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DEVELOPMENT REPORT

中国地热能发展报告

2018

自然资源部中国地质调查局
国家能源局新能源和可再生能源司
中国科学院科技战略咨询研究院
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前　言

地热能是蕴藏在地球内部的热能，是一种清洁低碳、分布广泛、资源丰富、安全优质的可再生能源，通常分为浅层地热能、水热型地热能、干热岩型地热能。地热能开发利用具有供能持续稳定、高效循环利用、可再生的特点，可减少温室气体排放，改善生态环境，在未来清洁能源发展中占重要地位，有望成为能源结构转型的新方向。《地热能开发利用“十三五”规划》提出，到2020年，中国地热能年利用量折合7000万吨标准煤，在一次能源消费总量中占比将达1.5%左右，比2015年提高1个百分点，“十三五”时期地热能利用增量将占非化石能源增量的三分之一。构建地热能全产业链，大力推进地热能开发利用，不仅可加大清洁能源供应比例，同时也能促进康养、旅游、种养殖等行业的健康和高质量发展。

贯彻落实习近平总书记关于推动能源生产和消费革命及“推进北方地区冬季清洁取暖”的重要讲话精神，应切实推进地热能开发利用“十三五”规划目标的实现，加快推动地热能资源高效勘探、开发技术的进步和利用水平的全面提升，促进能源转型，解决冬季取暖、防治雾霾等重大问题，实现人民“富裕起来以后”对清洁用能和美好生活的向往。按照

党的十九大精神，要抓住决胜全面建成小康社会、推进能源革命向纵深发展这一重要机遇，加速推进中国地热能大发展。发布《中国地热能发展报告》，旨在总结中国地热能发展现状，明确未来地热能发展思路，阐明地热能发展战略与政策取向，为中国地热能快速发展汇集多方力量，凝聚广泛共识。

目　录

一、世界地热能发展现状

世界地热能资源丰富，分布广泛但不均衡，主要集中在4个高温地热带。地热能开发利用量逐年增加，效率不断提高，主要用于直接利用（供暖、制冷、工业干燥、康养、旅游、种养殖等）和发电。地热能开发利用技术不断创新，为规模化合理开发利用地热能提供了有力支撑。世界主要资源国促进地热能产业可持续发展的许多激励政策和具体做法，对中国具有重要的借鉴意义。

（一）世界地热能资源丰富

世界地热能资源潜力大。国际能源署（IEA）、中国科学院和中国工程院等机构的研究报告显示，世界地热能基础资源总量为1.25×10^{27}焦耳（折合4.27×10^{8}亿吨标准煤），其中埋深在5000米以浅的地热能基础资源量为1.45×10^{26}焦耳（折合4.95×10^{7}亿吨标准煤）。

中低温（25—150℃）地热能资源分布广泛，高温（>150℃）地热能集中分布在大西洋中脊、红海—东非裂谷、环太平洋、地中海—喜马拉雅地热带。由于所处地理位置和大地构造背景的差异，四大高温地热带沿线国家的地热能资源较为丰富，主要包括冰岛、肯尼亚、美国、日本、菲律宾、印度尼西亚、新西兰、中国、土耳其等。如地处环太平洋地热带上的美国，埋深在1万米以浅的水热型、干热岩型地热能

基础资源量分别为9.6×10^{21}焦耳、1.4×10^{25}焦耳；地处地中海—喜马拉雅地热带上的土耳其，埋深在3000米以浅的地热能基础资源量为3.96×10^{23}焦耳。

目前，世界上已开发利用的地热田主要分布在高温地热带上，如位于大西洋中脊地热带的冰岛克拉夫拉（Krafla）地热田，红海—东非裂谷地热带的肯尼亚奥卡利亚（Olkaria）地热田，环太平洋地热带的美国盖瑟尔斯（Geysers）地热田、墨西哥塞洛普力拓（Cerro Prieto）地热田、菲律宾通嘉兰（Tongonan）地热田、印度尼西亚卡莫江（Kamojiang）地热田、新西兰怀拉开（Wairakei）地热田，地中海—喜马拉雅地热带的意大利拉德瑞罗（Larderello）地热田、中国羊八井地热田和羊易地热田等。

（二）世界地热能开发利用水平逐年提高

1．地热能直接利用

利用浅层地热能的国家逐年增加。从2000年的26个增至2015年的48个。截至2015年底，开发利用浅层地热能的地源热泵总装机容量约为5万兆瓦，占世界地热能直接利用总装机容量的71%左右；地源热泵安装台数与2010年相比增长51%。2015年，美国累计安装地源热泵机组约140万台，2010—2015年年均增长10万台。瑞典、德国、法国、瑞士四国引领欧洲浅层地热能产业发展，地源热泵装机容量占整个欧洲的64%。

水热型地热能利用呈现良好的发展态势。截至2015年底，

全世界水热型地热能供暖装机容量为7556兆瓦，占世界地热能直接利用总装机容量的10.7%，年利用量为8.82×10^{16}焦耳，与2010年相比增长44%。利用水热型地热能供暖规模较大的国家有中国、土耳其、冰岛、法国、德国等。

2．地热能发电

地热能发电是地热能利用的重要方式。2015年，世界水热型地热能发电装机容量为1.26万兆瓦，与2010年相比增加1700兆瓦，增长16%。其中，闪蒸发电系统装机占比61.7%、干蒸汽发电占比22.7%、双循环工质发电占比14.2%、其他占比1.4%。

目前，干热岩型地热能的开发利用正处于试验研究阶段，开展试验的有美国、法国、德国等8个国家。截至2017年底，累计建设增强型地热系统（EGS）示范工程31项，累计发电装机容量约为12.2兆瓦。

（三）典型国家的地热能发展提供了有益经验借鉴

立法先行，理顺地热能管理体制机制。为支持地热能产业发展，发达国家普遍通过立法来确立地热能法律属性，明确管理权责主体，理顺政府管理体制机制。例如美国的《1967年加州地热法案》《1970年联邦地热蒸汽法案》明确了地热能法律属性及其所有权问题；冰岛政府制定《地下资源研究和利用法》《自然资源保护法》和《能源法》等一系列法律，理顺了地热能开发利用管理体制机制，较好地保障了地热能产业发展。

政策激励，推进地热能规模化开发利用。发达国家地热

能产业发展具有鲜明的政府引导与政策引领特征。冰岛、美国、日本、德国等国均出台包括税收抵免在内的税收优惠政策，对地热能开发利用项目给予一定比例的财政补贴。美国《地热能源研究、开发与示范法》等法律规定，对符合当地利用条件的地热能等可再生能源项目提供贷款担保。扶持政策对地热能产业的有序、健康、快速发展起到显著的推进作用，如美国地热能发电装机容量多年位居世界第一，冰岛利用地热能供暖占全国供暖建筑面积的90%以上。

科技创新，推动地热能高效勘探开发利用。世界地热能发展典型国家均重视科技创新，通过加大科研经费投入、设立重大科技研发计划、组织联合研发团队等方式，持续推动地热能勘探开发利用颠覆性技术攻关，助力地热能产业提质增效。2013年，欧盟推出“地平线2020（horizon2020）”计划，投入8360万欧元资助11项地热能研究项目，推动地热能增强型地热系统等前沿科技和关键技术攻关。2015年，美国政府提供1.4亿美元设立FORGE项目，在增强型地热系统等方面开展了一系列攻关，有力促进了地热能勘探开发利用技术进步和产业发展。

国际合作，助力发展中国家地热能较快发展。发展中国家也高度重视地热能产业发展，通过吸引国外资金和先进技术开发利用本国地热能。如肯尼亚奥卡利亚（Olkaria）地热田，通过广泛吸引包括中国、冰岛在内的国际合作和技术援助，实现对埋深为2200米的330℃水热型地热能的开发利用，为肯尼亚地热能发展打下了良好基础。

二、中国地热能发展现状

中国地热能资源丰富，但资源探明率和利用程度较低，开发利用潜力很大。近年来，中国地热能勘探、开发及利用技术持续创新，地热能装备水平不断提高；浅层地热能利用快速发展，水热型地热能利用持续增长，干热岩型地热能资源勘查开发开始起步，地热能产业体系初步形成。同时，中国地热能发展也存在不充分不协调的深层次问题亟待解决。

（一）中国地热能资源潜力很大

“十二五”期间，中国地质调查局组织完成全国地热能资源调查，对浅层地热能、水热型地热能和干热岩型地热能资源分别进行评价。结果显示，中国大陆336个主要城市浅层地热能年可采资源量折合7亿吨标准煤，可实现供暖（制冷）建筑面积320亿平方米，其中黄淮海平原和长江中下游平原地区最适宜浅层地热能开发利用。

中国大陆水热型地热能年可采资源量折合18.65亿吨标准煤（回灌情景下）。其中，中低温水热型地热能资源占比达95%以上，主要分布在华北、松辽、苏北、江汉、鄂尔多斯、四川等平原（盆地）以及东南沿海、胶东半岛和辽东半岛等山地丘陵地区，可用于供暖、工业干燥、旅游、康养和种养殖等；高温水热型地热能资源主要分布于西藏南部、云南西部、四川西部和台湾省，西南地区高温水热型地热能年可采

资源量折合1800万吨标准煤，发电潜力7120兆瓦，地热能资源的梯级高效开发利用可满足四川西部、西藏南部少数民族地区约50%人口的用电和供暖需求。

据初步估算，中国大陆埋深3000—10000米干热岩型地热能基础资源量约为2.5×10^{25}焦耳（折合856万亿吨标准煤），其中埋深在5500米以浅的基础资源量约为3.1×10^{24}焦耳（折合106万亿吨标准煤）。鉴于干热岩型地热能勘查开发难度和技术发展趋势，埋深在5500米以浅的干热岩型地热能将是未来15—30年中国地热能勘查开发研究的重点领域。

（二）中国地热能产业体系已显现雏形

中国是世界上开发利用地热能资源最早的国家之一，骊山汤等温泉的利用可追溯至先秦时期。20世纪50年代，中国开始规模化利用温泉，相继建立160多家温泉疗养院。70年代初，中国地热能资源开发利用开始进入温泉洗浴、地热能供暖、地热能发电等多种利用方式阶段。21世纪以来，在政策引导和市场需求推动下，地热能资源开发利用得到较快发展。

浅层地热能利用快速发展。中国浅层地热能利用起步于20世纪末，2000年利用浅层地热能供暖（制冷）建筑面积仅为10万平方米。伴随绿色奥运、节能减排和应对气候变化行动，浅层地热能利用进入快速发展阶段，2004年供暖（制冷）建筑面积达767万平方米，2010年以来以年均28%的速度递增。截至2017年底，中国地源热泵装机容量达2万兆瓦，位居世界第一，年利用浅层地热能折合1900万吨标准煤，实现

供暖（制冷）建筑面积超过5亿平方米，主要分布在北京、天津、河北、辽宁、山东、湖北、江苏、上海等省市的城区，其中京津冀开发利用规模最大。

水热型地热能利用持续增长。近10年来，中国水热型地热能直接利用以年均10%的速度增长，已连续多年位居世界首位。中国地热能直接利用以供暖为主，其次为康养、种养殖等。1990年全国水热型地热能供暖建筑面积仅为190万平方米，2000年增至1100万平方米，至2015年底全国水热型地热能供暖建筑面积已达1.02亿平方米。其中，天津市供暖建筑面积为2100万平方米，居全国城市首位，占全市集中供暖建筑面积的6%；河北省雄县供暖建筑面积为450万平方米，满足县城95%以上的冬季供暖需求，创建了中国首个供暖“无烟城”，形成了水热型地热能规模化开发利用“雄县模式”。据不完全统计，截至2017年底，全国水热型地热能供暖建筑面积超过1.5亿平方米，其中山东、河北、河南增长较快。中国地热能发电始于20世纪70年代，1970年12月第1台中低温地热能发电机组在广东省丰顺县邓屋发电成功；1977年9月第1台1兆瓦高温地热能发电机组在西藏羊八井发电成功，中国成为世界上第8个掌握高温地热能发电技术的国家。1991年，西藏羊八井地热能电站装机容量达25.18兆瓦，其供电量曾占拉萨市电网的40%—60%。截至2017年底，中国地热能发电装机容量为27.28兆瓦，排名世界第18位。

干热岩型地热能资源勘查开发处于起步阶段。干热岩型地热能是未来地热能发展的重要领域。美国、德国、法国、

日本等国经过20—40年不等的探索研究，在干热岩型地热能勘查评价、热储改造和发电试验等方面取得了重要进展，积累了一定经验。相比而言中国起步较晚，2012年科技部设立国家高新技术研究发展计划（863计划），开启了中国关于干热岩的专项研究。2013年以来中国地质调查局与青海省联合推进青海重点地区干热岩型地热能勘查，2017年在青海共和盆地3705米深处钻获236℃的干热岩体，是中国在沉积盆地区首次发现高温干热岩型地热能资源。通过深入试验研究，未来有望在干热岩型地热能开发技术方面取得突破，可推动中国地热能发电及梯级高效利用产业集群较快发展。

地热能勘探开发利用装备较快发展。用于地热能勘探开发的地球物理、钻井、热泵、换热等一系列关键装备日趋成熟。地球物理勘查方面，中国拥有世界先进的二维地震、三维地震、时频电磁、大地电磁、重磁等装备。钻井工程方面，中国已成功研制万米钻机，石油钻井深度超过8000米，全孔取芯的大陆科学钻探钻井深度达7018米，这些钻机均可用于地热能钻井工程。2018年完成的中国大陆科学钻探松科二井高温水基泥浆耐温达242℃，实施井底动力的螺杆钻具耐温达180℃，可替代螺杆钻具的涡轮钻具耐温突破240℃。热泵装备方面，目前中国已是地源热泵生产与消费大国，国产成套设备生产水平日益提高，国产设备占据了大部分国内市场。近年来，随着国家财税和相关激励政策的出台实施，地源热泵系统和水热型地热能供暖系统发展迅速，带动了上下游相关新材料和高端装备产业、科研和服务业快速发展。

（三）中国地热能勘探、开发及利用技术持续创新

地热能勘探技术不断成熟。自20世纪70年代以来，地热地质、地球物理、地球化学、钻井工程等理论和技术方面取得重要进展。

一是地热地质研究方面，在大地热流场、地热成因、热富集规律分析、地热能资源评价等方面取得一系列研究成果，正在积极探索深部地热成因、地热田三维地质建模、热储精细描述、采灌均衡下的资源评价等，为地热能资源勘查开发提供理论指导。

二是地球物理方法初步形成从重磁电普查到地震勘探详查的多种方法综合地球物理勘探技术。近年来，地热能赋存的地质与地球物理特征综合系统研究能力和水平、三维地震地质结构模型精细刻画技术取得长足进步，提高了水热型和干热岩型地热能资源靶区优选和钻孔定位的精度和效率。

三是地球化学勘探技术体系已逐步形成。经过数十年的发展，基本建立了一套基于气体、水和岩石的化学与同位素等地球化学方法，可用于地热能异常区判定、热储温度估算、地热水成因推断、结垢与腐蚀作用预测等。

四是钻井技术取得很大进步。20世纪90年代后期至今，中国开始将石油钻完井技术工艺与相关地热能工程施工结合，大大提高了钻井效率，缩短了建井周期。先后在西藏羊八井、肯尼亚、土耳其等地区成功钻探多口300℃以上的高温地热井。

地热能开发利用技术取得进展。热泵技术快速发展，形成适合中国国情的大型地源热泵、高温热泵和多功能热泵系统，主要技术与装备已基本实现国产化。

地热尾水回灌技术取得一定进展，岩溶型热储的尾水同层密闭回灌技术较为成熟；砂岩热储的经济回灌技术进行了大量科学试验与生产实践，取得较大进展，但尚未达到大规模经济性推广要求。

开展了地热能梯级利用技术积极探索，在京津冀和东南沿海地区初步建立发电、供暖二级地热能梯级开发利用示范基地。

（四）中国地热能行业管理体制和政策正不断完善

法律框架基本建立。1986年《中华人民共和国矿产资源法》规定，矿产资源属于国家所有，勘查、开采矿产资源须经批准取得探矿权、采矿权，开采矿产资源必须按照国家有关规定缴纳资源税和资源补偿费；《中华人民共和国矿产资源法实施细则》明确地热为能源矿产。1988年《中华人民共和国水法》规定，水资源包括地下水；各省、自治区、直辖市人民政府出台的《中华人民共和国水法》实施办法规定，对直接从地下取水的单位和个人，实行取水许可制度，征收水资源费。此后，针对地热能资源管理中出现的问题，1995年国务院法制办对天津市人民政府法制局印发《关于地下热水属性和适用法律问题的复函》，1998年中编办印发《关于矿泉水地热水管理职责分工问题的通知》，2003年国务院法制办印

发《对国土资源部<关于请进一步明确矿泉水地热水管理职责分工问题的函>的复函》，进一步厘定了地热能资源管理的法律依据和有关事项。2009年新修订的《中华人民共和国可再生能源法》将地热能列入可再生能源。以上法律的形成，基本建立了地热能勘探、开发、利用的法律依据，奠定了地热能有序发展的制度基础。

管理制度初步形成。中国已基本建立地热能资源管理制度，包括勘查许可、采矿许可、打井审批、钻井施工监理、矿业权公开出让、从业单位备案、矿产资源补偿费征收管理、矿业权价款管理、资源保护和科技项目管理等多项制度，较好地维护了地热能勘查开发利用秩序。北京、天津、重庆、云南、河北、内蒙古等省（自治区、直辖市）相继出台地方性法规或规章，山东济南、江苏南通、陕西渭南、河北保定等城市也颁布实施了地热能资源管理规范性文件，京津冀等地还制定了地热能开发利用方案审查、地质环境影响评价、地热回灌保护、年度指标核定、开发单位年检等制度，一定程度上规范了当地地热能资源的合理开发利用与保护。

政策措施陆续完善。2013年1月，国家能源局、财政部、国土资源部、住房城乡建设部联合发布《关于促进地热能开发利用的指导意见》。2017年1月，国家发展改革委、能源局、国土资源部联合印发《地热能开发利用“十三五”规划》。2017年12月，国家发展改革委、国土资源部、环境保护部、住房城乡建设部、水利部、能源局联合印发《关于加快浅层地热能开发利用促进北方采暖地区燃煤减量替代的通

知》。2017年12月，国家发展改革委、能源局、财政部、环境保护部、住房城乡建设部、国务院国资委、质检总局、银监会、证监会、军委后勤保障部制定《北方地区冬季清洁取暖规划（2017—2021年）》。以上政策的出台，有力支持了地热能产业较快发展。

（五）中国地热能产业发展仍存在不充分不协调问题

一是对地热能资源勘查评价和科学研究不充分。中国进行过两次全国性地热能资源评价，仅对少数地热田进行了系统勘查，研究基础薄弱，分省、分盆地资源评价结果精度较低，与发达国家相比存在明显差距。目前中国仅有实测大地热流数据1230个，而美国实测的大地热流数据达17000多个。在干热岩型地热能勘查开发方面，美国已进行40多年研究探索，取得多方面研究成果，德国、法国、英国、日本、澳大利亚等国也开展了卓有成效的工作，而中国才刚刚起步。

二是对地热能产业发展初期扶持的政策不充分。目前中央和地方政府出台了一些财政和价格鼓励政策，对加快浅层地热能开发利用及促进北方地区清洁供暖具有积极的引导作用，但政策不完善，执行不到位、不充分。第一，地热能相关的财税法律规定可操作性差。目前关于地热能财税支持方面的法律法规缺乏实施条款和落实细则，对优惠税率和补贴力度等激励政策没有统一明确的标准，出台的政策“落地难”。资源税税额标准偏低，不能真实反映能源消耗带来的社会成本，缺少体现可再生能源性质的地热能“取热不耗水”

税收激励政策。第二，对地热能开发利用的优惠力度不足。按照可再生能源电价附加政策要求，对地热能发电商业化运行项目给予电价补贴政策，但目前具体开发和利用的优惠政策却不多。现有地热能优惠政策细化支持措施还存在缺陷，主要体现在土地使用、设备制造和产品消费的配套政策仍不明确。第三，补贴模式不科学，支持方式有待完善。补贴模式单一，采用事前补贴和生产环节补贴，补贴效果大打折扣；直接补贴方式居多，缺乏市场化手段；补贴发放不及时、不到位，补贴资金领取周期过长。

三是地热能产业发展不协调问题依然突出。主要表现在：第一，地热能勘查评价精度与开发利用发展速度不协调。地热能勘查基础薄弱，精度低，缺乏系统勘查，在开发利用选区、开采规模确定等方面存在盲目性，既增加了项目投资风险，更导致地热能粗放式、低效开发利用和环境污染。第二，科技创新与地热能大规模开发利用不协调。深部地热能勘探、水热型地热能采灌均衡、干热岩型地热能开发利用、中低温地热能高效发电等关键技术及装备亟待突破，促进地热能规模化开发利用、满足市场有效需求的新技术和新装备有待创新。第三，地热能项目开发与城市总体规划不协调。虽然已发布的与地热能开发利用相关的规划和文件达10多个，这些政策有力地促进了中国地热能产业的较快发展，但这些规划之间不配套，不同层级规划之间不衔接，现行地热能开发利用规划没有融入地方和城市发展规划，导致规划的任务在实际中缺乏可操作性，《地热能开发利用“十三五”规划》中提

出的地热能利用目标将难以实现。第四，政府监管与地热能可持续开发利用不协调。政出多门的监管体制、监管能力和水平与地热能的较快发展不适应，相关标准和技术规范不完备，对地热能开发利用监管缺位和越位现象并存，尚未建设水热型地热能和浅层地热能开发动态监测系统，严重阻碍了地热能健康可持续发展。

四是地热能资源管理制度不协调。中国现行法律体系中，“地热”受3个法律管控，但相关规定均没有准确把握地热能的基本属性，法律适用性和可操作性亟待解决。《中华人民共和国矿产资源法》规定“地热”属于能源矿产，因“地热”资源具有可再生性，用不可再生的矿产资源管理方式进行管理，不能满足地热能大规模勘探开发利用的需要。《中华人民共和国水法》规定“地下热水”属于水资源，因地热能开发利用要求“取热不耗水”，用管水的方式管热，制约了地热能的合理开发利用。《中华人民共和国可再生能源法》虽然强调地热能属于可再生能源，但只有原则性规定，缺乏如风能、太阳能具体可落地的管理手段和措施。

三、中国地热能发展的对策建议

中国地热能资源基础雄厚，市场空间广阔，发展趋势良好，是极具发展潜力的朝阳产业。环境效益方面，地热能产业规模发展将对中国调整能源结构、防治环境污染具有十分重要的意义；经济效益方面，地热能产业规模发展将为中国经济增长及经济结构转型升级贡献新动能；社会效益方面，地热能高质量发展将带动装备制造、地质勘查、建筑、现代农业、休闲旅游等上下游产业全面发展，促进就业不断增加。

（一）中国地热能发展的总体思路

1．指导思想

深入贯彻习近平新时代中国特色社会主义思想和党的十九大精神，决胜全面建成小康社会，全面加强生态环境保护，把地热能高质量发展作为提升生态文明、推动能源革命、构建绿色能源体系的重要内容，实现人民对清洁用能、美好生活的向往。以“绿水青山就是金山银山”为引领，以优化能源结构、防治大气污染、应对气候变化、发展绿色产业为导向，立足国情和地热能资源禀赋，坚持面向未来、面向现代化、面向市场，主动融入京津冀协同发展、长江经济带发展和“一带一路”建设，全面统筹地热能产业链高质量发展，优化产业整体规划和布局，着力增强市场微观主体活力，着力形成完善的地热能资源调查评价与科学开发利用技术支撑

体系，着力推进与其他能源等产业深度融合，着力建设技术先进、环境友好、经济可行的地热能产业集群，加快推动产业健康可持续发展，助力建设美丽中国。

2．基本原则

一是坚持因地制宜原则。以助力大气污染防治为核心任务，在京津冀等生态环境形势比较严峻的华北等地区，浅层与水热型地热能开发利用并重，有效替代燃煤锅炉，解决好农村散煤使用问题，助力推进北方地区冬季清洁取暖。在长江中下游平原等夏热冬冷地区积极推进浅层地热能开发利用，满足人民温暖过冬、清爽度夏的需要，助力长江经济带绿色发展。在西南高温地热能分布地区有序推进地热能发电，改善边远高寒地区生产生活条件，为可靠、经济、清洁的基荷电源提供补充。与“一带一路”沿线国家加强交流合作，助力国家“一带一路”建设，为应对气候变化做出贡献。

二是坚持循序渐进原则。从中国地热能资源禀赋与市场需求匹配度的实际情况出发，近中期，以供暖（制冷）为主，加大政策支持力度，理顺体制机制，提升社会各界对地热能产业的认知度和认同感，加快地热能高效开发利用，着力建设绿色产业链。抓紧攻关深部地热能勘探开发利用技术，为未来地热能大规模开发奠定基础。先行先试发展以地热能为基础的绿色产业，形成示范工程，逐步向全国推广。2035年之后，随着勘查开发利用技术的逐步成熟、市场体系的不断完善，努力把地热能培育成为绿色发展新动能，为中国能源

结构优化调整发挥重要作用。

三是坚持高质量发展原则。加快推进地热能由单一、粗放、低效的传统产业增长方式转变为多元、集约、高效的现代产业发展方式。推广地热田精细勘查和地热能梯级利用，提高资源利用效率，提升地热能项目效益水平。倡导“地热能+”，推广多种清洁能源深度融合，因地制宜实施多能协同发展。通过培育雄安新区地热能产业集群等重点示范工程引领京津冀地热能高质量发展。加快科技创新，驱动产业转型升级和提质增效，加速人才培养，促进产业可持续发展。

（二）推动中国地热能高质量发展的对策建议

1．尽快摸清中国地热能资源家底

加大财政投入力度，鼓励各类社会资本积极参与，开展全国地热能资源调查评价。以华北、松辽、江汉、鄂尔多斯、苏北等盆地（平原）为重点，尽快查明水热型地热田的地质条件、热储特征、地热能资源的质量和数量，并对其开采技术经济条件做出评价，为合理开发利用提供依据。加快深部地热能资源探测和开发技术攻关，为干热岩型地热能规模化、商业化开发利用做好准备。

建立政府主导的地热能资源勘查开发利用全产业链的数据汇交、共享与服务制度，形成全国地热能资源开发利用大数据平台，主要包括地热能资源基础数据、开发利用动态和效率监测数据及产业网络信息管理系统等，为地热能资源调查评价与科学开发利用提供支撑。

2．攻关地热能勘探开发利用关键技术

中央财政和地方财政应设立地热能资源调查和科技创新重大专项资金，加大对地热能勘探开发利用核心关键技术研发的投入力度，加强地热能专用设备和特种技术的研发。一是研发可直接探测地下温度场的地球物理、地球化学综合技术手段，实现地下温度场三维精细刻画。二是加强高温定向钻井技术和装备研发，突破耐高温低成本钻井关键技术瓶颈，实现核心装备升级。三是加强砂岩热储的经济回灌技术攻关，改进回灌井成井工艺，优化采灌井网系统布局。四是开展干热岩型等深部地热能勘查开发技术攻关，突破储层改造和高效换热关键技术。五是探索梯级综合高效利用技术体系和商业模式，对发电、供热、制冷、现代农业、商业应用等相关核心技术进行攻关。

3．先行先试培育地热能高质量发展示范区

一是建立雄安新区地热能区域性高效开发利用示范区。根据雄安新区规划建设创造“雄安质量”的目标要求，将地热能利用的“雄安模式”打造成中国高质量发展样板。在规划理念上，由地热能开发跟着城区组团走转变为地热能规划先行；在供能来源上，由水热型为主转变为浅层地热能和水热型地热能乃至干热岩型地热能并举；在供能方式上，由单一供暖转变为电热冷等多联供；在用能方式上，由单一地热能转变为多能互补；在用能周期上，由一个供暖季转变为一年四季；在产业链条上，由单一能源产业转变为地热能上中下游一体化产业集群。

二是建设北京城市副中心浅层地热能集群化利用示范区。统筹地下地上空间规划建设，建设分布式、互补型的大型浅层地热能开发利用能源站系统，形成集群化利用示范区，满足北京城市副中心大型建筑集合体供暖（制冷）需要，助力绿色低碳城市建设。

三是建设共和干热岩型地热能勘查和试验性开发工程。面向未来地热能发展需要，瞄准干热岩型地热能科技前沿，以青海共和盆地为试验区，实施战略科技攻坚，大力推进干热岩型地热能资源勘查开发的理论、技术、工程与装备研发，力争早日实现干热岩型地热能资源勘查开发重大突破。

四是建设地热能特色小镇示范区。以江苏如东小洋口地区等为示范区，建设以地热能为基础的梯级开发利用的清洁能源高效利用特色小镇。充分体现“吃干榨尽”热能的高效利用理念，形成供热、制冷、发电、浴疗、温泉休闲、养老、高效现代渔业和农业、花卉烘干加工等清洁能源产业集群，为加快发展由清洁能源支撑的绿色产业体系提供示范。

在各地先行先试的同时，要尽快建立进一步改革开放的试错和容错机制，充分调动各方参与改革创新的积极性，大胆探索试点，践行新发展理念，及时总结经验，待条件基本成熟后再在全国推广。

4．出台优惠政策支持地热能高质量发展

在地热能产业发展初期，应参照风电、光伏等可再生能源的财政、税收和金融等支持政策，对水热型和干热岩型地热能勘探开发利用给予大力支持。将地热能开发利用纳入可

再生能源基金补贴范围内，并按照可再生能源绿色证书制度发放绿证配额。落实地热能开发利用企业及相关设备和材料制造企业的相关增值税、房产税、城镇土地使用税优惠政策。研究制定地热能替代化石能源供热、制冷、发电的财政补贴政策，以热（冷）量、电量为单位进行补贴。

试点推广特许经营权。为吸引社会力量、金融资本参与地热能勘查评价，推进地热能产业规模化开发和规范发展，开展地热能开发特许经营权试点，参与基础性公益性地热能勘查并将勘查评价数据统一纳入国家地热能大数据管理平台的企业，可优先获得地热能资源特许经营资格（采矿权）。

5．建立完善地热能的管理和监管体制机制

一是做好地热能专项规划。将地热能利用专项规划纳入国土空间规划体系，明确地热能开发利用总体目标和基本思路。将地热能供热（制冷）纳入当地基础设施建设专项规划，实现地热能开发科学布局，高效发展。

二是完善地热能管理制度。按照一件事由一个部门负责的原则，尽快制定与《中华人民共和国可再生能源法》配套的地热能开发利用管理办法。明确利用水资源与地热能资源、取水与取热的边界和标准。完善地热能勘探开发市场准入规则、矿业权招拍挂出让和第三方服务等相关制度。完善地热尾水回灌制度，强化回灌状况监督，加强地热能资源和环境保护。强化监管，规范市场秩序，加大对违法违规企业的处罚力度。建立地热能勘探开发利用的统计报表制度。

三是建立地热能开发利用考核体系。在具备条件的北方地区和长江经济带能源转型综合应用示范工程（地区）等，将地热能利用列入地区生态文明建设考核指标体系，作为节能减排考核体系的加分项。

结 束 语

大力发展清洁能源是当今时代主题之一。面对国际地热能开发利用热潮和国内对清洁能源的巨大需求，中国地热能开发利用在“政产学研”的共同努力下实现了快速发展，勘查开发利用技术取得了长足进步，中国已经是世界地热能资源大国和开发利用大国。

随着《北方地区冬季清洁取暖规划（2017—2021年）》的大力推进和“煤改地热能”等的有序展开，以北京城市副中心、雄安新区、江苏如东小洋口等为代表的地热能开发利用示范区建设，以及京津冀地区深部地热勘查、青海共和盆地干热岩型地热能勘查和试验性开发工程等的大力推进实施，必将带动和引领中国地热能发展进入快车道，成为应对气候变化、打赢蓝天保卫战和优化能源结构的重要力量，为高质量绿色发展和生态文明建设做出重要贡献。

《中国地热能发展报告》的推出，旨在搭建推进中国能源大转型与探索地热能产业健康、快速发展的交流沟通平台。期待《中国地热能发展报告（2018）》的发布，能进一步激发社会各界深入探索地热能行业改革路径，凝聚共识，协同发展。在此，我们诚挚地感谢各相关部门、研究机构、行业学会、企业、国际机构及众多专家的大力支持和帮助。

China Geothermal Energy Development Report

(2018)

China Geological Survey, Ministry of Natural Resources

Department of New and Renewable Energy,
National Energy Administration

Institute of Science and Development,
Chinese Academy of Sciences

Institute of Resources and Environment Policies,
Development Research Center of the State Council

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Preface

Geothermal energy is heat energy contained in the interior of the Earth and it is a clean, low carbon, widely distributed, largely reserved, safe and high quality renewable energy. In general, geothermal energy can be classified into three types-shallow, hydrothermal and hot dry rock. Geothermal energy development has characteristics of stable, recyclable and renewable, and can help reduce emission of carbon dioxide and improve environment. It plays an important role on clean energy development, and is expected to be a new direction for the energy structure adjustment. The *13th Five-Year Plan of Geothermal Development and Utilization* specifies, by 2020 utilization of geothermal energy will reach 70 million tons of standard coal equivalent annually, which will account for around 1.5% of primary energy consumption, and the share will increase by 1% compared to 2015. During the "13th Five-Year" period, the increment of geothermal energy utilization will account for one-third of the whole increment in non-fossil energy. Great promoting the development and utilization of geothermal energy and constructing the whole industry chain will not only improve the proportion of clean energy supply, but also boost high-quality development in spa, tourism, farming, cultivation and other industries.

Implement the important speech spirit of the General Secretary Xi Jinping-General strategy on promoting energy production and consumption revolution and promoting winter clean heating in North China, it has to carry forward the goals of the *13th Five-Year Plan of Geothermal Development and Utilization*, accelerate technical progresses in geothermal energy exploration and development, improve utilization level, solve issues such as space heating in winter and haze

treatment, and realize people's dream of cleaner energy utilization and better living "after got rich". In accordance with the spirit of the nineteenth conference of the Communist Party of China, grabbing the great opportunity to build a moderately prosperous society in all aspects, to promote the deep development of energy revolution, and to accelerate the great development of China's geothermal energy. The release of *China Geothermal Energy Development Report* is aiming at summarizing current development status, clarifying the development outline, specifying developing strategy and policies, and gathering power and consensus for the rapid development of geothermal energy in China.

Contents

1. Global Geothermal Energy Development Status

Geothermal resources on the planet are abundant, widely but unevenly distributed. They are mainly concentrated in four high-temperature geothermal belts. The development and utilization of geothermal energy has been increasing year by year, and its efficiency has been gradually improved. It is mainly used for direct utilization (space heating, cooling, industrial drying, health, tourism, cultivation, and so on.) and power generation. Technologies of geothermal development and utilization are being innovated constantly, which provides a strong support to the rational development and utilization of geothermal energy. The incentive policies of other countries help promote the sustainable development of their geothermal industry, which provides an important reference to China.

1.1 Abundant Global Geothermal Resources

The potential of the world's geothermal energy resources is great. According to reports from the International Energy Agency (IEA), the Chinese Academy of Sciences and the Chinese Academy of Engineering, the total amount of geothermal resources in the world is 1.25×10^{27}J (equivalent to 4.27×10^{7} billion tons of standard coal), among them geothermal resources between 0-5 km is 1.45×10^{26}J (equivalent to 4.95×10^{6} billion tons of standard coal).

The geothermal resources of middle-low temperature (25-150℃) are widely distributed, and the geothermal resources of high temperature (>150℃) is concentrated in the geothermal belts of the middle of the Atlantic Ridge, the Red Sea-East African Rift, the Pacific Rim and the

Mediterranean-Himalaya. Due to differences in geographical location and tectonic background, countries along the four high-temperature geothermal belts are rich in geothermal resources, including Iceland, Kenya, the United States, Japan, the Philippines, Indonesia, New Zealand, China, and Turkey. For example, the United States, which sits on the Pacific Rim geothermal belt, is rich in geothermal resources. In the US, the amounts of hydrothermal type and hot-dry-rock type geothermal resources at the depth between 0-10km are 9.6×10^{21}J and 1.4×10^{25} J respectively. Turkey, on the Mediterranean-Himalayan geothermal belt, has 3.96×10^{23} J of geothermal resources at a depth between 0-3km.

Currently, the drilled geothermal fields in the world are mainly distributed in high-temperature geothermal belts, such as the Krafla geothermal field of Iceland in the Mid-Atlantic Ridge geothermal belt, the Okalia geothermal field of Kenya in the Red Sea-East Africa Rift geothermal belt, the Geysers geothermal fields of America, the Cerro Prieto geothermal field of Mexico, the Tongonan geothermal field of the Philippines, the Kamojiang geothermal field of Indonesia, and the Wairakei geothermal field of New Zealand in the Pacific Rim geothermal belt, the Larderello geothermal field of Italy in the Mediterranean-Himalayan geothermal belt, and the Yangbajing geothermal field and Yangyi geothermal field in China, and so on.

1.2 The Annually Improved Capabilities of Geothermal Energy Development and Utilization in the World

1.2.1 Direct Utilization of Geothermal Energy

The number of countries developing shallow geothermal resources has increased year by year, from 26 in 2000 to 48 in 2015. By the end of 2015, the total installed capacity of heat pumps for the development of shallow geothermal energy had reached 50,000 MW, accounting for

around 71% of the total installed capacity of the world's geothermal energy. The number of heat pumps increased by 51% compared with 2010. By 2015 the number of installed heat pumps in the US was over 1.4 million, with an average annual growth rate of 100 thousands between 2010 and 2015. Sweden, Germany, France and Switzerland lead the development of shallow geothermal industry in Europe. Their installed capacity of ground source heat pumps accounts for 64% of the total in Europe.

Utilization of hydrothermal energy presents favorable situation. By 2015, the installed capacity of hydrothermal energy space heating was 7,556MW, accounting for 10.7% of the installed capacity of global geothermal energy direct utilization. The annual geothermal energy utilization was 8.82×10^{16} J, which increased by 44% compared with 2010. Countries that are utilizing hydrothermal energy for space heating in a large scale include China, Turkey, Iceland, France and German etc..

1.2.2 Geothermal Power Generation

Geothermal power generation is an important way of geothermal utilization. By 2015, the installed capacity of hydrothermal power generation reached 12.6 thousand MW, which increased by 16% (1.7 thousand MW) compared with 2010. Among them, flashing geothermal power generation system accounted for 61.7%, dry steam geothermal power generation system accounted for 22.7%, binary geothermal power generation system accounted for 14.2%, and other types accounted for 1.4%.

At present, the development and utilization of the hot-dry-rock type geothermal energy is still in the experimental stage, and they have been done mainly in the US, France, Germany and other 5 countries. By 2017, the cumulative demonstration projects of enhanced geothermal system (EGS) reached 31, and the cumulative installed capacity was about 12.2 MW.

1.3 Experiences of Geothermal Energy Development in Typical Countries

Legislation first, straightens out the management system of geothermal energy. In order to support the development of geothermal energy industry, developed countries generally adopt legislation to establish the legal attribute of geothermal energy, clarify subjects of management responsibility and right, and straighten out the system and mechanism of government. For example, the *California Geothermal Act 1967* and *Federal Geothermal Steam Act 1970* of the United States clarified the legal attributes of geothermal energy and its ownership; a series of laws enacted by the government of Iceland, such as the *Study and Utilization Act of Underground Resources*, the *Natural Resources Protection Act* and the *Energy Act*, straighten out the management system of the exploitation and utilization of the geothermal energy and ensure a better development of the geothermal energy industry.

Policy incentives, promote the large-scale development and utilization of geothermal energy. The development of geothermal energy industry in developed countries has distinctive characteristics of government guidance and policy guidance. Iceland, the United States, Japan, Germany and other countries have introduced tax incentives including the production tax credits, and a certain proportion of financial subsidies for geothermal energy development and utilization projects. The *Geothermal Energy Research, Development and Demonstration Act* of the US and other legal provisions provide loan guarantees for renewable energy projects such as geothermal energy that meet local conditions. The introduction of supportive policies has played a significant role in promoting the orderly, healthy and rapid development of the geothermal energy industry in the corresponding countries. For instance, the installed capacity of geothermal power

generation in the United States ranks the first in the world for years, geothermal space heating in Iceland accounts for over 90%.

Scientific and technological innovation, promote the efficient exploration, development and utilization of geothermal energy. The typical countries of the world's geothermal energy development all pay attention to scientific and technological innovation. By increasing the investment of scientific research, setting up major research and development plans, and organizing joint research and development teams, these countries continue to promote geothermal energy exploration and development and utilization subversive technology to improve geothermal energy industry. In 2013, the European Union launched the *Horizon 2020* project and invested 83.6 million euros in 11 geothermal energy research projects to promote geothermal energy forward-looking technologies and key technologies. In 2015, the United States government provided 140 million US dollars to create the *FORGE* project, tackling a series of problems in the field of enhanced geothermal system, which has greatly promoted the technological progress and industrial development of geothermal energy exploration and development.

International cooperation, assists geothermal development in developing countries. Developing countries also attach great importance to the development of geothermal energy industry. They develop and utilize domestic geothermal energy by attracting foreign advanced technology. Taking the Olkaria geothermal field in Kenya for example; Kenyan government has realized the development and utilization of 330°C hydrothermal geothermal energy with a depth of 2,200m through extensively attracting international cooperation and technical assistance from countries like China and Iceland, which laid a good foundation for the development of Kenya's geothermal energy.

2. China's Geothermal Energy Development Status

China is rich in geothermal resources. However, the ratio of explored and utilized geothermal energy is still low. Thus, the development of geothermal energy has great potential in China. In recent years, with the continuous innovation in exploration and development technologies, the equipment that is associated with developing and using geothermal energy is also improved rapidly. The utilization of shallow geothermal energy has increased remarkably, and the developing of hydrothermal resources continuously increases while the exploration of hot-dry-rock type geothermal energy has also started. The industry system of developing geothermal energy has been preliminarily formed. At the same time, the deeply-seated problems of inadequate and uncoordinated development need to be resolved urgently.

2.1 Great potential of China's geothermal resources

During the "12th Five-Year" period, the national survey and assessment of geothermal resources was conducted by China Geological Survey, the resource amount of shallow geothermal energy, hydrothermal energy and hot-dry-rock type geothermal energy were calculated. According to the evaluation results, the recoverable reserves of shallow geothermal resource in 336 cities equals to 0.7 billion tons of standard coals, which can meet the heating and cooling demand of 32 billion square meters. Among them, the Huanghuaihai Plain and the middle and lower plains of the Yangtze River are favorable areas for developing shallow geothermal energy.

The recoverable reserve of hydrothermal resource is equivalent to

1.865 billion tons of standard coals (under the condition of rejection), among which the medium-to-low temperature geothermal resource accounts for 95%. The medium-to-low temperature geothermal resources are distributed not only in plain areas (basins) such as the North China basin, Songliao basin, Subei basin, Jianghan basin, and Ordos basin, but also in hilly areas, such as the southeastern coast, Jiaodong Peninsula, and Liaodong Peninsula. The medium-to-low temperature geothermal energy is mainly used for heating, drying, tourism, cultivating and so on. The high temperature geothermal resources are mainly distributed in south of Tibet, west of Yunnan, west of Sichuan, and Taiwan Province. Annual recoverable reserves of the high temperature geothermal resources in Southwest China are equivalent to 18 million tons of standard coals, and the potential of power generation capacity reaches 7,120MWe. The cascade utilization of high temperature geothermal resource in Southwest China can meet power needs and heating demands of 50% population of western Sichuan and some minority in southern Tibet.

According to a preliminary estimation, the resource amount of hot dry rock within the depth of 3km to 10km in mainland China is about 2.5×10^{25}J (equivalent to 856 trillion tons of stand coals), among which, the resource of hot dry rock within 3km to 5.5km is about 3.1×10^{24}J (equivalent to 106 trillion tons of stand coals). Considering the difficulty in exploring and utilization of hot-dry-rock type geothermal energy, the hot-dry-rock type geothermal energy that buried between 3km to 5.5km are the priority research areas in the next 15 to 30 years.

2.2 China's geothermal energy industry system has been constructed

China is one of the earliest countries that develop geothermal energy and the utilization of hot spring can date back to pre-chin period. In the

1950s, China began to utilize hot spring in large scale, building 160 different thermal spring sanitariums successively. At the beginning of 1970s, China's geothermal energy was utilized in many different ways: bathing, space heating, power generation, and so on. Since the beginning of the 21st century, impelled by policies guidance and market demands, the development and utilization of geothermal energy has developed rapidly.

Shallow geothermal energy grows rapidly. The development and utilization of shallow geothermal energy began at the end of the 19th century and at the year of 2000; the hearting/cooling area of ground source heat pump was merely 100,000 square meters. As people pay more attention to energy saving and climate change, the development and utilization of shallow geothermal energy grows rapidly. The heating/cooling area of ground source heat pump was 7.67 million square meters in 2004 and since 2010, the heating/cooling area of shallow geothermal energy grows at the rate of 28%. By the end of 2017, the installed capacity of China's heat pumps had reached 20,000MWe, ranking the first in the world and the development and utilization of shallow geothermal energy reduce the burning of 19 million tons of standard coals and meet the heating and cooling demand of 0.5 billion square meters, mainly in the city district of Beijing, Tianjin, Hebei, Liaoning, Shandong, Hubei, Jiangsu, Shanghai, and so on. Among them, the heating/cooling area of shallow geothermal energy ranks first in the Beijing-Tianjin-Hebei region.

Hydrothermal energy grows continuously. During the past ten years, the average annual increase rate of hydrothermal energy was 10%, and the amount hydrothermal energy utilization ranked the first in the world for many years. Geothermal energy is primarily used for space heating, then used for bathing, cultivating, and so on. In the year of

1990, hydrothermal energy heating area was merely 19 million square meters, and increased to 11 million square meters in 2000, and at the end of 2015 the number had reached 102 million square meters. Among them, geothermal energy heating area in Tianjin was 21 million square meters, ranking the first in China cities and accounting for 6 percent of total hydrothermal energy heating area. In Xiongxian county of Hebei province, the hydrothermal heating area was 4.5 million square meters, which had satisfied more than 95% heating demand of whole urban area. The developing of geothermal energy in Xiongxian county made it become the first no-smoking town in China and the "Xiongxian Model" was proposed to develop hydrothermal geothermal energy in scale. According to incomplete statistics, by the end of 2017, the hydrothermal heating area in China had exceeded 150 million square meters; among them, Shandong, Hebei and Henan province grow well. China's geothermal energy power generation began at 1970s. The first middle-to-low temperature geothermal power station was established on December 1970 in Dengwo Village of Fengshun County, Guangdong province and successfully generated power. On September of 1977, the first high temperature geothermal power station-Yangbajing power station was successfully constructed with 1MWe installed capacity, which made China became the 8th country to own geothermal energy power generation technology. In 1991, the installed capacity of Yangbajing geothermal power generation of Tibet reached 25.18MWe, and the generated electricity accounting 40-60 percent of total electricity in Lhasa city at that time. By the end of 2017, the installed capacity of geothermal energy power generation in China was 27.28MWe, ranking 18th in the world.

The development and utilization of hot-dry-rock type geothermal energy is still at the early stage. The development and utilization of

hot-dry-rock type geothermal energy is the future of geothermal energy. After 20 to 40 years of research, countries like US, German, France and Japan have made significant accomplishments and accumulated valuable experience in the exploitation of hot-dry-rock type geothermal energy, reservoir reconstruction, and power test. Comparably, China's researches on the hot-dry-rock type geothermal energy were relatively late. It began from the National High-tech Research and Development Program (863 Program) which conducted by the Ministry of Science and Technology. Since 2013, China Geological Survey and Qinghai Province have been collaboratively propelling the exploitation of hot-dry-rock type geothermal energy in key areas in Qinghai province. In 2017, 236℃ hot dry rock was drilled at the depth of 3,705m in Gonghe Basin of Qinghai Province and this was the first time to find such high temperature hot-dry-rock type geothermal energy in sedimentary basins of China. Through deep research, in the future, the development and utilization technologies for hot-dry-rock type geothermal energy will make great breakthrough to promote the rapid development of China's geothermal energy power generation and cascade utilization industries.

The equipment for developing and utilizing geothermal energy improves rapidly. A set of key equipment that used for geophysical exploration, drilling, heat pumps, heat exchange are greatly improved. In the aspect of geophysical exploration, China has equipped with world-leading 2D/3D seismic, time-frequency electromagnetic methods (TFEM), magnetotelluric sounding, gravity and magnetic and other equipment. In the aspect of drilling, China has successfully developed rig available for 10km and oil rig for more than 8km. The technology for full-hole coring can reach as deep as 7,018m. All of these rigs can be used for geothermal energy drilling. The SongKe No.2 Well, a scientific drilling well launched by Chinese government, was completed in 2018.

The water-based mud can resistant temperature as high as 242℃, the PDM drilling equipment can resistant temperature as high as 180℃ while turbine tools that instead drilling equipment can resistant temperature as high as 240℃. In the aspect of heat pumps, currently, China has become a major producer and consumer of ground source heat pumps. As the improvement of production ability, domestic equipment has occupied most of the heat pump market. In recent years, with the issuing of national financial policies and other stimulated policies, ground source heat pump system and hydrothermal energy heating system developed drastically, and also promote the rapid development of associated new materials, high-end equipment, scientific researches and related services.

2.3 Continuous technical innovation for geothermal energy exploration, development and utilization in China

The technology system for geothermal energy exploitation continuously improved. Since 1970s, China has made significant achievements in geology, geophysics, geochemistry, drilling, and so on.

The first one is geological study on geothermal system. China has made great progress in geothermal flow distribution, origin of geothermal energy, distribution pattern, geothermal resources evaluation, and so on. Currently, China is positively investigating the origin of deep geothermal energy, three dimensional geological model of geothermal field, fine description of the structure of heat reservoirs, the evaluation of resource amounts under the condition of rejection. All of these studies will provide theoretical guidance for the exploration and development of geothermal energy.

The second one is the study on geophysical methods. A variety of comprehensive geophysical prospecting techniques, from gravity, magnetoelectric survey to detailed seismic prospecting, have

been preliminarily formed. In recent years, with the technology of comprehensive interpretation of seismic data and fine descriptive technology for 3D seismic geological model, the accuracy and efficiency of target selection and borehole location for hydrothermal energy and hot-dry-rock type geothermal energy has been greatly improved.

The third one is the study on geochemistry. China has gradually built a technology system for geochemistry exploitation. After several decades' development, based on isotope and chemical characteristics of gas, water and rock, Chinese institutes have basically employed/created a set of geochemical methods which can be used in judging abnormal area of geothermal energy, evaluating heat reservoirs' temperature, inferring the origins of geothermal water, predicting scaling and eroding, and so on.

Fourthly, there is a great improvement in geothermal energy drilling. Since the end of 1990s, China has attempted to combine technology of oil drilling and completion with developing of geothermal energy which greatly improved the efficiency of drilling and shorten the period of drilling. China has successfully completed many high-temperature drilling projects (above 300℃) in Yangbajing of Tibet, Kenya, Turkey and some other regions.

The technologies for geothermal energy utilization improved steadily. With the development of heat pump technology, China has the ability to recreate large-scale heat pump system, high temperature heat pump system, multifunctional heat pump system which are feasible in China's markets. Major technologies and facilities have been basically localized.

Tail water reinjection technology has improved. The technology of tail water uni-layered reinjection in confined space in karstic reservoirs is relatively mature. After numerous scientifically experiments, the technology of economic reinjection in sand reservoirs has made

significant progress, however, to promote it to a large scale still need more experiments and researches.

The cascade utilization of geothermal energy has been positively studied in China and some demonstration projects have been constructed in Beijing-Tianjin-Hebei region and southeastern coastal areas where developing geothermal energy for power generation, space heating, and so on.

2.4 The management system and policies of China's geothermal energy industry are constantly improving.

The regulatory framework is basically established. In 1986, *Mineral Resources Law of the People's Republic of China* stipulates that mineral resources belong to the state. Exploration and exploitation of mineral resources must be approved to obtain the right of exploration and mining. Mining mineral resources must pay taxes on mineral resources and compensation fee for mineral resources in accordance with the relevant provisions of the state. *Rules for the Implementation of Mineral Resources Law of the People's Republic of China* clearly defines geothermal energy as mineral resources. In 1988, *Water Law of the People's Republic of China* stipulates that water resources include groundwater; the implementation measures of *Water Law of the People's Republic of China* promulgated by the people's governments of provinces, autonomous regions and municipalities stipulate that water intake should get the permit from regulation departments for taking water directly from the ground, and water resources fees shall be paid. Since then, to solve the problems arising in the management of geothermal energy resources, Legislative Affairs Office of the State Council issued *Reply Letter on the Attributes and Applicable Laws of Geothermal Water* to Legal Bureau of the People's Government of Tianjin in 1995; State Commission Office

of Public Sectors Reform issued *Notice on the Division of Responsibility for the Management of Mineral Water and Geothermal Water* in 1998; Legislative Affairs Office of the State Council issued *Reply Letter to Ministry of Land and Resources about Letter on Further Clarifying the Division of Responsibilities for the Management of Mineral Water and Geothermal Water* in 2003, which further defines the legal basis and related matters of the management of geothermal resources. In 2009, the newly revised *Renewable Energy Law of People's Republic of China* incorporated geothermal energy into renewable energy. The formation of these laws have basically established the legal basis for the exploration, development and utilization of geothermal energy, and laid the institutional foundation for the orderly development of geothermal energy.

The management system has been preliminarily formed. China has basically established the management system for geothermal resources, including exploration license, mining license, drilling approval, drilling construction supervision, open sale of mining rights, record employment unit, management of compensation fee pay for mineral resources, mining right price management, source protection, science and technology project management and many other systems. They have preferably maintained the order of exploration, development and utilization of geothermal energy. Beijing, Tianjin, Chongqing, Yunnan, Hebei, Inner Mongolia and other provinces (autonomous regions, municipalities) have promulgated local regulations or regulations in succession. Ji'nan in Shandong, Nantong in Jiangsu, Weinan in Shaanxi and Baoding in Hebei and other cities have also promulgated and implemented the standardized documents for the management of geothermal energy resources. Beijing-Tianjin-Hebei region and other places have developed a series systems for geothermal energy

development and utilization review, geological environmental impact assessment, geothermal tail water reinjection protection, annual index verification, annual development unit inspection, and so on. To a certain extent, they have standardized the rational development, utilization and protection of local geothermal resources.

Policies and measures have been improving in succession. In January 2013, National Energy Administration, Ministry of Finance, Ministry of Land and Resources, and Ministry of Housing and Urban-Rural Development jointly issued *Guidance on the development and utilization of geothermal energy*. In January 2017, National Development and Reform Commission, National Energy Administration, and Ministry of Land and Resources jointly issued *The 13th Five-Year Plan for the development of Geothermal Energy* in China. In December 2017, National Development and Reform Commission, Ministry of Land and Resources, Ministry of Environmental Protection, Ministry of Housing and Urban-Rural Development, Ministry of Water Resources and National Energy Administration jointly issued *Notice on Accelerating the Development and Utilization of Shallow Geothermal Energy to Promote the Replacement of Coal Burning in Northern Heating Areas*. In December 2017, National Development and Reform Commission, National Energy Administration, Ministry of Finance, Ministry of Environmental Protection, Ministry of Housing and Urban-Rural Development, State-owned Assets Supervision and Administration Commission of the State Council, General Administration of Quality Supervision, Inspection and Quarantine, China Banking Regulatory Commission, China Securities Regulatory Commission, and Logistics Support Department of Military Commission's issued *Winter Clean Heating Planning in the North Region (2017-2021)*. The introduction of these policies has strongly supported the rapid development of geothermal energy industry.

2.5 The problems of inadequate and uncoordinated still exist in China's geothermal industry

Firstly, more work should be done regarding the exploration and evaluation of geothermal energy resources and scientific research. The national geothermal resources evaluation had been carried twice in China, however, only a few geothermal fields have been systematically explored and the research foundation is relatively weak. The evaluation results on resources of each province and each basin are less accurate, and there is a significant gap when compared with developed countries. At present, the number of heat flow data in China is only 1,230, while United States has more than 17,000 heat flow data. In the field of dry hot rocks exploration and development, the United States has been studied hot-dry-rock type geothermal energy for more than 40 years, and achieved many research results. Germany, France, Britain, Japan and Australia have also carried out fruitful work. However, China just started.

Secondly, the policies are not sufficient in the early stage of geothermal energy industry development. Recently, the central and local governments have introduced some financial and price policies to accelerate the development and utilization of shallow geothermal energy and promote clean heating in the northern areas. However, policies are not quite perfect and the implementations of the policies are not in place and insufficient. First of all, the laws and regulations related to geothermal energy are in poor operability. At present, the laws and regulations on financial and tax support for geothermal energy are lack of implementation terms and rules, and there are no unified and clear standards for incentive policies, such as preferential tax rate and subsidy, and the policies are "difficult to carry out". The standard of resource tax is relatively low, which cannot reflect the real cost to social and the

advantages of developing geothermal energy. Next, there is insufficient preferential treatment for the development and utilization of geothermal energy. According to the additional policy requirements of renewable energy electricity price, the electricity price subsidy policy is given to the commercial operation projects of geothermal energy power generation. But, there are no enough preferential policies for specific development and utilization at the moment. There are still shortcomings in the existing geothermal energy preferential policies, which are mainly reflected in the lacking of policies for land utilization, equipment manufacture and product consumption. Finally, subsidy models are unscientific and support methods need to be improved. The form of subsidy only adopts the way of pre-subsidy and production-linked subsidy, and the results are greatly reduced. Direct subsidy is the main way, but still has the problem of lacking market-based methods and the period is long.

Thirdly, the problem of uncoordinated still exists in geothermal energy industry. Mainly shows in: The first one, the accuracy of geothermal exploration and evaluation lags behind the speed of development and utilization. The exploration base of geothermal energy is weak, low precision, as well as lack systematic exploration. In the field of the preferable areas election and development scale determination there are some blindness, which not only increases the risk of project investment, but also leads to extensive, inefficient development and bring more environmental problems. The second one, technological innovation and geothermal energy development and utilization are not in harmony. The key technologies and equipment of geothermal energy exploration, hydrothermal energy injection, dry hot rocks development and utilization, medium-to-low temperature geothermal energy efficient power generation need to be innovated urgently to realize develop geothermal energy in large scale. Next, geothermal energy development

projects are not coordinated with the overall planning of city. Although there are more than 10 provinces published geothermal energy planning and relevant documents, which greatly promoted the development of geothermal energy industry in China, these plans are not compatible, and there are no links between different levels of planning. The current development and utilization planning of geothermal energy is not integrated into the local and urban development plans. It leads to the lack of operability of planning in practice. It is also difficult to achieve the goals of *The 13th Five-Year Plan for the development of geothermal energy* in China. Last but not the least, government regulation is not compatible with sustainable development and utilization of geothermal energy. The multi-management and less of regulation capability of government are not compatible with the rapid development of geothermal energy. The existing problems include less of relevant standards and technical specifications, supervision missing and offside. Through shallow geothermal energy and hydrothermal energy has been developed for years, dynamic monitoring system has not been constructed, which seriously hinders the healthy and sustainable development of geothermal energy industry.

Fourthly, the geothermal energy resource management system is not coordinated. In China's current legal system, "geothermal" is controlled by three laws, but the relevant regulations have not accurately understood the basic properties of geothermal energy. Thus, the applicability and operability of the laws need to be solved urgently. *The Mineral Resources Law of People's Republic of China* stipulates that "geothermal" belongs to the minerals. Since "geothermal" is renewable, the management mode of non-renewable mineral resources can't meet the needs of large-scale exploration and exploitation of geothermal energy. *The Water Law of People's Republic of China* stipulates that

"underground hot water" belongs to water resources. Since the utilization of geothermal energy does not consume water, employing the way of managing water resources to manage geothermal restricts the rational development of geothermal energy is not correct. Although *The Renewable Energy Law of People's Republic of China* emphasizes that geothermal energy is renewable energy, it is only in principle and it lacks the management means and measures like it given to wind energy and solar energy.

3. Suggestions on China's Geothermal Energy Development

China has abundant geothermal resources, vast market demand, and good development tendency. It is a sunrise industry with great potential. The development of geothermal energy industry will be of great significance for China to adjust its energy structure and prevent environmental pollution. In terms of economic benefits, the rapid progress of geothermal energy industry will take a more important position in China's economic growth and economic structural transformation and upgrading. The high-quality development of geothermal energy industry will not only promote employment increase, but also facilitate a comprehensive development of both upstream and downstream industries, such as equipment manufacturing, geological exploration, construction, modern agriculture and leisure tourism.

3.1 The China's overall guideline for geothermal energy development

3.1.1 Guiding ideology

The geothermal energy industry development guidance can be regarded as an in-depth implementation of The Thought on Socialism with Chinese Characteristics for a New Era and The Spirit the 19th National Congress of the Communist Party of China, both of which call for a decisive victory in building a moderately prosperous society in all respects, including ecosystem. High-quality development of geothermal energy industry will play an important part role in promoting ecological civilization and energy revolution, building a green energy system, and realizing people's yearning for clean energy and a better life. Guided by

"Lucid waters and lush mountains are invaluable assets", the geothermal energy industry is committing to optimizing energy structure, preventing and controlling air pollution, coping with climate change, and developing green industry. Based on national conditions and geothermal energy resources endowment, the geothermal energy industry is actively integrating into the coordinated development of Beijing-Tianjin-Hebei, the development of the Yangtze River economic belt and the construction of the "Belt and Road", embracing modernization, the world and the future. Efforts will be made to comprehensively plan the high-quality development of the geothermal energy industry chain, optimize the overall planning and layout of the industry. The industry will be dedicated to enhancing the vitality of the micro-subjects in the market, focusing on comprehensive geothermal energy resources survey and evaluation, building a scientific development and utilization technology support system. Also, the industry will focus on promoting deep integration with other energy industries, building a technologically advanced, environmentally friendly, and economically viable geothermal energy industry cluster, accelerating the healthy and sustainable development of the industry, and helping to build a beautiful China.

3.1.2 Basic principles

(1)The principle of adaptation to local conditions. The core task is to help prevent air pollution. In the central and eastern China where the ecological environment is relatively severe, such as Beijing, Tianjin, and Hebei, geothermal energy will be used, on a priority basis, for heating/cooling. This measure will help replace the traditional coal-fired boilers, address pollution caused by non-centralized coal burning in rural areas, and help promote clean winter heating in northern region. In the western China, geothermal energy will be used in power generation in an orderly manner, providing clean energy for the development of the

western region. In hot-summer and cold-winter areas of China, shallow geothermal energy will be used to meet the need of heating and cooling and help the green development of the Yangtze River economic belt. We will also strengthen cooperation in the field of geothermal energy with countries participating in the "Belt and Road" initiative and other countries to cope with climate change together.

(2)The principle of step by step. Based on China's geothermal energy resources endowment and market needs, in the near- and midterm future, heating and cooling will be the main usage of geothermal energy, while power generation will be secondary. During this period, a green industry chain will be built. Geothermal heating will be taken as a stepping stone, which will help to increase policy support, accelerate the efficient development and utilization of geothermal energy, and enhance the awareness and recognition of geothermal energy industry in all sectors of society. Meanwhile, we will pay close attention to tackling key problems of the EGS, laying the foundation for large-scale geothermal power generation in the future. Demonstration projects for early and pilot implementation of Green industry based on geothermal energy will be gradually promoted to the whole country. After 2035, with the gradual maturity of exploration and development technology and the continuous improvement of the market system, efforts will be made to cultivate geothermal energy into a driving force for green development, and play an important role in optimizing and adjusting China's energy structure.

(3)The principle of adhering to high quality development. We will move faster to advance the change of geothermal energy industry development pattern from a single, extensive, inefficient one to a diversified, intensive, efficient modern one. Precise exploration and cascade utilization of geothermal energy will be widely used in order to improve resource utilization efficiency and improve geothermal project

profit. In addition, we will push forward with the "Geothermal Plus" and speed up deep integration and coordinated development of multiple clean energy sources based on local circumstances. We will strengthen our capability for making technological innovations, work toward accelerating geothermal energy industry transformation and upgrading, and speed up talent cultivation. These measures will enable us to achieve a well-performing and sustainable development of the geothermal energy industry.

3.2 Suggestions on promoting the high-quality development of geothermal energy in China

3.2.1 To carry out the high quality geothermal resources evaluation through China as soon as possible is an urgent issue by far.

Some actions need to be taken to facilitate the development of China's geothermal resources evaluation, such as increasing financial investment, encouraging active participation of all kinds of social capital, and carrying out investigations and evaluations of national geothermal resources. Focusing on North China, Songliao, Jianghan, Ordos, Subei and other basins (plains), China should accelerate the ascertaining of geological conditions, reservoir characteristics, quality and quantity of both hydrothermal type and hot-dry-rock type geothermal areas (fields), and evaluate the technical and economic conditions for its development. Besides above mentioned suggestions, China should also speed up the exploration and development of deep geothermal resources, and prepare for the large-scale and commercialized development of hot-dry-rock type geothermal energy.

China should not only establish the system of data collection, sharing and service for the government-led whole industrial chain in geothermal energy exploration, development and utilization, but also form the

national data platform for geothermal energy development and utilization which includes basic data of geothermal resources, dynamic and efficiency monitoring data of geothermal development and utilization, and industrial network information management system, aiming at proving supports for geothermal energy investigation and evaluation and scientific development and utilization.

3.2.2 Key techniques for the development and utilization of geothermal energy should be tackled fast.

The central finance and local finance should set up the major specialized funds for geothermal resources survey and for scientific and technological innovation, increase the investment in the research and development of key technologies for geothermal energy exploration and development, and strengthen the research and development of special equipment and special technology for geothermal energy.

The first is to develop comprehensive geophysical and geochemical technique that can directly detect the underground temperature field, so as to realize three-dimensional fine characterization of the underground temperature field. The second is to strengthen the research and development of directional drilling technology and equipment at high temperature, to break through the key technical bottlenecks of high temperature and low cost drilling, and to achieve the upgrading of core equipment. The third is to tackle technical problems in the economical recharge technology of sandstone reservoir, to improve the well completion technology of recharge wells, and to optimize the layout of the production and recharge system. The fourth is to make technical breakthroughs in hot dry rock exploration and development, and to break through the key technologies of reservoir construction, reconstruction and efficient heat exchange. The fifth is to explore a multistep, comprehensive, and efficient model of utilizing technology system and

business mode, and to tackle key technologies in power generation, heating, cooling, commercial application, and other related areas.

3.2.3 High-quality demonstration areas for geothermal energy development in a leading and exploratory way should be cultivated.

The first is to establish a demonstration area for efficient development and utilization of geothermal energy in Xiong'an New Area. To make the "Xiong'an Model" of geothermal energy utilization into a global model in accordance with the goal and requirement of the "Xiong'an Quality" in the planning and construction of Xiong'an New Area. In terms of planning concept, geothermal planning will be carried out first instead of the previous geothermal development following urban agglomeration. For the source of energy supply, the original hydrothermal-focused type will be reformed as the geothermal, hydrothermal and hot dry rock integrated type. For the way of energy supply, the single heating supply will be replaced by multiple supplies of electricity, heating and cooling supplies. The way of energy consumption will be transformed from single geothermal consumption into multi-energy consumption. The energy-consumption cycle will be changed from one heating season to four seasons. The industrial chain will be transformed from the single energy industry into an integrated industrial cluster of upper, middle and lower streams of geothermal energy.

The second is to establish a demonstration area for shallow geothermal energy utilization in Beijing's subsidiary administrative center. With the coordinated planning and construction of underground and up-ground space, build a distributed and complementary large-scale energy station system for shallow geothermal energy development and utilization, form a demonstration area of cluster utilization, meet the needs of heating and cooling of large building aggregates of Beijing's subsidiary administrative center, and assist the construction of green low carbon city.

The third is to establish a pilot site for hot-dry rock exploration and development in the Gonghe Basin. Facing the future development needs for geothermal energy and aiming at the technology frontier of hot dry rock, we will carry out pilot tests to tackle difficulties in strategic science and technology in the Gonghe basin of Qinghai, vigorously promote the development of theory, technology, engineering and equipment for the exploration and development of dry-hot-rock type geothermal resources, and strive to achieve a major breakthrough in the exploration and development of the hot-dry-rock type geothermal resources as soon as possible.

The forth is to build a demonstration town featured in geothermal energy. Taking the Xiaoyangkou of Jiangsu Rudong as a demonstration area, to build a town based on geothermal energy and featured in the cascade and high efficient development and utilization of clean energy. Following the comprehensive and high efficient utilization concept, it will form a clean energy industry cluster for heating, cooling, electricity generation, bath therapy, hot spring leisure, old-age service, efficient modern fishery, agriculture, flower drying and so on. It will provide a demonstration for the acceleration and development of green industry system supported by clean energy.

Apart from the construction of pilot sites over the country, at the same time, we should set up the trial and error mechanism of further reform and opening up as soon as possible, fully mobilize the enthusiasm of all parties to participate in the reform and innovation, explore the pilot boldly, practice the new concept of development, sum up the experience in time, and then popularize it in the whole country after the conditions are basically mature.

3.2.4 Preferential policies should be introduced to support the high-quality development of geothermal energy.

At the early stage of geothermal energy industrial development,

support policies of finance, tax and finance for wind power, photovoltaic and other renewable energy can be referenced, so as to give great support to the exploration and utilization of hydrothermal and hot dry rock type geothermal energy. The geothermal development and utilization should be included into the subsidy range of the renewable energy fund, and should be issued with green certificate quotas in accordance with the green certificate system of renewable energy. Relevant preferential policies of value-added tax, property tax and urban land use tax should be implemented for enterprises of hydrothermal and hot dry rock energy development and utilization as well as other related equipment and materials manufacturing enterprises. Financial subsidy policies for geothermal energy to replace fossil energy for heating, cooling and power generation should be studied and formulated, based on the amount of heating (cooling) and electricity as the unit.

Carrying out pilot promotions of the franchise right. In order to attract social forces and financial capital to participate in geothermal exploration and evaluation, and to promote the scale development and standard development of geothermal energy industry, pilot promotions of the franchise right for geothermal development will be carried out. Enterprises participating in the exploration of basic public welfare geothermal energy and integrating the survey and evaluation data into the national geothermal energy data management platform will be granted the priority of obtaining the franchise qualification of geothermal resources (mining rights).

3.2.5 The management and monitoring system of geothermal energy should be established and improved.

The first is to make a proper special planning for geothermal energy. The special planning of geothermal energy utilization will be included in the national spatial planning system, and the overall objectives and

basic ideas of the geothermal energy development and utilization will be clearly defined. The geothermal energy heating (cooling) will be included in the special planning of local infrastructure construction, so as to realize the scientific layout and efficient development of geothermal energy development.

The second is to improve the management system of geothermal energy. In accordance with the principle of "One department is responsible for one thing", the management measures for geothermal energy development and utilization will be formulated in line with the *renewable energy law of the People's Republic of China* as soon as possible. The boundaries and standards for utilizing water resources, geothermal resources, and for both water and heat intakes will be clearly defined. The market access regulations of geothermal energy exploration and development, the bid, auction, listing and selling of mining rights, and third party services will be perfected. The reinjection system of geothermal tail water will be perfected, effective implementations will be made, and the geothermal resources and environmental protections will be strengthened. The strengthened supervision, standardized market order, and increased penalties for illegal enterprises will be targeted. Finally, a statistical report system for geothermal energy exploration, development and utilization will be established.

The third is to establish an evaluation system for geothermal energy development and utilization. In areas of the northern region and the Yangtze River economic belt that meet the requirements, transform their energy system into comprehensive application demonstration projects (areas). The utilization of geothermal energy should be included in the assessment system of regional ecological civilization construction, and act as an additional part of the assessment system for energy conservation and emission reduction.

Closing Remarks

The rapid development of clean energy has become one of today's hot topics. Facing international upsurge in the development and utilization of geothermal energy and the huge domestic demand for clean energy, the development and utilization of geothermal energy in China has achieved a rapid growth with the joint efforts of "Government, Industry, University and Institutes". China has made great progress in the exploration, development and utilization technology, and has ranked as one of the top countries in the world with rich resources and high degrees of geothermal energy development and utilization.

With the vigorous promotion of the *Clean Winter Heating Planning for the Northern Region (2017-2021)* and the orderly launching of the "Coal to Geothermal Energy", the construction of demonstration areas for geothermal energy development and utilization, represented by Beijing's subsidiary administrative center, Xiong'an New Area and Jiangsu's Rudong Xiaoyangkou, as well as the implementation of deep geothermal exploration in areas of the Beijing-Tianjin-Hebei region and demonstration projects of hot dry rock utilization in Qinghai Gonghe Basin, will promote and lead China's geothermal energy exploration and development to the fast lane It will become an important force to cope with climate change, and serve to win the blue sky defense battle and to optimize the energy structure. Meanwhile it will make great contributions to the green development and the ecological civilization construction.

The introduction of *China geothermal energy development report* aims to build an exchange and communication platform to promote the great transformation of China's energy and to explore the healthy and rapid development of geothermal energy industry. We look forward

to the release of the *China geothermal energy development report of 2018* to further stimulate the community to explore the reform path of the geothermal industry, to condense consensus, and to cooperate with the development of geothermal energy utilization. Here, we sincerely thank all relevant departments, research institutes, industry associations, enterprises, international institutions and many experts for their strong support and assistance.