

# 中国非道路移动机械排放控制现状与展望 Progress and Prospect on Emission Control of Non-Road Mobile Machinery in China

纪亮 研究员 中国环境科学研究院机动车排污监控中心

2023年10月16日，北京

Ji Liang, Researcher

Vehicle Emission Control Center

Chinese Research Academy of Environmental Science

October 16, 2023, Beijing

# 目录

## Contents



1

行业发展与排放现状  
Development and Emission of NRMM

---

2

排放控制主要进展  
Major Progress in Emission Control

---

3

未来政策预期  
Recommendations on Future policy

---

第

1

部分

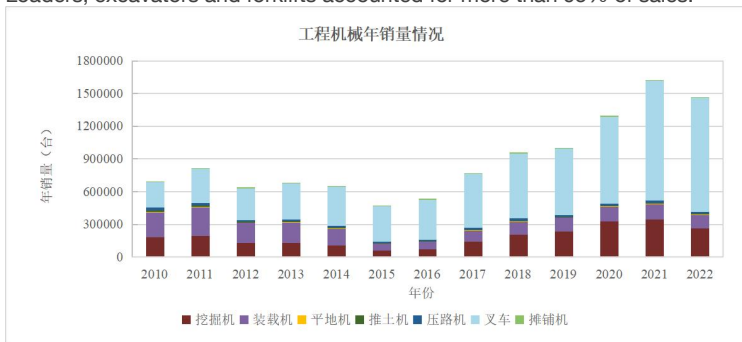
行业发展与排放现状

Development and Emission of NRMM

# 1、行业现状 NRMM in China

## • 工程机械 Construction Machinery

- 销量呈上升趋势，2010年69万台，2022年的146万台
- 根据存活曲线方法测算，2022年保有量约940万台
- 工程机械主要为挖掘机、装载机、叉车，2020年占比达97%
- Sales are on the rise, from 0.69 million (2010) to 1.46 million (2022)
- Calculated by survival curve method, in 2022, there were 9.4 million construction machinery
- Loaders, excavators and forklifts accounted for more than 95% of sales.



## • 农业机械 Agricultural Machinery

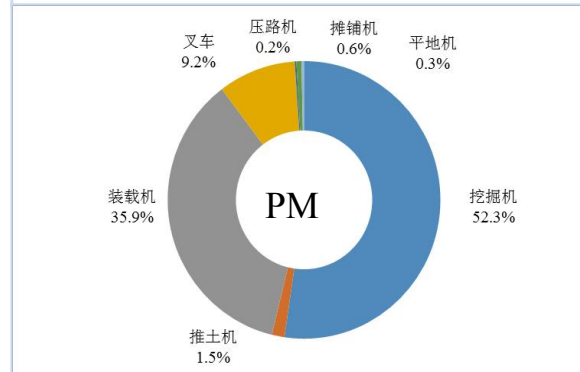
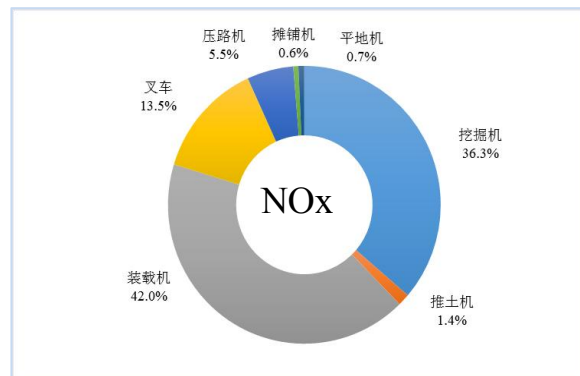
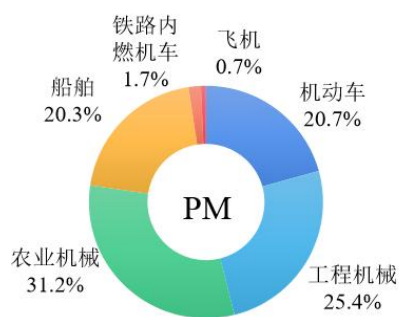
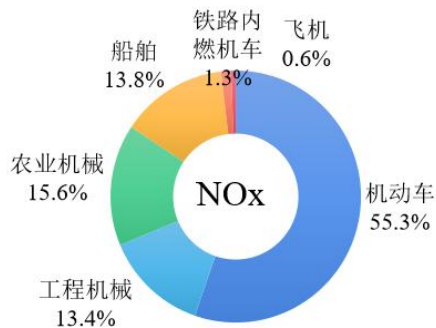
- 向大型化发展，近年来总动力在10亿千瓦左右
- 农业机械主要为拖拉机、收获机械，占比超过60%
- Large Machinery Tendency, the total power is about 1 billion kW
- Tractors and harvesting machinery accounted for more than 60%



| 工程机械类别 | 主要应用场景 |      |      |        |      |      |          |          |      |      |      |          |     |
|--------|--------|------|------|--------|------|------|----------|----------|------|------|------|----------|-----|
|        | 住房建设   | 公路建设 | 隧道挖掘 | 机场建设运营 | 铁路建设 | 水库建设 | 铁路货场建设运营 | 港口码头建设运营 | 煤矿生产 | 矿石开采 | 工业企业 | 物流中心配送中心 | 仓库等 |
| 起重机械   | √      | √    |      | √      | √    |      | √        | √        |      |      |      |          |     |
| 叉车     |        |      |      | √      |      |      | √        | √        |      |      | √    | √        | √   |
| 推土机    |        | √    |      | √      | √    | √    | √        | √        | √    | √    |      |          |     |
| 装载机    | √      | √    | √    | √      | √    | √    | √        | √        | √    | √    | √    |          |     |
| 平地机    |        | √    | √    | √      |      |      |          |          |      |      |      |          |     |
| 摊铺机    |        | √    | √    | √      |      |      |          |          |      |      |      |          |     |
| 压路机    |        | √    | √    | √      |      |      |          | √        |      |      |      |          |     |
| 挖掘机    | √      | √    | √    | √      | √    | √    | √        | √        | √    | √    |      |          |     |

## 2、非道路移动机械排放占比高 Emission Contribution of NRMM

- 移动源NO<sub>x</sub>排放量约占全行业的60%
- 非道路移动机械NO<sub>x</sub>排放量占移动源的29%，PM排放量占移动源的57%
- 工程机械中，约92%的NO<sub>x</sub>、97%的PM来自于挖掘机、装载机和叉车
- Mobile source NO<sub>x</sub> emissions account for about 60% of the total
- NRMM NO<sub>x</sub> emissions accounted for 29% of mobile source, and PM emissions accounted for 57% of mobile source
- In construction machinery, about 92% of NO<sub>x</sub> and 97% of PM come from excavators, loaders and forklifts



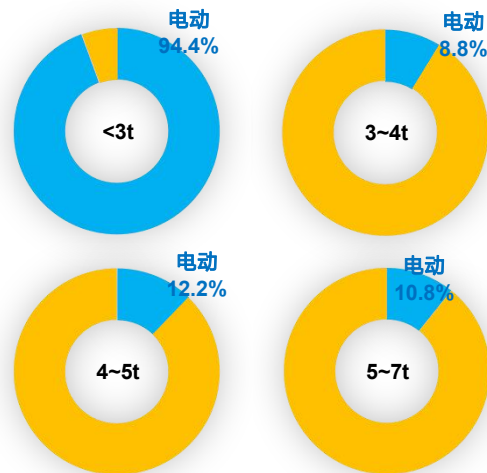
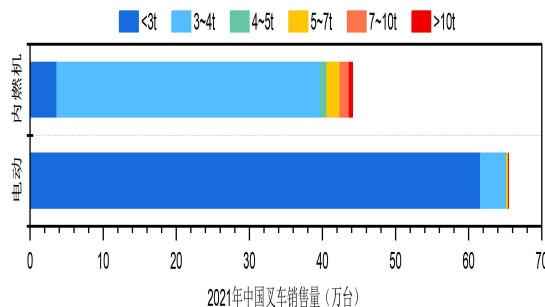
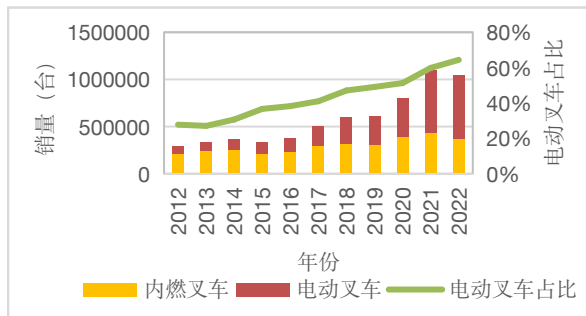
数据来源：《中国移动源环境管理年报（2022）》

# 3、新能源化发展概况

## Development of New Energy Machinery

叉车是当前电动化比例最高的机械类型 Forklifts are currently the most electrified type of machinery

- 电动叉车销量占比持续增长，2021年开始超过60%，3吨以下94.4%为电动产品，7吨以上电动化很少
- The proportion of electric forklift sales continues to grow, exceeding 60% from 2021, 94.4% of electric products under 3 tons, and few electric products over 7 tons



装载机、挖掘机、汽车起重机是当前大型电动机械研发和示范应用的主要机械类型

- 柳工、徐工、三一重工、中联重科、龙工等，均已布局电动挖掘机、装载机、汽车起重机、叉车等研发和产品设计
- 2021年全国约500-600台电动装载机，200-300台电动挖掘机
- 2022年全国约1200台电动装载机，1000台电动挖掘机

国内外主流农机企业开展新能源拖拉机和收获机械研发，多数为概念机或样机，商业化产品极少

数据来源：中国工程机械工业协会，柳工，三一重工，杭叉，合力叉车

Loaders, excavators and truck cranes are the main types of machinery used in research and development and demonstration of large-scale electric machinery

- Many manufacturers have laid out research and product design of electric excavators, loaders, truck cranes, forklifts, etc
- In 2021, about 500-600 electric loaders and 200-300 electric excavators in total
- In 2022, about 1,200 electric loaders and 1,000 electric excavators in total

Most of Agricultural Machinery are concept machines or prototypes, and few commercial products

第

2

部分

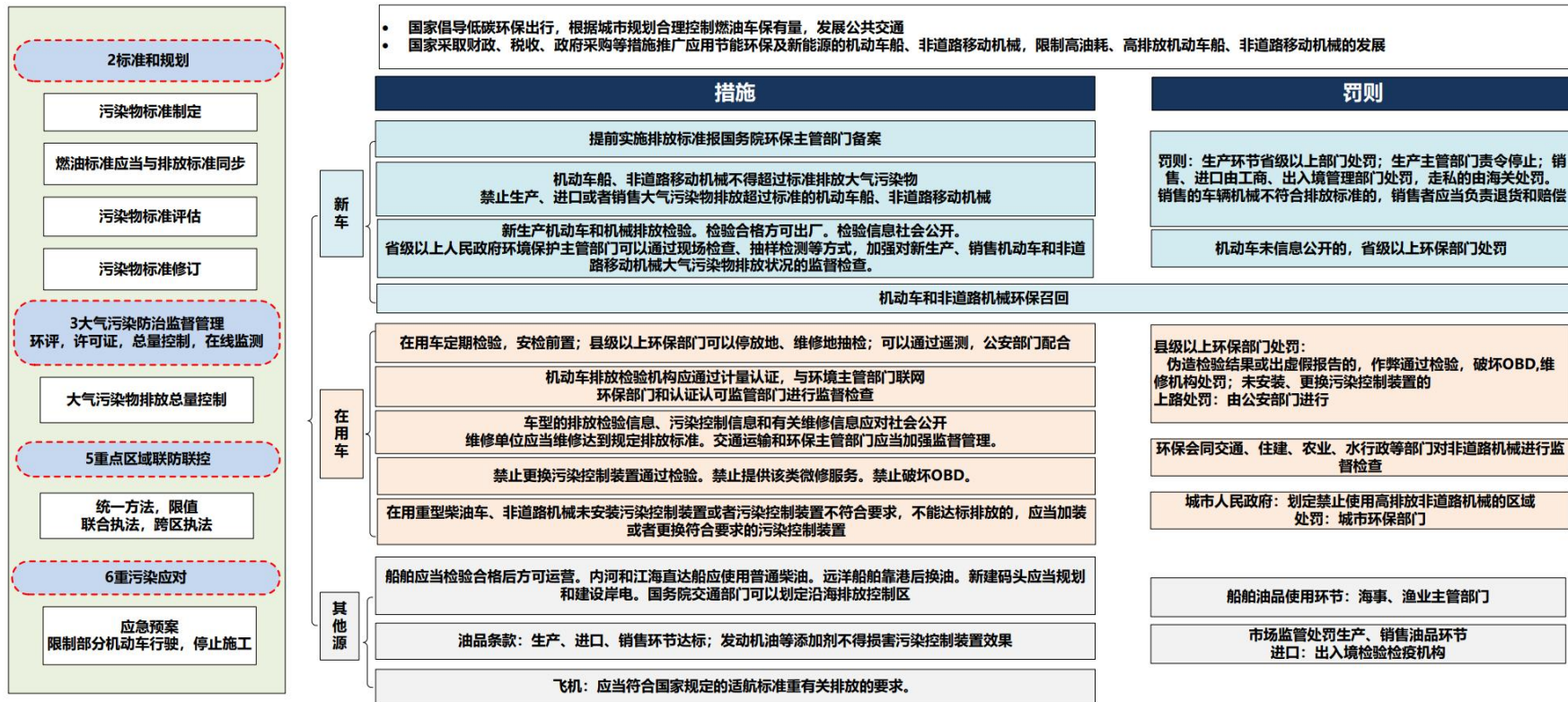
排放控制主要进展

Major Progress in Emission Control

# 1、污染防治法律更趋完善

## Improvements on Pollution Prevention and Control Laws

### 大气污染防治法2015：4防治措施 第三节机动车船等污染防治



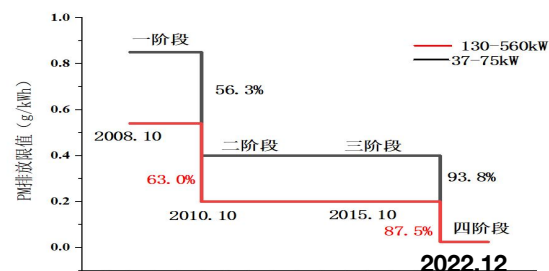
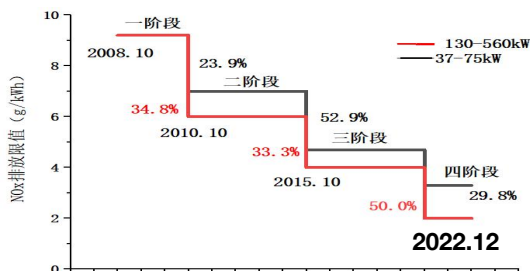


# 2、标准推动技术升级换代

## Standards Promoted Technological Upgrading

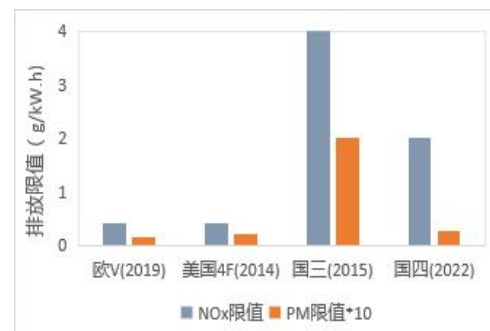
- 2020年底，发布国四标准修改单及其技术要求，推动非道路移动机械排放控制水平大幅提升
- At the end of 2020, the National IV standard amendment and its technical requirements has been issued, which will greatly improve the emission control level of non-road mobile machinery

| 技术要求     |        | 中国   | 欧盟 | 美国      |
|----------|--------|------|----|---------|
|          |        | 第四阶段 | V  | Tier 4F |
| 控制范围     | 柴油机    | √    | √  | √       |
|          | 气体发动机  | ×    | √  | √       |
|          | 双燃料发动机 | ×    | √  | √       |
|          | 机械整机限值 | √    | ×  | ×       |
| 测试循环     | 稳态测试   | √    | √  | √       |
|          | 瞬态测试   | √    | √  | √       |
|          | 非标准循环  | √    | √  | NTE     |
| PCD/NCD  |        | √    | √  | √       |
| 曲轴箱污染物要求 |        | ×    | √  | √       |
| 烟度要求     |        | √    | ×  | √       |
| PEMS要求   |        | √    | √  | ×       |
| 远程监控     |        | √    | ×  | ×       |
| 精准定位     |        | √    | ×  | ×       |



|     | 国四 | EU V | USA 4F |
|-----|----|------|--------|
| DOC | √  | √    | √      |
| DPF | √  | √    | ⊙      |
| SCR | ⊙  | √    | √      |
| ASC | ⊙  | √    | √      |

1、75kW-560kW  
2、⊙ 非必选项

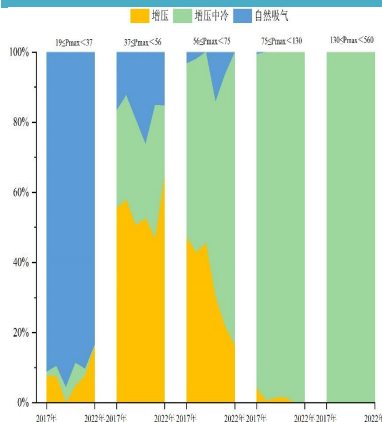


# 2、标准推动技术升级换代

## Standards Promoted Technological Upgrading

推动发动机与后处理技术提升，先进技术应用逐步扩大

Promotes the engine and post-processing technology, the application of advanced technology expanded

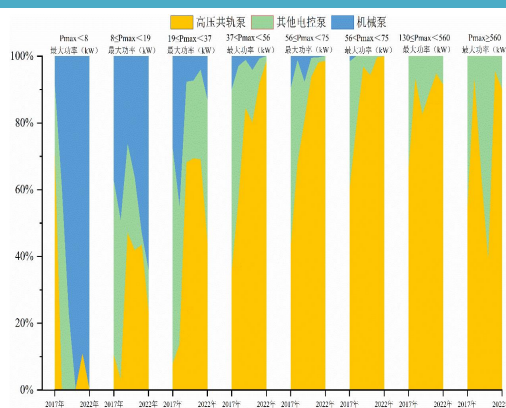


- 发动机进气方式，56 kW到75 kW的发动机，82%采用增压中冷技术
- 75 kW到560 kW的发动机，全部采用增压中冷技术

Engine intake system (Supercharging and intercooling technology)

- 56 kW to 75 kW engine 82%
- 75 kW-560 kW engine 100%

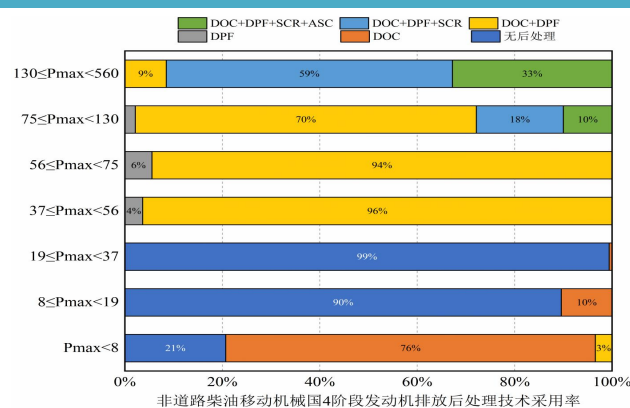
数据来源：非道路移动机械环保信息公开数据



- 发动机燃油喷射系统，小于37kW的发动机，机械泵比例的较高，超过50%
- 37kW及以上的发动机，高压共轨技术比例逐年升高，2022年占比均超90%

Engine fuel injection system

- <37kW engine, >50% mechanical pumps
- >37kW engine, >90% high pressure common rail technology in 2022



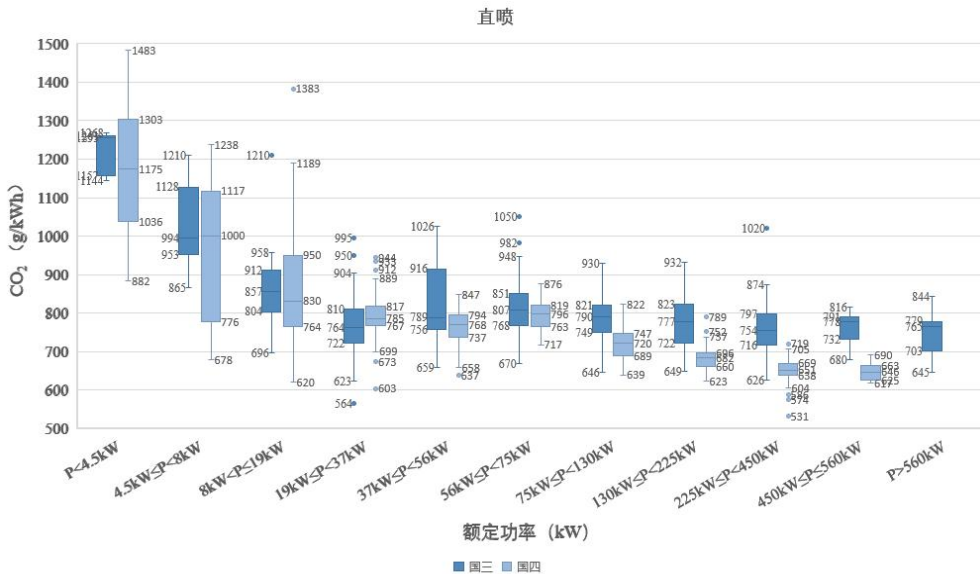
- 后处理技术，37kW到75kW的发动机，主要采用DOC+DPF
- 75kW到130kW的发动机，主要采用DOC+DPF技术，占比79%
- 130kW到560kW的发动机，DOC+DPF+SCR占59%

Aftertreatment technology

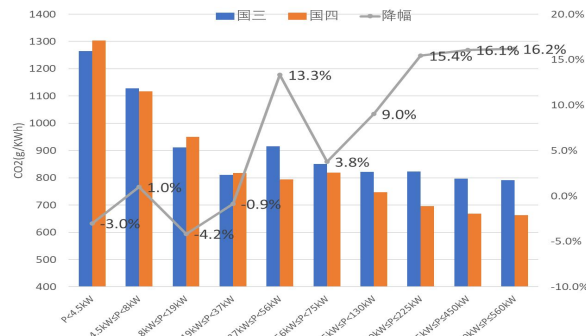
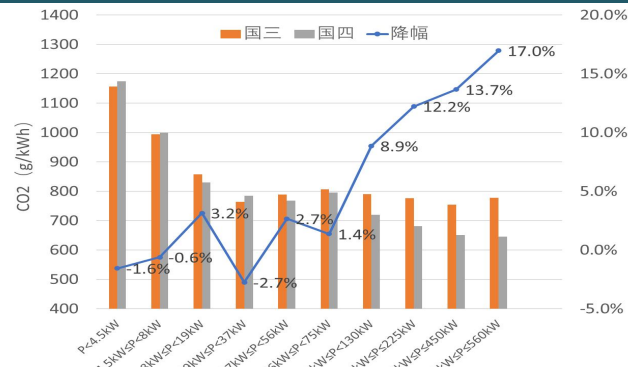
- 37kW-75kW, mainly DOC+DPF
- 75kW-130kW, mainly DOC+DPF(79%)
- 130kW-560kW, DOC+DPF+SCR(59%)

# 2、标准推动技术升级换代 Standards Promoted Technological Upgrading

污染物降低的同时，二氧化碳排放显著降低  
Simultaneously and Significantly Reduction on Pollutants and CO<sub>2</sub> Emissions



- 国三到国四，排放升级的同时，75kW以上发动机CO<sub>2</sub>整体水平有明显下降
- 37kW以上发动机，CO<sub>2</sub>排放中位数、75分位值随着功率的增加而降幅明显
- China III to China IV, >75kW engine CO<sub>2</sub> emission significantly decrease
- >37kW, The median and 75th percentile of CO<sub>2</sub> emission decreased significantly with the increase of power



数据来源: 信息公开数据, VECC网站

# 3、达标监管体系逐步完善 Improvements of The Supervision System

- 严格新生产机械达标监管，推进排放标准升级，落实非道路环  
保信息公开制度
- Strictly supervise new production machinery to meet  
standards, upgrade emission standards, and implement  
environmental information disclosure
- 推进非道路移动机械编码登记  
截至2022年底，全国累计上传非道路移动  
机械编码登记数据260万条
- 加强非道路移动机械排放控制区划定  
截至2022年底，全国337个地级市中有315  
划定低排放控制区
- Promote the registration of NRMM  
By the end of 2022, 2.6 million machineries had been  
registered in the whole country
- Strengthen the delineation of emission control areas for  
NRMM  
By the end of 2022, 315 out of 337 cities had designated  
low-emission control zones

**非道路移动机械用柴油机油保信息**  
信息公开编号: CN 86 GC 0001 000000 000001

潍柴动力股份有限公司声明: 本公司根据《中华人民共和国大气污染防治法》和生态环境部相关规定公开非道路移动机械用柴油机油保信息, 本公司所公开的信息均具有真实性、准确性、及时性等法定属性。本公司承诺: 编号为WP2-ANC278E41的非道路移动机械用柴油机油保信息符合《非道路移动机械用柴油机油保与污染物排放限值及测量方法(中国第四、五阶段)》(GB 20899-2014)第四阶段、《非道路移动机械用柴油机油保用油技术通则》(GB 19054-2020)的要求, 方能符合由标准规定的特殊属性准入要求。

| 第一部分 柴油机油基本属性 | 第二部分 油品规格         | 第三部分 油品规格技术要求 |
|---------------|-------------------|---------------|
| 01 柴油机油号      | WP2-ANC278E41     | 01 柴油机油号      |
| 02 品牌名称       | GF-5WP2-ANC278E41 | 02 品牌名称       |
| 03 厂牌名称       | WEICHAI           | 03 厂牌名称       |
| 04 制造商        | 潍柴                | 04 制造商        |
| 05 经销商        | 江苏惠康东方            | 05 经销商        |
| 06 制造商地址      | 潍柴动力股份有限公司        | 06 制造商地址      |
| 07 生产厂地址      | 江苏省常州市武进区21号      | 07 生产厂地址      |
| 08 产品分类       | 柴油机油              | 08 产品分类       |
| 09 保存期限       | 12月               | 09 保存期限       |
| 10 生产日期       | 2020              | 10 生产日期       |
| 11 生产日期范围     | 2019-2024         | 11 生产日期范围     |
| 12 生产一致性声明    | 符合                | 12 生产一致性声明    |
| 13 备注         |                   | 13 备注         |
| 14 备注         |                   | 14 备注         |
| 15 备注         |                   | 15 备注         |
| 16 备注         |                   | 16 备注         |
| 17 备注         |                   | 17 备注         |
| 18 备注         |                   | 18 备注         |
| 19 备注         |                   | 19 备注         |
| 20 备注         |                   | 20 备注         |
| 21 备注         |                   | 21 备注         |
| 22 备注         |                   | 22 备注         |
| 23 备注         |                   | 23 备注         |
| 24 备注         |                   | 24 备注         |
| 25 备注         |                   | 25 备注         |
| 26 备注         |                   | 26 备注         |
| 27 备注         |                   | 27 备注         |
| 28 备注         |                   | 28 备注         |
| 29 备注         |                   | 29 备注         |
| 30 备注         |                   | 30 备注         |
| 31 备注         |                   | 31 备注         |
| 32 备注         |                   | 32 备注         |
| 33 备注         |                   | 33 备注         |
| 34 备注         |                   | 34 备注         |

信息公开时间: 2021年2月4日



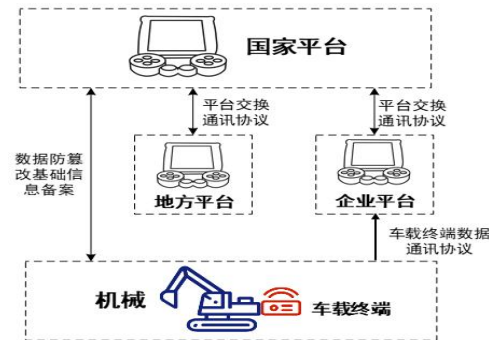
# 3、达标监管体系逐步完善

## Improvements of The Supervision System

- 建设非道路移动机械远程在线监控平台
- 推进工程机械安装精准定位系统和实时排放监控装置
- 实现机械运行、排放数据实时远程在线监控
- Construction of NRMM Remote Online Monitoring Platform
- Accurate Positioning system and Real-time Emission Monitoring Device
- Real-time Remote Online Monitoring of Mechanical Operation and Emission Data



| 发动机运行数据项 (如适用)  |                            |
|---|----------------------------|
| 车速  | 进气量                        |
| 大气压力 (直接测量或估计值)                                       | SCR入口温度                    |
| 发动机净输出扭矩  | SCR出口温度                    |
| 摩擦扭矩  | DPF压差                      |
| 发动机转速   | 发动机冷却液温度                   |
| 发动机燃料流量   | 油箱液位                       |
| SCR上游NO <sub>x</sub> 传感器输出值                           | 实际EGR阀开度                   |
| SCR下游NO <sub>x</sub> 传感器输出值                           | 设定的EGR阀开度                  |
| 反应剂余量   |                            |
| Engine operating data (if applicable)                 |                            |
| Speed   | Air intake                 |
| Atmospheric pressure (directly measured or estimated) | SCR inlet temperature      |
| Engine net output torque                              | SCR outlet temperature     |
| Friction torque                                       | DPF pressure difference    |
| Engine speed  | Engine coolant temperature |
| Engine fuel flow amount                               | Fuel tank level            |
| SCR upstream NO <sub>x</sub> sensor output value      | Actual EGR valve opening   |
| SCR downstream NO <sub>x</sub> sensor output value    | Set EGR valve opening      |
| Reactant balance                                      |                            |



# 3、达标监管体系逐步完善

## Improvements of The Supervision System

加油站油品质量达标率逐步提高，成效显著  
The quality of diesel has been significantly

2019年5月 May 2019

- 京津冀及周边地区采集加油站柴油样品19552个，超标率约4.5%。
- **19,552 diesel gas station samples in BTH ; over-standard rate: 4.5%.**

2019年11月 Nov 2019

- “回头看”抽检采集893个样品，仅6座加油站的7个样品硫含量超标
- **893 diesel gas station samples; 7 samples from 6 gas stations sulfur exceed standard.**

2020年11月 Nov 2020

- 重点区域共采集2708个柴油样品，全部来自社会加油站，超标率约2.0%。相比2019年，超标率明显降低。
- **2,708 diesel gas station samples; over-standard rate: 2.0%.**



# 3、达标监管体系逐步完善

## Improvements of The Supervision System

### 地方监管经验——山东

#### Local supervision experience -- Shandong Province

- **高排放机械禁用区 High emission machinery prohibited zone**
  - ❑ 在2019年完成第一轮划定基础上，2022年将高排放禁用区扩大到乡镇政府驻地
  - ❑ 全面禁用国一及以下机械，部分区域加严至禁用国二机械
  - ❑ On the basis of completing the first round of demarcation in 2019, the high-emission prohibited zones will be expanded to township government locations in 2022
  - ❑ China I and below is prohibited, some areas are tightened to China II
- **实时定位监控: Real-time location:**
  - ❑ 统一全省要求，提出各市各年度安装联网比例要求
  - ❑ **成效:** 2022年全省安装联网数量达到15.3万台，比例达到31%，提前完成2023年目标
  - ❑ **实施方式:** 各市生态环境局建设机械实时定位监控平台，进行数据收集、展示、管理，并向省平台进行转发
  - ❑ Unify the requirements of the province, and put forward the requirements of the proportion of installed networking in each city in each year
  - ❑ **Method:** build a real-time positioning and monitoring platform
  - ❑ **Results:** In 2022, the number of installed networking in the province reached 153,000 units, the proportion reached 31%(better than 2023 target)

- **建立机械进出场登记制度 Establish machinery entry and exit registration system**

- ❑ **推行场所:** 施工工地、物流园区等
- ❑ **要求:** 监管平台和微信小程序“进出登记”模块，禁止未编码喷码、不符合禁用区要求、冒黑烟或排放超标机械进场作业
- ❑ **Implementation places:** construction sites, logistics parks, etc.
- ❑ **Requirements:** Supervision platform and wechat mini program "entry and exit registration" module, prohibit non-coded coding, do not meet the requirements of the prohibited zone, black smoke or excessive emissions machinery entry operation.



# 4、积极推进零排放机械

## Promotion Zero-emission Machinery

### 《柴油货车污染治理攻坚战行动计划》（环大气〔2018〕179号） Action plan for diesel truck pollution control battle

- 加快新能源非道路移动机械的推广使用，在重点区域城市划定的禁止使用高排放非道路移动机械区域内，鼓励优先使用新能源或清洁能源非道路移动机械。
- 重点区域港口、机场、铁路货场、物流园新增和更换的岸吊、场吊、吊车等作业机械，主要采用新能源或清洁能源机械。
- **Accelerate the promotion and use of new energy non-road mobile machinery, and encourage the priority use of new energy or clean energy non-road mobile machinery in the areas designated by key regional cities to prohibit the use of high-emission non-road mobile machinery.**
- **The new and replaced shore cranes, yard cranes, cranes and other operating machinery in ports, airports, railway freight yards and logistics parks in key areas mainly use new energy or clean energy machinery.**

### 《柴油货车污染治理攻坚行动方案》（环大气〔2022〕68号） Action plan for diesel trucks pollution control battle

- 因地制宜加快推进铁路货场、物流园区、港口、机场，以及火电、钢铁、煤炭、焦化、建材、矿山等工矿企业新增或更新的作业车辆和机械新能源化。
- 鼓励新增或更新的3吨以下叉车基本实现新能源化。
- **According to local conditions, we will accelerate the new energy of railway freight yards, logistics parks, ports, airports, as well as the new or updated operation vehicles and machinery of thermal power, steel, coal, coking, building materials, mining and other industrial and mining enterprises.**
- **Encourage new or updated forklifts under 3 tons to basically achieve new energy.**

### 《重污染天气重点行业移动源应急管理技术指南》 Technical guide for emergency management of mobile source in key industries in heavily polluted weather

- 首次提出场内车辆和非道路移动机械管控要求
- 按照阶段机械数量进行分级管理
- 建立非道路移动机械电子台账
- A级或B级企业，场内机械应全部是国三及以上标准或纯电动机械
- **Firsttime, the control requirements for on-site vehicles and non-road mobile machinery were proposed**
- **According to the number of stage machinery for hierarchical management**
- **Establish non-road mobile electromechanical ledger**
- **Grade A or B enterprises, the machinery should be all national three and above standards or pure electric machinery**

表5 非道路移动机械电子台账信息表

| 名称     | 类型     | 描述   |
|--------|--------|--|
| 环保登记编码 | 字符(32) |  |
| 生产日期   | 日期     | 格式: YYYYMMDD   |
| 排放阶段   | 字符(1)  | 国 0:0; 国 1:1; 国 2:2; 国 3:3; 国 4:4; 国 5:5; 国 6:6; 电动:D; 无排放阶段: X; |
| 机械环保代码 | 字符(64) |  |
| 发动机铭牌  | BLOB   |  |



# 4、积极推进零排放机械

## Promotion Zero-emission Machinery

### 地方实施经济补贴政策

#### Implement Economic Subsidy Policies at Local

#### 北京市燃油机械淘汰更新补贴 Beijing fuel machinery elimination and renewal subsidies

- 《北京经济技术开发区促进高排放老旧柴油货运车和柴油叉车淘汰资金支持政策》
- 补助时间:** 2016年10月1日至2018年6月30日
- 补助项目:** 柴油叉车以旧换新, 即淘汰柴油叉车后购买电动叉车, 且承诺今后不再使用5吨以下(含5吨)柴油叉车的, 可享受开发区政府资金补助。
- “Beijing Economic and Technological Development Zone promotes the financial support policy for the elimination of high-emission old diesel freight trucks and diesel forklifts”
- Time:** 2016.10.01 to 2018.06.30
- Content:** no longer use less than 5 tons diesel forklift can receive the development zone government funding subsidies

#### 山东省老旧机械淘汰更新补贴 Shandong Province old machinery elimination and renewal subsidies

- 实施方式:** 省级财政资金2000万元, 由各市(区)进行补贴发放, 补贴类型: 拆解报废、以新换旧、更换发动机
- 成效:** 2022年在全国率先开展老旧机械淘汰更新试点, 完成淘汰国一及以下老旧机械4100余台。
- Method:** 20 million Provincial financial funds, subsidies issued by the cities (districts), subsidy types: dismantling scrap, new for old, replacement of the engine
- Result:** first old engine replacement in China, eliminate 4100+ units China I and below machinery in 2022

- 补助标准:** 按照淘汰柴油叉车的额定载荷进行分档
- 成效:** 电动叉车已占全区叉车总数的99%
- Subsidies Standard:** based on load rating
- Result:** forklift electrification rate 99%

| 额定载荷 | M<2t  | 2t≤M<3t | 3t≤M<4t | 4t≤M<5t | M≥5t  |
|------|-------|---------|---------|---------|-------|
| 补贴金额 | 1万元/台 | 2万元/台   | 3万元/台   | 4万元/台   | 5万元/台 |

| Load                        | M<2t | 2t≤M<3t | 3t≤M<4t | 4t≤M<5t | M≥5t |
|-----------------------------|------|---------|---------|---------|------|
| Subsidy (ten thousand/unit) | 1    | 2       | 3       | 4       | 5    |

第

3

部分

未来政策建议

Recommendations on Future policy

# 未来政策建议

## Recommendations on Future policy

### (1) 完善法规标准体系 Improvements on Laws, Regulations and Standards

#### • 法律法规：

- 制订非道路移动机械排放控制管理办法，明确非道路移动机械信息公开、在用环节监管方式等法律责任

#### • 技术标准：

- 升级非道路柴油机械排放标准，污染物与CO<sub>2</sub>协同控制

#### • 技术指南：

- 修订非道路移动源排放清单编制技术指南，更新污染物与二氧化碳排放因子
- 制修订工程机械、农业机械、园林机械等清洁低碳技术政策或指南，引导零排放技术发展

#### • Laws and Regulations：

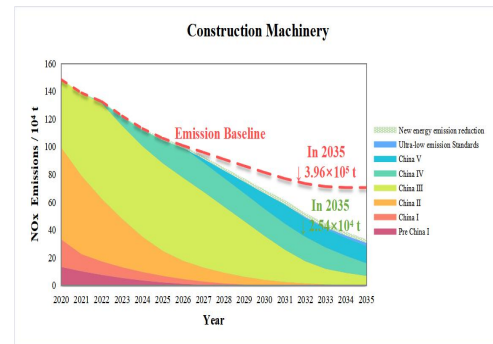
- Administrative measures for emission control of NRMM
- Clarify information disclosure and supervision methods of in-use NRMM

#### • Technical Regulations：

- Upgrade the emission standards of NRMM, coordinating the control of pollutants and CO<sub>2</sub>

#### • Technical Guide：

- **Revising technical guidelines for the compilation of NRMM emissions inventories**
- Policies or guidelines on clean and low-carbon technologies for construction machinery, agricultural machinery, garden machinery, etc.



# 未来政策建议

## Recommendations on Future policy

### (2) 完善监管体系 Improvements on supervision system

- 进一步强化部门协同
  - 重点行业企业及使用场所绩效分级、与行业超低排放管控等相结合
  - 新能源移动机械纳入环境监管
- Further strengthen cooperation between departments
  - Performance classification of industry enterprises and use sites, industry ultra-low emission control, etc.
  - Environmental supervision on new energy mobile machinery

### (3) 建立奖励激励机制 Establish Incentive Mechanism

- 推动零排放非道路移动机械应用，制定零排放示范区实施方案
  - 激励政策是最有效的推动措施，加强相关政策的细化研究
  - 配套基础设施建设和使用的激励
  - 对于提前淘汰机械，根据使用时长、排放阶段和功率范围等，区分不同补贴额度，鼓励更新为新能源机械
  - 加强对新能源及超低排放机械实际使用的效果评估
- Promote the application of zero-emission non-road mobile machinery, and formulate implementation plans for zero-emission demonstration zones
  - the most effective promotion measure, strengthen the detailed study of related policies
  - Incentives for supporting infrastructure construction and use
  - Encourage early phasing out of machinery by new energy machinery
  - Strengthen the evaluation of the effect of the actual use of new energy and ultra-low emission machinery



感谢关注，  
敬请批评指正！

Thanks for  
Your Attention

- 纪亮 研究员
- 中国环境科学研究院  
机动车排污监控中心
- Ji Liang, Researcher
- Vehicle Emission Control Center,  
Chinese Research Academy of  
Environmental Science
- E-mail: [jiliang@craes.org.cn](mailto:jiliang@craes.org.cn)
- Tel: +86-10-84915655