuel Vehicles.*



3.1.1. Lack of professional technical training for maintenance personnel

With the increasingly strict environmental regulations, the proper use and recycling of refrigerants have become important issues. However related training is often overlooked. In the field of air conditioning maintenance, there is a significant shortage of professional technical training for maintenance personnel.

The national standard "Operating Conditions for Automotive Maintenance Industry" (GB/T 16739) does not provide specific requirements for air conditioning maintenance technicians. This led to significant differences in training content and standards among different regions and institutions.

3.1.2. Non-compliant maintenance practices

Non-standard practices exist in the operation of maintenance enterprises. For example, when air conditioning systems repair, some workshops prioritize saving time and costs by discharging refrigerants directly into the atmosphere (free venting) instead of recovering and storing them.

Without a standardized procedure, there is often an insufficient ability to identify accurately refrigerant components in the automobile maintenance workshops. Technicians frequently re-charge the air conditioning systems based on user requirements, resulting in mixed use of different types of refrigerants. This cross contamination complicates recycling efforts and increases the difficulty of harmless treatment.

Other operational challenges in refrigerant recycling for vehicles identified to be mentioned are that after replacing the components of the air conditioning system, the pipeline seals were not replaced before assembly. There is also often a lack of completion inspection or improper inspection methods after maintenance is completed

3.1.3. Insufficient utilization of recovery equipment for recycling

Although standards such as "Technical Specification for Refrigerant Recovery, Purification, and Filling of Automotive Air Conditioning" (JT/T 774-2010) and "Testing Methods and Limits for R-134a Leakage of Automotive Air Conditioning Refrigerant" (JT/T 816-2021) provide clear requirements for refrigerant recovery, purification, and filling in the automotive maintenance industry, practical implementation faces challenges due to the lack of mandatory regulatory enforcement. Consequently, many car repair companies do not equip them with necessary equipment or do not use it effectively, resulting in a large amount of refrigerant being directly discharged into the atmosphere during the repairs.

The increased maintenance time and costs by using refrigerant recovery equipment are important reasons why many companies are unwilling to adopt these devices and operational processes without legal or regulatory enforcement.

3.1.4. Low level of enterprise management

Despite the guidance of relevant regulations such as the "Regulations on the Management of Motor Vehicle Maintenance" (GB/T 16739), actual implementation often falls short of expectations, resulting in significant deficiencies in compliance with standards by some maintenance companies. In some regions, the qualification review process for automobile repair enterprises may be relatively relaxed and not strictly enforced which has led to the proliferation of repair shops with varying levels of technical expertise and management skills.

At the internal management level, these diverse enterprises often lack effective scientific and standardization processes. Common issues include disorganized workflow and unclear employee responsibilities, resulting in general low work efficiency. Consequently, the service quality can vary widely due to the lack of unified standards. In such cases, customer satisfaction is difficult to guarantee.

4. INTRODUCTION TO PILOT PROJECT

The overall aim of the conducted COPA pilot project is to develop, pilot and test a standardized process for conducting workshops on refrigerants recovery from air conditioners conducted during car maintenance, compared against a baseline of emissions that represents the business-as-usual scenario.

Based on the data collected during the pilot and a developed baseline calculation methodology, the project aims to calculate, assess and verify the potential emission reduction available through the recycling of automobile refrigerants using standardized quality processes.

4.1. OVERVIEW AND TIME SCHEDULE OF PILOT PROJECT

This pilot project aims to gather valuable experience and reduce emissions through standardized recycling of air conditioning refrigerants in the automotive maintenance industry in one region of China.
By closely cooperating with the demonstration enterprises to collect data, test, optimize and standardize the refrigerant recovery process, the project seeks to enhance both the quantity and efficiency of refrigerant recovery. Specifically, the pilot program covers the following aspects, each of will be detailed in the following sections:

1. Selection of demonstration enterprise and pilot workshop: Completed in March 2024.
2. Development, testing and finalization of data collection questionnaire: Conducted from March to May 2024.
3. First round of data collection: lasted for 4 weeks, from May 27th to June 23rd, 2024.
4. Training of technicians on the use of refrigerant recovery machines: Conducted for 2 weeks, from June 24th to July 7th, 2024.
5. Second round of data collection: lasting for 4 weeks, from July 8th to August 4th, 2024.
6. Data analysis, lessons learned and recommendations: from August 5th to September 1st, researchers assessed the data collected, summarized lessons learned and made suggestions based on the pilot activity.

4.2. HARSON GROUP AS PILOT ENTERPRISE

Since its establishment in 1998, Guangzhou Harson Group has gradually developed into a leading national auto repair service group integrating auto repair, auto parts, and software data services. Headquartered in Guangzhou, and with over 20 years of industry accumulation and innovative spirit, Harson provides always excellent car repair and maintenance experiences for car owners. In the field of automotive air conditioning and refrigerant maintenance and recycling, Harson adheres to a standardized and scientific operating philosophy, to ensuring high-quality service for every car owner. Following the enterprise classification introduced in *Table 1* in *chapter 2*, Harson Group exemplifies traditional third-party service providers.

Harson was selected as the cooperating unit for the pilot project based on the following aspects:

- **Business Strength and Brand Influence:** As a leading full-value chain automotive repair enterprise in China, Harson operates across four major business segments: automotive repair, auto parts, new energy vehicle services, and software data services. It provides digital integrated solutions for mid-to-high-end vehicle owners and automotive repair/parts service shops. Harson's business strength and brand influence strongly support the success of the pilot project.
- **Extensive store coverage and professional team:** Harson has over 250 stores in 168 cities in China, with a professional service team of over 8000 employees, including 1230 technicians. Harson repairs over 400000 vehicles annually. This extensive network and professional workforce provide a solid foundation for future replication and broader promotion of the pilot project.
- **Technical and standardization advantages:** As the founder and leading brand in luxury car repair, Harson has played a significant role in creating and improving operational standards and management norms in automotive repair technology, customer service, and store operations. Its collaboration with numerous vocational colleges in China and its vocational job certification qualifications highlight its strength in technological innovation and standardization.
- **Good cooperative relationship:** CATARC and Harson already have a good cooperative relationship. This built on a solid foundation of collaboration in automotive maintenance and remanufacturing.

In summary, choosing Harson as the pilot enterprise leverages strength in business scale, network coverage, professional team, technology and standardization, and established partnerships, providing strong support for the successful implementation of the automotive air-conditioning refrigerant recovery pilot project.

4.3. THE PILOT STORE IN GUANGZHOU IN THE HARSON REGION

Among the many stores in the Harson Group, the Tianjin store located in northern China was initially selected to the demonstration project. The choice was driven by the store's rich experience in automotive air conditioning refrigerant recovery, and its close proximity to CATARC also located in Tianjin, facilitating easier coordination and communication during the pilot implementation. However, due to the low temperature in northern China at the project's launch, which do not coincide with the peak period for car maintenance and air conditioning services, after comprehensive consideration, the project decided to relocate the pilot to Guangzhou, It is in southern China where the warmer climate supports better the project's requirements.

In addition to the above, Guangzhou is the headquarter of Harson Group, providing ideal conditions to conduct the pilot work.

The Guangzhou Harson Automotive Maintenance Pilot Enterprise occupies an area of approximately 3000 square meters and has 38 employees, focusing on serving brands such as Mercedes Benz, BMW, Audi, etc. The following are pictures from the pilot store.

Figure 4. *Harson Pilot Store (Guangzhou).*

4.4. PILOT METHOD: DEVELOPING SURVEYS IN EXCEL AND WORD FOR DATA COLLECTION

Two types of tables were developed for this data collection: one is the data collection table, and the other is the data summary table.

The data collection form was distributed to the pilot storefront in Word format, printed out, and used by the storefront workers to collect and record data manually. The receipt collection form consists of two parts. The first part is the explanation section, which explains various collection fields to facilitate the collection personnel to understand the accurate meanings of the fields. The second part is the data collection section, where the personnel input the relevant data. A sample data collection table is shown in *Figure 3*.

The data summary table is in Excel format, to consolidate data from individual collection tables for data statistics and analysis. The data summary table is compiled by CATARC.

Figure 5. *Sample Data Collection Table (Before Adjustment). [1/2]*

汽车维修制冷剂回收数据采集表项目说明

序号	车辆序号
收集日期	制冷剂收集的日期
车型	车辆类型，例如：SUV、轿车、MPV
车龄	车辆使用时间
品牌	车辆品牌，例如：比亚迪、宝马、大众等
车牌号	车辆牌照
进店维修空调的原因	车辆进入维修店的原因
上一次制冷剂充注时间	上次车辆充注制冷剂的时间
制冷剂初始充注量（克）	车辆出厂的时候充注的制冷剂量
制冷剂型号	空调系统使用的制冷剂类型
制冷剂回收时长（分钟）	制冷剂回收过程中使用的时间
回收过程中存在的问题	在制冷剂回收过程中出现的问题
回收总量（克）	维修后需要处理或回收的制冷剂总量
回收制冷剂状况	请注明回收的制冷剂的污染程度
回收制冷剂处理方式	制冷剂回收以后的处理方式
新充注制冷剂类型	再次充注到空调器中的制冷剂，包括原始新制冷剂或再利用的制冷剂
顾客满意度（10分）	让顾客对所提供的服务打分，从1到10。10分为最满意
备注	数据收集过程中的任何事项
操作人员	操作人员的姓名

Figure 5. *Sample Data Collection Table (Before Adjustment). [2/2]*

汽车维修制冷剂回收数据采集表

序号 ______________________　　　　回收日期 ______________________

车辆基本信息	车型	车龄	品牌	车牌号	
空调及制冷剂信息	进店维修空调的原因	上一次制冷剂充注时间	制冷剂初始充注量（克）	制冷剂型号	制冷剂回收时长（分钟）
	选项（ ） A - 空调制冷问题 B - 整车常规保养 C - 其他原因	用	用	选项（ ） A - R12 B - R134a C - R474a D - R744 E - R290 F - HFO-1234yf	
	回收过程中存在的问题	回收总量（克）	回收制冷剂状况	回收制冷剂处理方式	新充注制冷剂类型
			选项（ ） A -纯净 B -半污染 C -污染	选项（ ） A - 交给正规制冷剂回收处理机构 B - 采用再利用设备处理 C - 存储 D - 直接排放 E - 其他途径	选项（ ） A - 新制冷剂 B - 再利用制冷剂
其他信息	顾客满意度（10分）		备注		操作人员

注意：在电脑数据录入时，含有选项的题目请使用下拉选项选择。

4.4.1. Testing data collection in the workshop, adjust Excel and Word

Before officially starting the data collection work, a 4-week preliminary test to confirm the applicability and rationality of the data collection form was conducted. During the testing period, about 20 rows of data were collected. A key issue was identified through data comparison: the lack of the amount of virgin refrigerant used. Therefore, in the adjusted data collection table, the collection field "If additional refrigerant is added, please fill in the weight (grams) of the refrigerant added" has been added. The adjusted data collection table is shown in *Figure 4*.

Figure 6. *Sample Data Collection Table (Adjusted). [1/2]*

汽车维修制冷剂回收数据采集表项目说明

序号	车辆序号
收集日期	制冷剂收集的日期
车型	车辆类型，例如：SUV、轿车、MPV
车龄	车辆使用时间
品牌	车辆品牌，例如：比亚迪、宝马、大众等
车牌号	车辆牌照
进店维修空调的原因	车辆进入维修店的原因
上一次制冷剂充注时间	上次车辆充注制冷剂的时间
制冷剂初始充注量（克）	车辆出厂的时候充注的制冷剂量
制冷剂型号	空调系统使用的制冷剂类型
制冷剂回收时长（分钟）	制冷剂回收过程中使用的时间
回收过程中存在的问题	在制冷剂回收过程中出现的问题
回收总量（克）	维修后需要处理或回收的制冷剂总量
回收制冷剂状况	请注明回收的制冷剂的污染程度
回收制冷剂处理方式	制冷剂回收以后的处理方式
新充注制冷剂类型	再次充注到空调器中的制冷剂，包括原始新制冷剂或再利用的制冷剂
如果同时补充了额外的制冷剂，请填写补充制冷剂的重量（克）	此处说明是否将新制冷剂添加到回收制冷剂中，以完成车辆空调系统的完全充注。
顾客满意度（10分）	让顾客对所提供的服务打分，从1到10。10分为最满意
备注	数据收集过程中的任何事项
操作人员	操作人员的姓名

Figure 6. *Sample Data Collection Table (Adjusted). [2/2]*

汽车维修制冷剂回收数据采集表

序号 ______________________________ 回收日期 ______________________________

车辆基本信息	车型	车龄	品牌	车牌号	
空调及制冷剂信息	进店维修空调的原因	上一次制冷剂充注时间	制冷剂初始充注量（克）	制冷剂型号	制冷剂回收时长（分钟）
	选项（ ） A - 空调制冷问题 B - 整车常规保养 C - 其他原因	用	用	选项（ ） A - R12 B - R134a C - R474a D - R744 E - R290 F - HFO-1234yf	
	回收过程中存在的问题	回收总量（克）	回收制冷剂状况	回收制冷剂处理方式	新充注制冷剂类型
			选项（ ） A - 纯净 B - 半污染 C - 污染	选项（ ） A - 交给正规制冷剂回收处理机构 B - 采用再利用设备处理 C - 存储 D - 直接排放 E - 其他途径	选项（ ） A - 新制冷剂 B - 再利用制冷剂
	回收过程中存在的问题	回收总量（克）	回收制冷剂状况	回收制冷剂处理方式	新充注制冷剂类型
其他信息	顾客满意度（10分）		备注		操作人员

注意：在电脑数据录入时，含有选项的题目请使用下拉选项选择。

4.4.2. Unexpected weather event challenging pilot

During the implementation of the pilot project, the pilot project encountered an unpredictable natural challenge – extreme weather and flooding. Guangzhou experienced severe rainstorms in April, leading to widespread flooding that significantly impacted the normal activities in the region including a reduction in the number of vehicles entering the store for maintenance. This unexpected weather event undoubtedly affected our data collection work.

In order to compensate the impact of flooding, the pilot team decided on the following measures:

1. Extension of data collection period: To ensure the integrity and accuracy of the data, the data collection time was extended to compensate for the reduced number of vehicle repairs caused by the flooding.
2. Multi-channel data collection: In addition to collecting data from the demonstration enterprise store, the team considered actively seeking cooperation with other repair stores of Harson in Guangzhou to obtain more data on refrigerant recovery and balance the data bias caused by floods. However, this approach was not ultimately pursued.
3. Comprehensive comparison with historical data: To ensure the accuracy of the collected pilot data, the comparison was made between the data from the pilot with historical data from the previous years in order to assess the impact of weather on the pilot.

Fortunately, the comparison of the pilot store with similar period before the flooding showed no significant deviation in the number of car visits. Given that rainstorms often affect Guangzhou in different degrees during spring-periods, it was decided not to take further compensation measures, instead use the actual collected data to reflect the condition of this pilot project.

4.5. FIRST DATA COLLECTION SURVEY

From May 27th to June 23rd, the first survey and baseline data collection for the ongoing air conditioning refrigerant recovery project were conducted. The main purpose of this stage was to understand the actual condition of air conditioning refrigerant recovery during the formal implementation of the project, including refrigerant recovery amount, recovery time, refrigerant types, recovery methods, and existing problems. The data reflects the business-as-usual status of the pilot store and is crucial for evaluating project progress, measuring improvement effects, and formulating follow-up strategies.

During this period, a total of 13 valuable data points were collected, providing an important reference for the subsequent implementation of the project. This data will help us more accurately assess the project's progress and challenges, ensuring development of targeted strategies can promote the effective implementation of air conditioning refrigerant recovery efforts.

Table 3. *Data of first round*

General information on the vehicle					Information on the re				
ID number	Collection date	Vehicle Information			Reasons for servicing the vehicle's A/C system in the workshop	Last refrigerant charge	Initial refrigerant charge (g)	Refrigerant type	Collection time (minutes)
		Vehicle type	Age of vehicle	Brand					
1	2024/5/29	Sedan	4	BMW	Routine maintenance of the entire vehicle	/	509	R134a	15 min
2	2024/5/30	Sedan	10	Mercedes-Benz	Routine maintenance of the entire vehicle	/	700	R134a	16 min
3	2024/6/3	Sedan	6	Mercedes-Benz	Routine maintenance of the entire vehicle	/	630	R134a	10 min
4	2024/6/5	Sedan	11	BMW	Routine maintenance of the entire vehicle	/	680	R134a	10 min
5	2024/6/5	MPV	8	Buick	Routine maintenance of the entire vehicle	/	1000	R134a	10 min
6	2024/6/6	Sedan	10	Audi	Routine maintenance of the entire vehicle	/	570	R134a	10 min
7	2024/6/17	Sedan	5	Mercedes-Benz	Routine maintenance of the entire vehicle	/	590	R134a	10 min
8	2024/6/17	Sedan	12	Audi	Routine maintenance of the entire vehicle	/	580	R134a	10 min
9	2024/6/19	SUV	12	Mercedes-Benz	Routine maintenance of the entire vehicle	/	1200	R134a	10 min
10	2024/6/15	Sedan	7	BMW	Routine maintenance of the entire vehicle	/	850	R134a	15 min
11	2024/6/10	Sedan	4	Honda	Routine maintenance of the entire vehicle	/	480	R134a	15 min
12	2024/6/21	Sedan	10	Mercedes-Benz	Routine maintenance of the entire vehicle	/	680	R134a	10 min
13	2024/6/22	Sedan	5	BMW	Routine maintenance of the entire vehicle	/	600	R134a	10 min

frigerant and the air conditioning system						Extra infromation		
Problems encountered during service	Amount recovered (g)	Condition of collected refrigerant	Disposal method of collected refrigerant	Refilled with recycled or virgin refrigerant	Has extra refrigerant been added to make a full charge? Please use only if recycled refrigerant was used. (g)	Customer satisfaction (10 points)	Remarks	Technician
None	430	Pure	Recycling in-situ	Virign	79	10	None	Lv H.
None	520	Pure	Recycling in-situ	Virign	180	10	None	Lv H.
None	470	Pure	Recycling in-situ	Virign	160	8	None	Lv H.
None	510	Pure	Recycling in-situ	Virign	170	9	None	Lv H.
None	800	Pure	Recycling in-situ	Virign	200	8	None	Fang Y. J.
None	400	Pure	Recycling in-situ	Virign	170	9	None	Fang Y. J.
None	500	Semi-polluted	Recycling in-situ	Virign	90	8	None	Lv H.
None	470	Pure	Recycling in-situ	Virign	110	7	None	Lv H.
None	860	Pure	Recycling in-situ	Virign	340	8	None	Lv H.
None	650	Pure	Recycling in-situ	Virign	200	9	None	Lv H.
None	0	Semi-polluted	Free venting	Virign	480	9	None	Lv H.
None	510	Pure	Recycling in-situ	Virign	170	8	None	Lv H.
None	300	Pure	Recycling in-situ	Virign	300	9	None	Lv H.

4.6. TRAINING ACTIVITIES

After the first data collection was completed, according to the plan, the pilot enterprises store technicians, who were already equipped with air conditioning refrigerant recovery and reuse equipment (air conditioning managers) in the workshop, received a tailored training for 2 weeks. The technical personnel of CATARC and Harson jointly developed the "Specification for Refrigerant Recovery in Automotive Maintenance Enterprises" to the training sessions. The trainer conducted a two-week training program, consisting of daily 2-hours sessions for workshop's air conditioning maintenance technicians. During the training, the newly developed standardized process for air conditioning refrigerant recovery was introduced.

Figure 7. *Refrigerant Recovery machine.*

In this pilot project store, there are five staff members whose daily work involves air conditioning refrigerant recovery, including 2 workshop personnel and 3 technical personnel. All of them participated in the training.

This training was led by a senior technical director from Harson Group, known for his extensive experience in standard setting and training. Previously, he conducted training on projects such as "Automotive Air Conditioning Maintenance Project", "Electric Air Conditioning Compressor Maintenance Project", and "Conventional Fault Detection Project for Air Conditioning Systems".

The training was primarily based on "Specification for Refrigerant Recovery in Automotive Maintenance Enterprises", jointly developed by China Automotive Technology Research Center (CATARC) and Harson. This training consisted of 10 sessions, each lasting 2 hours. Training includes explanation and operation.

For example:

- Refrigerant detection and identification: To conduct refrigerant detection and identification operations in accordance with the requirements of 4.2 of the "Refrigerant Recovery Specification for Automotive Maintenance Enterprises".
- Refrigerant recovery: To carry out refrigerant recovery operations in accordance with the requirements of Section 4.3 of the 2022 "Refrigerant Recovery Specification for Automotive Maintenance Enterprises".
- Safety: To ensure the use of personal protective equipment such as safety goggles and rubber gloves are worn during the operation.
- Currently, this training is a routine within the Harson Group though no corresponding certificate is issued. During the training, the participants showed great interest, engaged actively, quickly mastered the necessary skills in the practical operation.

This training was conducted in the form of "standard document development", "in-store training", and "practical assessment", enabling store personnel to rapidly master various operational skills.

Due to the above facts, the relevant training modes, course materials, and experiences from this pilot project can be replicated in Harson's other stores in China with appropriate adjustments. At the same time, the "Refrigerant Recovery Specification for Automotive Maintenance Enterprises", which served as the basis for the pilot training, enhances the program's broad applicability. Transforming Harson's pilot training it into an industry standard in China would promote adoption nationwide, thereby enhancing the standardization of refrigerant recovery processes and potentially increasing the amount of refrigerant recovered in China.

Figure 8. *Training Site Picture.*

4.7. SECOND DATA COLLECTION SURVEY

After the training was finished, the second round of data collection was carried out for four weeks period from July 8th to August 4th. During the second survey, a total of 24 data points were collected.

The data collected in the second survey is important, as they help determine if there are any differences in amounts of refrigerants recovered or changes in the processes of treating the cars AC during maintenance work after the store personnel received the training sessions. The collected data also benefit the calculation of the baseline, as explained in detail in *chapter 5*.

Table 4. *Data of second round*

General information on the vehicle					Information on the refrig					
ID number	Collection date	Vehicle Information			Reasons for servicing the vehicle's A/C system in the workshop	Last refrigerant charge	Initial refrigerant charge (g)	Refrigerant type	Collection time (minutes)	e
		Vehicle type	Age of vehicle	Brand						
1	2024/7/9	Sedan	13	Audi	Routine maintenance of the entire vehicle	/	600	R134a	10 min	
2	2024/7/10	Sedan	9	Audi	Routine maintenance of the entire vehicle	/	600	R134a	10 min	
3	2024/7/12	Sedan	\	BMW	Poor cooling performance of the air conditioning	/	850	R134a	2 min	
4	2024/7/14	Sedan	\	BMW	Poor cooling performance of the air conditioning	/	850	R134a	3 min	
5	2024/7/15	Sedan	10	Toyota	Poor cooling performance of the air conditioning	/	1000	R134a	3 min	
6	2024/7/16	Sedan	\	Benz	Poor cooling performance of the air conditioning	/	1220	R134a	4 min	
7	2024/7/16	Sedan	\	Benz	Poor cooling performance of the air conditioning	/	690	R134a	5 min	
8	2024/7/16	Sedan	10	BMW	Routine maintenance of the entire vehicle	/	470	R134a	10 min	
9	2024/7/16	Sedan	12	Honda	Poor cooling performance of the air conditioning	/	520	R134a	15 min	
10	2024/7/16	GT	6	Porsche	Routine maintenance of the entire vehicle	/	560	R134a	10 min	
11	2024/7/17	Sedan	\	BMW	Routine maintenance of the entire vehicle	/	675	R134a	5 min	
12	2024/7/17	Sedan	8	Benz	Routine maintenance of the entire vehicle	/	980	R134a	15 min	
13	2024/7/20	Sedan	\	Dodge	Routine maintenance of the entire vehicle	/	624	R134a	5 min	

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erant and the air conditioning system						Extra infromation		
Problems ncountered during service	Amount recovered (g)	Condition of collected refrigerant	Disposal method of collected refrigerant	Refilled with recycled or virgin refrigerant	Has extra refrigerant been added to make a full charge? Please use only if recycled refrigerant was used. (g)	Customer satisfaction (10 points)	Remarks	Technician
None	570	Semi-polluted	Recycling in-situ	Virign	30	10	None	Fang Y .j.
None	570	Semi-polluted	Recycling in-situ	Virign	30	10	None	Liu D. L.
None	290	Semi-polluted	Recycling in-situ	Virign	560	7	None	Lv H.
None	341	Semi-polluted	Recycling in-situ	Virign	509	9	None	Lv H.
None	780	Semi-polluted	Recycling in-situ	Virign	220	9	None	Lv H.
None	700	Semi-polluted	Recycling in-situ	Virign	520	7	None	Lv H.
None	598	Semi-polluted	Recycling in-situ	Virign	92	9	None	Lv H.
None	360	Pure	Recycling in-situ	Virign	110	8	None	Lv H.
None	0	Semi-polluted	Free venting	Virign	520	9	None	Lv H.
None	530	Semi-polluted	Recycling in-situ	Virign	30	9	None	Fang Y .j.
None	435	Semi-polluted	Recycling in-situ	Virign	240	9	None	Lv H.
None	780	Pure	Recycling in-situ	Virign	200	9	None	Lv H.
None	400	Semi-polluted	Recycling in-situ	Virign	224	9	None	Lv H.

Table 4. *Data of second round*

General information on the vehicle					Information on the refrig				
ID number	Collection date	Vehicle Information			Reasons for servicing the vehicle's A/C system in the workshop	Last refrigerant charge	Initial refrigerant charge (g)	Refrigerant type	Collection time (minutes)
		Vehicle type	Age of vehicle	Brand					
14	2024/7/20	Sedan	\	BMW	Other reasons	/	550	R134a	8 min
15	2024/7/25	Sedan	7	Audi	Routine maintenance of the entire vehicle	/	560	R134a	10 min
16	2024/7/25	Sedan	11	Audi	Routine maintenance of the entire vehicle	/	560	R134a	10 min
17	2024/7/26	Sedan	9	Audi	Routine maintenance of the entire vehicle	/	500	R134a	10 min
18	2024/7/27	Sedan	7	Buick	Poor cooling performance of the air conditioning	/	680	R134a	15 min
19	2024/7/28	Sedan	6	Land Rover	Routine maintenance of the entire vehicle	/	862	R134a	15 min
20	2024/8/1	Sedan	7	Audi	Routine maintenance of the entire vehicle	/	560	R134a	10 min
21	2024/8/2	Sedan	7	Porsche	Routine maintenance of the entire vehicle	/	980	R134a	15 min
22	2024/8/3	Sedan	9	Volkswagen	Routine maintenance of the entire vehicle	/	480	R134a	10 min
23	2024/8/3	Sedan	9	Audi	Routine maintenance of the entire vehicle	/	680	R134a	15 min
24	2024/8/4	Sedan	9	Audi	Poor cooling performance of the air conditioning	/	680	R134a	15 min

gerant and the air conditioning system						Extra infromation		
Problems encountered during service	Amount recovered (g)	Condition of collected refrigerant	Disposal method of collected refrigerant	Refilled with recycled or virgin refrigerant	Has extra refrigerant been added to make a full charge? Please use only if recycled refrigerant was used. (g)	Customer satisfaction (10 points)	Remarks	Technician
None	450	Semi-polluted	Recycling in-situ	Virign	100	/	None	Lv H.
None	480	Pure	Recycling in-situ	Virign	80	9	None	Lv H.
None	370	Pure	Recycling in-situ	Virign	190	9	None	Lv H.
None	20	Pure	Recycling in-situ	Virign	480	8	None	Lv H.
None	470	Pure	Recycling in-situ	Virign	210	9	None	Lv H.
None	720	Pure	Recycling in-situ	Virign	142	9	None	Lv H.
None	420	Pure	Recycling in-situ	Virign	140	9	None	Lv H.
None	730	Pure	Recycling in-situ	Virign	250	7	None	Lv H.
None	420	Pure	Recycling in-situ	Virign	60	7	None	Lv H.
None	420	Pure	Recycling in-situ	Virign	260	9	None	Lv H.
None	0	Semi-polluted	Free venting	Virign	680	9	None	Lv H.

4.8. TRAINING ACTIVITIES

Directly after the second survey had concluded, the researchers started comparing the data from the first and second surveys. The methodology for, and calculation of, the baseline scenario based on the collected survey was finalized during this period as well.

5. METHODOLOGY FOR THE CALCULATIONS OF THE BASELINE EMISSIONS

In accordance with one of the objectives of this project, a methodology was developed for calculating the baseline emissions of passenger cars serviced in the Harson workshop and of the Guangzhou metropolitan area. This methodology follows the IPCC Guidelines for National Greenhouse Gas Inventories[2] ((IPCC, 2006). First, the baseline was calculated for the workshop where the data collection took place and extrapolated to the Guangzhou metropolitan area. Second, different scenarios were developed to estimate the total emission reduction potential in the mobile air conditioning (MAC)[3] sector in Guangzhou as well as in the Harson workshops. The emissions calculated for each scenario are compared in the results chapter to study the impact of the use of refrigerant recycling machines, proper training and other measures that can be applied in the MAC sector in China. The MAC sector as referred to in this *chapter* includes only passenger cars for private use.

5.1. SCENARIOS

Four scenarios are considered for comparing results and calculating the baseline. These are Business as Usual (BAU), Workshop Scenario 1 (WS1), Workshop Scenario 2 (WS2) and Mitigation Scenario (MIT). WS 1 and 2 are based on the actual conditions of the workshop where the data collection campaigns (Phase 1 and 2) took place. The BAU scenario is based on the actual conditions of a regular auto repair shop in the country, where currently all refrigerant contained in the cars ACs is vented and replaced with virgin refrigerant. The MIT scenario is based on assumption that workshops follow international best practices for refrigerant management, this means using refrigerant recycling machines and safely storing and disposing of the used refrigerant that cannon be recycled. The possible leakage associated to the handling of refrigerants (not to the venting) is not considered in this study. The scenarios are characterized by the following practices and conditions:

BAU scenario: As it is common in China and many other countries around the world, workshops do not have refrigerant recycling machines. Therefore, all the gas contained in the MAC unit of a vehicle is vented during the servicing. This occurs as it cannot be properly cleaned (recycled) and the unit is refilled with virgin refrigerant until a full charge is reached.

WS1: Workshop Scenario 1 reflects the conditions of the workshop in the time of the **first data collection campaign.** The workshop had refrigerant recycling machines; however, no training had been conducted for the technicians to learn how to operate them. This could have led to irregular use of the machines depending on the technician. In addition, when the recycling machines were not in use, the refrigerant was vented.

WS2: Workshop Scenario 2 reflects the workshop conditions at the time of the **second data collection campaign**. At this time, all technicians were trained in the proper use of the refrigerant recycling machines. Therefore, it is assumed that in all cases the refrigerant was recycled whenever possible. Only in cases where the refrigerant was too contaminated to be recycled it was assumed to be vented.

MIT scenario: The mitigation scenario assumes that no refrigerant is vented in the workshops. Instead, all refrigerant is recycled or collected for reclamation (if recycling is not an option). This is an ideal scenario where direct refrigerant emissions from the workshop are zero and when all the refrigerants can be treated and reused.

2 https://www.ipcc-nggip.iges.or.jp/public/2006gl/index.html
3 In this case the sector consists of only passenger cars

5.1.1. Baseline Emissions Calculations and Standardization

The baseline (BL) is calculated under the assumption of the BAU scenario in order to estimate all the emissions that can be potentially reduced by introducing refrigerant recycling machines to servicing workshops and conducting proper training. In the BAU scenario, it is assumed that all the refrigerant contained in the vehicles is vented in the workshops and replaced with new refrigerant. Even though, it is not possible to collect data on the amounts of refrigerant vented in the workshops, as the gas is simply released from the vehicle and therefore cannot be weighted, data is available for these quantities because the recycling equipment has been in use since the start of the first data collection campaign and is able to measure the weight of the refrigerant being recycled. In addition, for the cases where the refrigerant was vented, an average value for the remaining charge of the vehicle was used. It is therefore assumed that the refrigerant contained in the vehicles serviced in the workshops is equal to the BL. For the calculation of the BL all the data collected was used, while the emissions on the WS1 and WS2 were calculated using data from only one of the data collection campaigns (respectively). The results were standardized by using the total number of cars that were used for the calculations of each scenario and the average number of cars serviced by the workshop on a 4-week period. This enabled a comparison of the results of the different scenarios.

All variables calculated are presented in *Table 5*. In the following sections the methodologies for the calculation of emissions in the workshop and in the Guangzhou metropolitan area are presented separately. It is important to note that the spatial boundaries of the two methodologies are different; for the workshop, only emissions that occur on-site are considered, while for the Guangzhou metropolitan area, both refrigerant leakage on the road and emissions in the workshop are considered. The text follows a logical calculation process where the emissions of the workshop are then upscaled to the metropolitan area using parameters and information from the Guangzhou metropolitan area. To calculate the emissions in carbon dioxide equivalent units (CO_2eq), the kilograms of refrigerant are multiplied by the Global Warming Potential[4] (GWP) of each refrigerant. The average charge of the cars surveyed in this study is 0.8 kg. In this case only the refrigerant HFC-134a is considered. This HFC has a GWP value of 1530 kgHFC-134a/kgCO_2eq (IPCC, 2022).

Table 5. *Variables calculated in the pilot project [1/2]*

N°	Variables	Name	Units	Special Boundaries	Temporal Boundaries	Sources
1	R_{rcyl}	Refrigerant recycled	kg	Workshop	4 weeks	Measured with refrigerant recycling machines. Data collection campaigns
2	R_{vent}	Refrigerant vented	kg	Workshop	4 weeks	Calculated using the measurements from the refrigerant recycling machines. Data collection campaigns
3	VR	Virgin refrigerant needed for servicing	kg	Workshop	4 weeks	Data collection campaigns
4	Em	Refrigerant emissions	CO_2eq	Workshop	4 weeks	Calculated using the measurements from the refrigerant recycling machines. Data collection campaigns

4 The GWP values used for the calculation are taken from the IPCC Sixth Assessment Report

Table 5. *Variables calculated in the pilot project [2/2]*

N°	Variables	Name	Units	Special Boundaries	Temporal Boundaries	Sources
5	BL_{BAU}	Baseline emissions	CO_2eq	Workshop	4 weeks	Estimation based on data
6	AvEm	Total avoided emissions	CO_2eq	Workshop	4 weeks	Estimation based on data
7	PR_{rcov}	Potential refrigerant for recovery	Kg	Workshop	4 weeks	Theoretical variable for MIT scenario
8	BL_{mac}	Baseline emissions	kg, CO_2eq	Guangzhou	1 year	Extrapolation using data from Harson
9	Em_{mac}	Refrigerant emissions	kg, CO_2eq	Guangzhou	1 year	Extrapolation using data from Harson
10	Em_{w}	Workshops refrigerant emissions	kg	Guangzhou	1 year	Extrapolation using data from Harson
11	Em_{road}	Refrigerant emission on the road	kg	Guangzhou	1 year	Extrapolation using data from Harson
12	PRR_{mac}	Potential refrigerant for recycling	kg	Guangzhou	1 year	Extrapolation using data from Harson
13	VR_{mac}	Virgin gas needed for servicing	kg	Guangzhou	1 year	Extrapolation using data from Harson
14	$AvEm_{mac}$	Total avoided emissions	kg	Guangzhou	1 year	Extrapolation using data from Harson

5.1.2. Methodology of Baseline Emissions Calculations in the Workshop

The recycled refrigerant is calculated for a 4-week period by summing all relevant data collected during each of the campaigns. This is calculated using **Equation 1**, which is the sum of all the refrigerant recycled that was reported by the technicians. In this equation **"n"** is the total number of cars serviced in the workshop during the data collection period and **"i"** is each entry.

Equation 1 $$R_{rcy} = \sum_{i=1}^{n} R_{recycled,i}$$

Similarly, **Equation 2** and **Equation 3** are used to calculate the refrigerant vented and the virgin refrigerant used in the workshops. All three variables are calculated in kilograms for each data collection campaign, corresponding to the WS1 and WS2, described above. To calculate these variables for a 1-year period, the total number of vehicles serviced in the workshop during this period could be used. This data was provided directly by Harson.

Equation 2 $$R_{vent} = \sum_{i=1}^{n} R_{vented,i}$$

Equation 3 $$VR = \sum_{i=1}^{n} R_{virgin,i}$$

The refrigerant emissions are calculated using **Equation 4**. This variable is calculated for a period of 4 weeks (corresponding to the duration of a data collection campaign) and then multiplied by the GWP value of R134a to obtain the emissions in CO_2eq. The emissions in the workshop equal the refrigerant vented, as it can be seen in the equation.

Equation 4 $$Em = R_{vent} \times GWP$$

As explained above, the calculated emissions for the BAU scenario are considered as the baseline (BL). In this scenario, it is assumed that all the refrigerant contained in the vehicles is vented in the workshops and replaced with new refrigerant. The baseline is calculated using **Equation 5**, where Q_{ref}, the amount of refrigerant vented, is multiplied by the GWP value of the refrigerant. in this case by 1530 kgHFC-134a/kgCO_2eq. It is important to note that the emissions that occur on the road (leakage) are not considered, nor are emissions from leakage during the handling of refrigerant in the workshop.

Equation 5 $$BL_{BAU} = Q_{ref} \times GWP$$

In addition, the avoided emissions are calculated using **Equation 6**, which compares the baseline emissions (BL_{BAU}) with the emissions calculated for each scenario (Em). This calculation makes it possible to determine the effectiveness in terms of emission reduction of each measure that was taken during the project[5]. The equation also serves to estimate the impact of best practice (MIT scenario), where all refrigerant is recycled or recovered.

Equation 6 $$AvEm = BL_{BAU} - Em_{scenario}$$

Lastly, **Equation 7** is used to calculate all the refrigerant that could be recovered from the workshops. Currently, the workshops do not have the capacity to recover and store refrigerant for safe disposal or reclamation, they can only recycle in-situ. This always some refrigerant left that could not be recycled due to poor quality. However, if sector best practices are followed, all the used refrigerant in the workshops will be recycled, reclaimed or properly disposed of (destroyed).

Equation 7 $$PR_{rcov} = R_{vent}$$

5.1.3. Methodology of Baseline Emissions Calculations in the Guangzhou Metropolitan Area

As it was previously mentioned, some of the variables that are calculated for the Harson workshop are also calculated for the Guangzhou metropolitan area. This is carried out by using the parameters shown in *Table 2*. The initial charge and the leakage rate were calculated using the data collected during the campaigns and compared with the data provided by Harson. These two parameters are an average of passenger cars in the metropolitan area, which are the type of vehicles serviced in the Harson workshops. The number of cars and the frequency of servicing were provided by Harson.

5 Measures applied during the pilot project include introducing refrigerant recycling machines and conducting training for their proper use.

Table 6. *Parameters for upscaling variables to the Guangzhou metropolitan area*

N°	Parameters	Name	Value	Units	Source
1	IC	Initial refrigerant charge	0.8	kg	Estimated using the data collected and data provided by Harson
2	LR	Annual leakage rate	4.1	%/year	Estimated using the data collected and data provided by Harson
3	n_c	Number of passenger cars in Guangzhou	2,800,000	N° of unites	Harson
4	S_y	Servicing frequency	6.5	Years	Harson
5	E_r	Emissions on the road relative to the initial charge during the servicing frequency period (6.5 years)*	27	%	Estimated using the data collected and data provided by Harson

* This parameter represents the emissions during the servicing frequency period (S_y) and is used to calculate the annual leakage rate (LR) by dividing it by S_y.

Equation 8 is used to estimate the baseline emissions in the BAU scenario for the Guangzhou metropolitan area. Here it is assumed that the total number of cars (n_c) emit their entire initial refrigerant charge (IC) during the servicing frequency-period (S_y), which in this case is 6.5 years. This assumes that any refrigerant that has not been leaked on the road during that period is then vented in the workshop.

Equation 8 $$BL_{mac} = n_c \times \frac{IC_{avg}}{S_y}$$

In the WS1 and WS2, some of the emissions are avoided through the recycling of refrigerant at the workshops during the servicing of the cars. **Equation 9** is used to calculate the emissions of the passenger cars in the Guangzhou metropolitan area for these scenarios. This equation is the sum of the emission that occur on the road due to refrigerant leakage (Em_{road}) and in the workshops when the refrigerant is vented (Em_w). **Equation 10** uses the initial charge, the leakage rate and the total number of vehicles to estimate the annual emissions that occur on the road. This differs from previous emissions calculated in the last subchapter, where the special boundary was restricted to the workshops.

Equation 9 $$Em_{mac} = Em_{road} + Em_w$$

Equation 10 $$Em_{road} = n_c \times IC_{avg} \times LR$$

Em_w are the emissions that occur in the workshops during the servicing of the vehicles. These emissions are zero on the MIT scenario and are calculated for the WS1 and WS2 scenarios using **Equation 11**, where all the potential refrigerant available for recycling (PRR_{mac}) is multiplied by a factor expressed as a percentage. This factor is calculated by dividing the total refrigerant recycled during the 4-week data collection period by the total amount of used refrigerant handled in the workshops. This total is the refrigerant recycled plus the vented one[6]. Moreover, the potential refrigerant for recycling is calculated using **Equation 12**. This is all the refrigerant left in the vehicles when they arrive in the workshop, and it is calculated by estimating the number of vehicles that are serviced every year $\frac{n_c}{S_y}$ times all the refrigerant that they contained.

Equation 11 $$PRR_{mac}\, Em_w = PRR_{mac} \times \left(\frac{R_{vent}}{R_{rcyl} + R_{vent}} \right)$$

Equation 12 $$PRR_{mac} = \frac{n_c}{S_y} \times \left(IC_{avg} - IC_{avg} \times E_r \right)$$

As explained before **Equation 8** and **Equation 9** calculate the total refrigerant lost by the vehicles on the road and in the workshops (emissions). Any refrigerant emitted would have to be replaced with virgin refrigerant (VR) in the workshops. Therefore, **Equation 13** (a) is valid for the BAU scenario and **Equation 13** (b) for the other three WS1, WS2 and MIT.

Equation 13 (a) $$VR_{BAU} = BL_{mac}$$ (b) $$VR = Em_{mac}$$

Finally, **Equation 14**, similar to **Equation 6**, is used to calculate the emissions avoided in each of the scenarios by comparing them to the passenger cars baseline emissions (BL_{mac}) in the Guangzhou metropolitan area.

Equation 14 $$AvEm_{mac} = BL_{BAU} - Em_{mac}$$

6 This factor is calculated using the average of the two data collection campaigns.

5.1.4. Data and Calculations Uncertainties

In accordance with the IPCC Guidelines for National Greenhouse Gas Inventories[7] for the calculation of emissions in the refrigeration and air conditioning (RAC) sector, uncertainties related to the data and the calculations are presented here.

The data collection, errors can occur when entering information into the spreadsheets, as well as due to misunderstandings on the use of the templates. However, to avoid errors and reduce uncertainties as much as possible, the data collection process was refined through a 4-week trial in which the template and the data collected were reviewed and modifications to the process were made. On the other hand, there is an uncertainty associated with the data collection because of the short period surveyed (4-weeks). This data collection process could miss changes in seasonality and temperature. For example, the number of cars serviced in workshops is expected to fluctuate with the need for air conditioning and therefore with ambient temperature. It is also important to note that the leakage (not the venting) during the handling of refrigerant in the workshops is not considered. Therefore, workshop emissions might be slightly underestimated, as this source is not included. Finally, the parameters (e.g. initial charge, leakage rate) used for calculating the variables for the Guangzhou metropolitan area are based on data from Harson and the surveys, which mainly services larger, higher-end European cars, which are more expensive in China than other brands. This is a potential source of data-errors as Harson does not service the full range of passenger cars in the metropolitan area. Other parameters such as the total number of cars in the metropolitan area are estimates.

5.2. RESULTS OF THE CALCULATIONS: BASELINE AND EMISSIONS

This chapter presents the results of the calculations, differentiated for the workshops and the Guangzhou metropolitan area. A comparison is made between the baseline emissions (BAU scenario) and those of the WS1 and WS2 and the mitigation scenario (MIT). However, to avoid redundancy the MIT scenario is not shown for the workshop emissions. For the metropolitan area of Guangzhou an average of the WS1 and WS2 is presented.

5.2.1. Workshop baseline and emissions

As explained in the methodology, the results were standardized using the average number of cars serviced in the workshop per day and in a 4-week period. These are shown in *Table 7*. Results were divided by the total number of cars that were used in the calculations of the emissions for each scenario and then multiplied by 19 (the average number of cars on a 4-week period). The number of cars used for the calculations for each scenario are presented in Table 4 together with the results.

7 https://www.ipcc-nggip.iges.or.jp/public/2006gl/index.html

Table 7. *Standardizing Parameters*

N°	Name	Value	Units	Source
1	Number of cars serviced per day in the workshop	0.67	N° of unites	Estimated using the data collected
2	Number of cars serviced in a 4-week period in the workshop	19*	N° of unites	Estimated using the data col-lected

* This value is calculated based on the data collected and therefore does not represent an annual average. During the survey period (May to August) the number of vehicles serviced is higher than the annual average as these are the warmer months when air conditioning is most commonly used. The average number of vehicles that are serviced at this workshop per month is 15.

In *Table 8* the baseline emissions calculated for the BAU scenario are 9.5 kg of R134a representing 14.481 kgCO_2eq. This scenario assumes that the refrigerant recycled is zero, as it is common in most workshops in China that service the MAC sector. In total, 13.1 kg of virgin refrigerant are needed in this scenario to service all the cars in a 4-week period. On the contrary, in the WS1 9,3 kg of refrigerant are recycled leading to only half a kilogram of emissions (776,3 kgCO_2eq). In the WS2 8.5 kg of R134a are recycled with a total emission of 0.7 kg (1051,2 kgCO_2eq).

Table 8. *Baseline and emissions results for the Harson workshop*

Variable	BAU Scenario (Baseline)	Workshop Scenario 1	Workshop Scenario 2
Start date	09.05.2024	27.05.2024	08.07.2024
End date	04.08.2024	23.06.2024	04.08.2024
Number of days	88	28	28
Number of weeks	12.57	4.00	4.00
Number cars surveyed	59	13	24
Cars surveyed per day	0.67	0.46	0.86
Standardized results			
Refrigerant recycled (R_{rcyl})	0 kg	9.3 kg	8.5 kg
Virgin refrigerant (VR)	13.1 kg	3.8 kg	4.6 kg
Refrigerant emissions (Em) or Potential refriger-ant for recovery (PR_{rcov})*	9.5 kg	0.5 kg	0.7 kg
Refrigerant emissions (Em)	**14,481 kgCO_2eq (BL)**	**776.3 kgCO_2eq**	**1,051.2 kgCO_2eq**
Total avoided emissions (AvEm)	-	**13,705 kgCO_2eq**	**13,430 kgCO_2eq**

* The refrigerant emissions (Em) equal the potential refrigerant for recovery (PR_{rcov}), because, in this case the emissions are counted only as the vented refrigerant in the workshop, and this is exactly the refrigerant that can be recovered. (*See Equation 7*)

The WS1, as mentioned, above uses the data collected on the first campaign when the workshop had already access to new refrigerant recycling machines. However, the emissions are slightly lower than in the WS2 which occurred after the technicians had received proper training. In total, of the 13 vehicles serviced during the first data collection campaign only the refrigerant of one of them was vented. This can be compared to the 24 vehicles serviced during the second data collection campaign, where the refrigerant of two of them was vented. One possible explanation for the venting of refrigerant is that, in these three cases, the refrigerant was too polluted to be recycled. In addition, it should be considered that the first data collection campaign happened a month after the data collection process started. The first 4 weeks were used to refine the templates and make sure all technicians knew how to collect the data properly. This period, consequently, allowed the technicians to learn how to (informally) use the machines properly which resulted in an outstanding rate of refrigerant recycling from the beginning of this pilot and the data collection process.

5.2.2. Guangzhou metropolitan area baseline and emissions

The baseline and the emissions for the metropolitan area of Guangzhou are presented in *Table 9* for the BAU, WS 1 & 2 and MIT scenarios. The annual emissions from all passenger cars in Guangzhou are estimated to be 527.261 tCO_2eq (344.615 kg). This total figure is the result of 92.360 kg of refrigerant leakage on the road (27%) and 252.255 kg of refrigerant vented in the workshops (73%). This figure clearly shows that the emissions that occur in the workshops, due to the venting of refrigerant, are more than two times higher than the refrigerant leakage happening on the road. Therefore, the most critical point for reducing refrigerant emissions of passenger cars in China is by addressing the refrigerant servicing practices of the workshops. Moreover, the emissions on the WS 1 & 2 are 165.772 tCO_2eq (108.348 kg) which is slightly less than a third of the baseline. This reduction of emissions is achieved thanks to the amount of refrigerant recycled (236.268 kg) on the scenarios WS 1 & 2.

__Table 9.__ Baseline and emissions results for the metropolitan area of Guangzhou

Variable	BAU Scenario (Baseline)	Workshop Scenarios 1 & 2 (average)	Mitigation Scenario (MIT)
Refrigerant recycled (R_{rcyl})	0 kg	236,268 kg	252,255 kg*
Refrigerant emission in the workshops Em_w	252,255 kg	15,988 kg	0 kg
Refrigerant emission on the road Em_{road}	92,360 kg	92,360 kg	92,360 kg
Refrigerant emissions (Em_{mac}) or Virgin refrigerant (VR)**	344,615 kg (BL)	108,348 kg	92,360 kg
Refrigerant emissions (Em_{mac})	**527,261 tCO_2eq (BL)**	**165,772 tCO_2eq**	**141,311 tCO_2eq**
Total avoided emissions ($AvEm_{mac}$)	-	**361,489 tCO_2eq**	**385,950 tCO_2eq**

* This number also represents the refrigerant that is reclaimed in cases where recycling in-situ is not possible.
** As shown in Equation 13 the refrigerant emissions (Em_{mac}) equal the virgin refrigerant (VR).

The MIT scenario assumes that all refrigerant that arrives in the workshops is recycled or reclaimed. Thus, in this scenario the emissions only occur on the road equivalent (as explained above) to a total of 141.311 tCO_2eq emitted every year. It is important to mentioned that the MIT scenario is theoretical and that some refrigerant might be also too polluted to be reclaimed. However, it shows that if all workshops in the metropolitan area of Guangzhou reach the high rates of refrigerant recycling seen during the data collection campaigns, the reduction will be very significant, as the difference of emissions between WS 1 & 2 and MIT is only 6%.

6. ANALYSIS OF PILOT PROJECTS - EXPERIENCES AND LESSONS LEARNED.

This COPA pilot project for developing, piloting, and testing the impact of introducing standardized processes for air conditioning refrigerant recovery was carried out in collaboration with the automobile maintenance enterprises Guangzhou Harson Group in one of the stores in the Harson region. The cooperation was fruitful, and the implementation of the pilot activities went well. This project explores effective refrigerant recovery models and mechanisms through practical operation and demonstration. The results of this collaboration will, if approved as standard for the industry, in the longer perspective promote the improvement of air conditioning refrigerant recovery work in the entire Chinese automobile maintenance industry.

It also became clear that it is not possible to plan every aspect of a pilot project. There will most likely always be surprises along the way when doing research and implementing pilot projects. The development and testing of the survey template for data collection proved to be more challenging and time-consuming then first anticipated. The translation from English to Chinese did not work well until certain aspects had been clarified with the technicians in the actual pilot store in Guangzhou. The terrible flooding and delay and destruction it brought to the region, is also not possible to foreseen when planning a project. The historical customer data from Harson was very important to understand the impact of this extreme weather event on the data collection.

The COPA demonstration project by CATARC together with the Harson Group does not only focuses on technical operations but involves multiple aspects such as personnel training and development of new standardized work-processes, equipment management, and company management system construction. During the pilot process, it was discovered that to improve the current situation of air conditioning refrigerant recovery in China's automotive maintenance industry and overcome the operational challenges that the industry face (as mentioned in *chapter 3.1*), it is beneficial to start from multiple dimensions, involving all stakeholders throughout the sector (technicians, researchers, trainers, management) to find a feasible solution working well and efficient on all levels.

The operational challenges for air conditioning refrigerant recovery in the automotive maintenance industry in China are difficult but not impossible to overcome. The experiences, results and data collected through this pilot, clearly show that there are activities and actions that, if implemented, can improve the situation and thereby considerable contribute to an increased recycling and recovery of refrigerants from air conditioners in automobiles and reduce emissions harmful to the environment, the climate and the ozone layer.

In the next sector, each of the operational challenges are listed with the lessons learned and building on experiences collected through this pilot project.

6.1. CHALLENGE: LACK OF PROFESSIONAL TECHNICAL TRAINING FOR MAINTENANCE PERSONNEL

- **Personnel technical ability: a solid foundation for standardized operations**
  The technical ability of the personnel is a solid foundation for standardized operations. In the demonstration project, the importance of personnel technical ability in standardizing operations was deeply realized. Maintenance technicians need to receive professional training to master the technology and operating procedures of refrigerant recovery.

  Before the pilot training weeks, some technical personnel were not familiar with the technology and operation process of refrigerant recovery, resulting in many problems and safety hazards during the recovery process. For example, failure to ensure that there is no air residue inside when connecting hoses, and failure to filter, dry, and remove oil during recycling operations. After professional training and practical operation, the technical ability of the technicians has significantly improved. The training teacher found that their operational errors gradually decreased, and their efficiency gradually improved in the later stage of training. The staff are now familiar with the connection methods of recycling machines and car air conditioning systems and have mastered the complete process of refrigerant recovery. After the piloted training weeks, the technicians were able to carry out recycling operations in a standardized manner, reducing errors and safety hazards during the operation.

6.2. CHALLENGE: NON-COMPLIANT MAINTENANCE PRACTICES

- **Standardized process: The key to the efficiency of refrigerant recovery**
  The demonstration project showed that establishing a standardized refrigerant recovery process is crucial. From connecting the system, recycling operations to vacuum treatment, every step needs to be strictly followed according to the operating instructions for high efficiency and security. Currently in China, the automobile repair sector has problems such as non-standard operation and chaotic processes in the refrigerant recovery process, as detailed in *chapter 3.2.2*. The implementation and publication of results from pilot projects such as the COPA-CATARC cooperation with the Harson Group in this study will help enterprises establish standardized refrigerant recovery processes and accelerate the development of standardized processes for the industry. With such new and tested standards, it will be possible for Technicians to strictly follow the operating instructions during the recycling process, ensuring the orderly progress, efficiency and quality of the recycling work.

6.3. CHALLENGE: INSUFFICIENT UTILIZATION OF RECOVERY EQUIPMENT FOR RECYCLING

- **Advanced equipment: efficiency and safety guarantee of refrigerant recovery**
  During the COPA pilot project, the importance of the equipment for refrigerant recovery became evident. Advanced refrigerant recovery equipment can significantly improve recovery efficiency and volume, if used correctly. By introducing an advanced refrigerant recovery equipment and providing training for technical personnel on equipment operation and maintenance during the pilot activities, the staff at the local store were able to use equipment for refrigerant recovery correctly, resulting in significant improvements in recovery efficiency and volume, while also ensuring process safety.

6.4. CHALLENGE: LOW LEVEL OF ENTERPRISE MANAGEMENT

- **Company management system: Stable support for refrigerant recovery work**
  Finally, as a last point, the COPA pilot team with CATARC with the Harson Group also realized the importance of company management for an efficient and safe refrigerant recovery work in the workshop stores. Automobile maintenance companies need to establish a comprehensive management system, including personnel training, equipment management, operational procedures, and other aspects.
  Currently, as described in *chapter 3*, there are automobile repair companies in the sector that experience many management problems, such as insufficient personnel training, poor equipment maintenance, and non-standard operating procedures. This has resulted in low efficiency and substandard quality of refrigerant recovery work. Through the implementation of the COPA pilot projects, the benefits of implementing a sound management system, as showcased by the with the Harson Group, has become evident. The company has developed detailed refrigerant recovery operation procedures and standards and strengthened technical personnel training and equipment maintenance work, and the results are showing. After the pilot project, the refrigerant recovery work of the enterprise has become even more standardized and efficient, not only improving the recovery efficiency and quality, but also reducing the recovery cost.

7. PROPOSAL AND RECOMMENDATIONS

Based on the data and experiences collected through the COPA-CATARC pilot project with the with the Harson Group, activities to further enhance and accelerate the development of the automotive repair industry in China has been developed. These recommendations are outlined in the following section and follow the same structure as the challenges from *chapter 3* and lessons learned in *chapter 6*.

7.1. STRENGTHEN PROFESSIONAL TRAINING AND SKILL ENHANCEMENT

In response to the lack of professional technical training for maintenance personnel, it is recommended that industry associations and enterprises jointly develop specific training standards for refrigerant recovery technology under the guidance of the government and require all automotive maintenance technicians to receive regular professional training. The training content should cover the properties of refrigerants, recovery techniques, operating procedures, and environmental regulations to ensure that maintenance personnel can proficiently master the relevant knowledge and skills of refrigerant recovery.

7.2. PROMOTE STANDARDIZED OPERATING PROCEDURES

To address the issue of non-standard maintenance operations, it is recommended to develop and promote standardized operating procedures for refrigerant recovery in the automotive maintenance industry. These processes should specify in detail every step from refrigerant recovery, storage, purification to refueling, ensuring that maintenance companies have clear guidance in practical operations.

7.3. IMPROVE THE ALLOCATION AND UTILIZATION RATE OF RECYCLING EQUIPMENTT

In response to the problem of underutilization of refrigerant recovery equipment in recycling, the government should introduce relevant policies to require automobile repair enterprises to equip refrigerant recycling equipment that meets standards and conduct regular inspections on the use of the equipment. At the same time, the government can provide certain financial subsidies or tax incentives to reduce the cost burden of purchasing and using recycling equipment for enterprises. In addition, training for operators of recycling equipment should be strengthened to ensure that they can use these devices correctly and effectively.

7.4. IMPROVE ENTERPRISE MANAGEMENT AND REGULATORY SYSTEM

To enhance the general management level of automobile maintenance enterprises, it is suggested that the government strengthen the supervision of enterprise capabilities. At the same time, enterprises should establish a sound internal management system, including developing detailed refrigerant recovery operating procedures, strengthening employee responsibility division and workflow management, and improving service quality. Industry associations and governments should regularly evaluate the management and technical level of maintenance enterprises, rectify or eliminate enterprises that do not meet standards, in order to promote the healthy development of the entire industry.

7.5. TRAINING AND CERTIFICATION FOR WORKSHOP TECHNICIANS

Based on the relevant experience of this pilot project, CATARC and the Harson Group can further develop professional training courses and certification certificates related to automotive air conditioning refrigerant recovery. This type of training is not only applicable to the automotive repair industry, aiming to enhance the technical personnel's mastery and application ability of refrigerant recovery technology, but also has the same applicability and value for the scrapped car recycling industry that needs to recover refrigerants. Through such professional training, technicians and workshop operators can systematically learn and master the latest technologies and standardized operations of refrigerant recovery, and then use these courses and certificates obtained to effectively demonstrate their professional abilities and qualifications in the field. In this way, not only can trained technicians enhance customers' trust in their service quality, but it can also better meet their specific needs for refrigerant recovery and disposal during vehicle maintenance, as well as the environmental requirements for proper refrigerant recovery and disposal.

7.6. NEW PILOT PROJECTS

Based on the experience of this pilot project, CATARC propose to launch a second pilot project in the future, proposing selecting other Southeast Asian countries as the regions for a second automotive repair enterprise refrigerant recovery pilot project. Indonesia or Thailand, for example, can be considered. These two countries not only have advantageous geographical locations, but also have experienced rapid economic development in recent years, with an increasing number of cars and a growing demand for car maintenance and refrigerant recovery. Hope this pilot project can have more time to collect more data.

Through such new pilot project, the policy implementation effectiveness, technical feasibility, and economic benefits of different countries and regions can be tested, verified and compared with the Guangzhou pilot. By implementing a detailed plan, including policy docking, technical training, equipment procurement and configuration, data collection and analysis, and strengthening international cooperation and exchange, a comprehensive evaluation and summary of the pilot effect will be conducted, providing valuable experience and reference for refrigerant recovery work worldwide.

8. NEXT STEP - STANDARD SPECIFICATION DEVELOPMENT

Based on the data and experiences from the pilot study and data collection, the China Automotive Technology Research Center will develop a proposal for standard specifications for refrigerant recovery processes in the automotive industry in China on national level.

8.1. BASIS AND MAIN CONTENT FOR STANDARD FORMULATION

The basis for the formulation of this standard fully reflects its scientific and practical nature. Firstly, the regulation takes into account the current development status of the automotive maintenance industry and the demand for environmental protection and resource utilization, ensuring a close integration between the content of the regulation and practical applications.

Secondly, the standard refers to relevant industry standards, regulatory requirements, and environmental policies, making its content supported and guided by regulations, and more authoritative and operable. Finally, the standard also summarizes the technical practices and experiences of refrigerant recovery and treatment, incorporating effective methods and strategies from practical operations, enhancing the practicality and guiding significance of the standard.

The following are the main contents of the standard under development by CATARC:

- Preface: This article elaborates on the background, purpose, and significance of the formulation of refrigerant recovery standards.
- Refrigerant recovery and treatment equipment: Detailed description of the types, performance requirements, maintenance, and calibration of equipment required for refrigerant recovery.
- Personnel requirements: Clarify the professional training, knowledge, and skills required for personnel involved in refrigerant recovery work.
- Refrigerant recovery operation process and specifications: Detailed description of the refrigerant recovery operation process, including pre operation preparation, detection and identification, recovery, storage and recording, purification and other links.
- Safety precautions and emergency measures: List the safety precautions that should be followed during the operation process and the possible emergency response measures.
- Regulation: Regulatory requirements have been proposed for establishing management systems, operating procedures, equipment inspection and maintenance, employee training, and other aspects.

8.2. THE EXPECTED ADVANTAGES OF THIS NEW STANDARD SPECIFICATION

This new standard specification is expected to have significant scientific quality. It is based on the physical and chemical properties of refrigerants, environmental regulations, and technical practice experience, and has developed detailed and comprehensive operating procedures and specifications to ensure that every step of the recovery process follows scientific principles, thereby achieving the best treatment effect. This standardized operation is based on science and will not only enhance the professionalism of recycling operations, but also lays a solid foundation for the sustainable development of the automotive industry in China.

At the same time, this new standard specification also shows progressiveness. It introduces high-precision refrigerant identification devices and efficient recovery machines, significantly improving the accuracy and efficiency of recovery, making the recovery process more precise and efficient. In addition, the standard emphasizes the maintenance and calibration of equipment to ensure stability and accuracy during long-term operation, further improving the quality of recycling operations.

By specifying the purification process, the new standard not only improves the quality of recycled refrigerants, but also makes them more in line with environmental protection and resource reuse requirements. Finally, establishing a comprehensive safety management system and emergency measures has effectively improved the safety of operations, providing comprehensive support for recycling operations.

8.3. THE PROCESS OF STANDARDIZING THE CONVERSION OF TRAINING DOCUMENTS

The key to making the new standard a true standardization process lies in its comprehensive implementation and execution in practice. This first requires strengthening training and education, by organizing maintenance enterprise personnel to participate in professional training, ensuring that they not only understand the standard requirements, but also master the operational skills proficiently, which is the foundation of standardization implementation. At the same time, enterprises need to develop internal management systems and operating procedures based on the new standards, clarify the responsibilities of each department and personnel, and ensure that the standards are systematically implemented within the enterprise.

The subsequent steps include establishing an effective supervision mechanism, setting up specialized supervision departments or positions, regularly inspecting and evaluating the recycling work, and ensuring that the standards are not ignored or deviated from in actual operation. At the same time, strengthening publicity and guidance is also crucial. Through diversified publicity methods such as bulletin boards, meetings, training, etc., we can deeply promote the importance and significance of standards to employees, enhance their environmental awareness and consciousness of implementing standards.

Finally, it is important to also establish incentive and punishment mechanisms, commend and reward enterprises that perform well in implementing standards, and take corresponding punishment measures for enterprises that violate standards. This is vital in order to form an effective positive and negative incentive mechanism and promote the new standards to truly become industry consensus and operational norms in practice.

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COPA
Cutting refrigerant emissions

Implemented by: Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH

In cooperation with: UNIDO, UNDP

Supported by: Federal Ministry for Economic Affairs and Climate Action; IKI International Climate Initiative

on the basis of a decision by the German Bundestag

Imprint

Published by
Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH

Registered offices
Bonn and Eschborn

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Climate and Ozone Protection Alliance (COPA)

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Design
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Frankfurt a. M. / Germany

On behalf of
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Oktober 2024

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