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CHINA GEOTHERMAL ENERGY

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新时代地热行业发展若干思考

REFLECTION ON DEVELOPMENT OF GEOTHERMAL INDUSTRY IN NEW ERA

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摘　要：当前，中国特色社会主义进入了新时代，社会各项建设取得重大成就，地热产业也发展壮大。在大力倡导生态文明建设、推进绿色发展、提升环境保护、推进资源的节约和循环利用的社会发展形势下，一些重要规划和政策的实施、一批重点区域和重大项目的建设、大量地热能开发利用新技术的推广，又给地热产业带来了新的发展契机。不同形式、不同利用方式的地热能都将迎来更广阔的市场、更高的产业增长态势。为顺应新时代行业发展，地热产业应抓住机遇，迎接挑战，创新突破，成就未来。本文将从上位决策、项目建设、技术创新、管理等方面，分析当下地热行业发展的形势、特点和存在的问题，提出相关建议，以共同探讨，相互借鉴。

关键词：新时代；地热；规划建设；技术创新；管理

当前，我国地热产业正迅猛、飞速发展，地热直接利用（非电）已连续多年位居世界首位。尤其是在刚刚过去的 2017 年，“十九大”召开、“地热能开发利用‘十三五’规划”发布、北京城市副中心建设、雄安新区设立等，使地热的开发利用进入黄金期。这既给我们地热人极大的鼓舞，同时也鞭策着我们继续奋进。

忆往昔，宝剑锋从磨砺出，地热行业取得的辉煌成就值得我们骄傲；瞻前路，竿头日进，我们更要保持自我，砥砺奋进，顺应新时代行业发展的潮流。借此，有些体会及感受要与大家分享，共同探讨、相互借鉴，一起努力将地热产业做大、做强，做成中国品牌。

1.2017 中国地热记忆

对于中国地热人来讲，2017 年是值得牢记的。这一年，上至国家层面的方针、政策、规划，下至众多重大地热项目的实施建设等，都揭示了一个重要信息——地热的开发利用已经被国家、社会真真正正地重视起来了。最深刻的感受莫过于以下几点：

1.1“十九大”记忆

2017 年 10 月 18 日，在中共“十九大”上，

习近平总书记在报告中提出，加快生态文明体制改革，建设美丽中国。其中“推进绿色发展”、“推进资源全面节约和循环利用”、“降低能耗”、“持续实施大气污染防治”“加大生态系统保护力度”等一系列重点词句在向我们传达，生态文明建设被提升到新高度。我们要建设的现代化是人与自然和谐共生的现代化，是走尊重自然、顺应自然、保护自然的发展道路。而作为可再生能源重要一员的地热，具有清洁、高效、再生、循环、储量大、分布广泛、就地取材的特点，合理开发利用既节约资源又保护环境，将会在生态文明建设中发挥显著作用。国家发展重环保，环保提升需地热。

1.2“上位规划”记忆

2017 年 1 月，国家发展改革委、国家能源局、国土资源部联合印发《地热能开发利用“十三五”规划》。这是地热行业首个全国规划。规划中提出，“十三五”时期，新增地热能供暖（制冷）面积 11 亿平方米，其中：新增浅层地温能供暖（制冷）面积 7 亿平方米；新增水热型地热供暖面积 4 亿平方米。到 2020 年，地热供暖（制冷）面积累计达到 16 亿平方米，地热发电装机容量约 530MW。并将具体指标分解向各个省市。地热行业发展有了国家的专项规划，有了指导方针和目标，更有了国家的支撑和保障。这是我国地热工作一个具有里程碑意义的新突破。

为了深入贯彻党的十九大精神，2017 年 12 月，国家发展改革委、国家能源局、财政部、环境保护部等 10 部门联合印发《北方地区冬季清洁取暖规划（2017—2021 年）》，旨在提高北方地区取暖清洁化水平，减少大气污染物排放。污染防治的重点区域是京津冀“2+26”个重点城市。规划提出，到 2019 年，北方地区清洁取暖率达到 50%，替代散烧煤（含低效小锅炉用煤）7400 万吨。到 2021 年，北方地区清洁取暖率达到 70%，替代散烧煤（含低效小锅炉用煤）1.5 亿吨。其中，地热供暖面积 2016 年底为 5 亿平方米，至 2021 年将增长到 10 亿平方米。

这些规划共同为我们的地热产业构建了一幅美好的发展蓝图。

1.3“重大项目”记忆

2017 年，一批国家重大建设项目采用地热“两能”为建筑供暖、制冷，无疑是对地热开发利用技术的肯定，同时也展现出地热在规模化应用方面的优势——高效、节能。以我们身边的大型建设项目为例：

根据《北京市“十三五”新能源和可再生能源发展规划》，到 2020 年，城市副中心行政办公区新能源和可再生能源利用比重力争达到 40% 以上，城市副中心整体区域新能源和可再生能源利用比重力争达到 15% 以上。一方面，可再生能源指标的实现，地热能是绝对的主力军。另一方面，运用创新的能源运行信息智慧调节技术，实现新能源和可再生能源与常规能源系统的智能耦合运行，打造国际先进水平的可再生能源示范区，这既是对地热利用技术的创新，也是为全球区域能源发展树立了良好的典范。优秀的经验和技术得以传播，提升整个地热行业发展，都得益于高水平的规划、先进的思路、重点区域和项目建设的良好契机，为行业发展提供更广阔的平台。北京城市副中心核心办公区一期项目，为打造“近零碳排放区”示范工程，采用地热“两能”为建筑供暖、制冷，大大降低了污染物排放和区域能耗。

在北京新机场建设项目中，目前已确定有近 250 万平方米的机场配套建筑采用浅层地温能进行供暖、制冷，有效提升了区域可再生能源利用率。

地热能已露锋芒，未来，在“绿色发展”成为主题的时代里，越来越多的项目将采用这种成熟的技术，同时，区域能源智慧管理、互联网 + 新能源、热网融合等一些创新事物将值得我们研究和关注。

2 新时代地热行业发展特点

今后地热的发展发向将是为解决北方供暖为主的开发利用。当前，地热行业主要体现如下几个特点：

2.1 地热空前热，加温全国浅层地温能行业热

当前，地热行业的发展既有了上位规划的支持，又有了普通大众的接受，在可再生能源供暖中可算是 No.1。“地热”概念已深入人心，其清洁、可再生、储量大等特点也深受社会大众的追捧。地热真的“热”起来了，同样，也带动了浅层地温能行业发展。全国浅层地温能供暖面积（如图 1）。从这样一组数字可以看出，浅层地温能产业发展正在快速增长，行业真正被地热“加热”了。

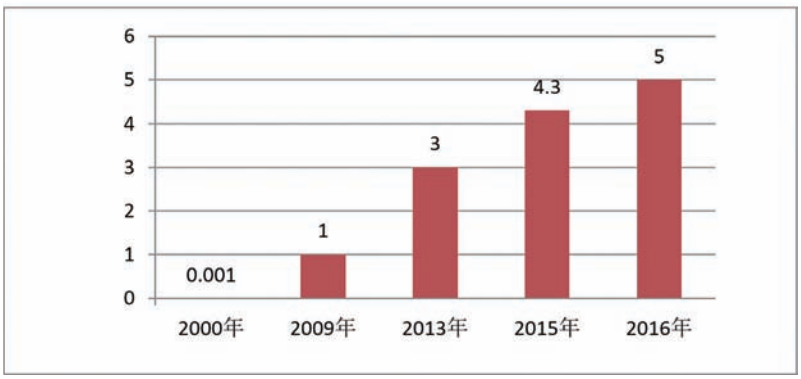

图 1 我国浅层地温能应用面积统计

2.2 北方地区清洁供暖和治理雾霾使浅层地温能产业发展呈高速状态

当前，我国北方地区冬季雾霾问题严重，京津冀地区尤为突出。冬季燃煤供暖是造成雾霾的重要原因。2016 年 12 月中央财经领导小组第十四次会议提出了北方清洁供暖问题。京津冀地方政府都在出台相关政策，采用煤改电、煤改气等方式，实现供暖清洁化改革。浅层地温能供暖作为一种清洁化的能源必将在当前的形势下发挥更加重要且不可替代的作用。北京市浅层地温能供暖面积，2010 年为 1957 万平方米，2015 年为 4000 万平方米，而在 2020 年，预计将达 5000 万平米以上。

2.3 鼓励政策密集出台，各级政府积极推动，全面利好浅层地温能产业发展

近两年，鼓励政策密集出台。2017 年 9 月，住建部、国家发展改革委等 4 部委联合下发《关于推进北方采暖地区城镇清洁供暖的指导意见》，指出推进北方地区冬季清洁取暖是中央提出的一项重要战略部署。要大力推进地热能等可再生能源供暖项目。2017 年 12 月，国家发展改革委、国土资源部等 6 个部委联合下发《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》，要求加快推进浅层地热能（亦称地温能）开发利用，大力推动本地区实施浅层地温能利用工作。

地方政府也纷纷响应号召，制定落实方案。以北京为例，继国务院发布《大气污染防治行动计划》后，于 2013 年发布了《北京市 2013-2017 年清洁空气行动计划》。2013 年 12 月，市发展改革委等 6 部门印发《进一步促进地热能开发及热泵系统利用实施意见》；2016 年 6 月，市发展改革委印发《关于进一步明确煤改地源热泵项目支持政策的通知》；2016 年 9 月，北京市发布《“十三五”时期新能源和可再生能源发展规划》；2017 年 2 月，市人民政府办公厅印发《2017 年北京市农村地区村庄冬季清洁取暖工作方案》等等。这一系列鼓励政策相继出台，都表明要大力发展浅层地温能系统建设，加大支持资金力度，补贴金额从 30% 到 50%，优惠电价等，支持力度空前强大。这也大大推动了市场的发

展，用户有需求、有补贴，设备商有销量、有市场，建设方有项目、有收益，政府调控有成效，环境保护有提升，一举多得，全面利好。

2.4 重点区域、项目建设使水热型地热供暖大展身手

以重点区域、项目建设为契机，综合运用多能互补模式和智慧能源技术，打造一批具有国际先进水平的新能源和可再生能源示范区，是当前政府大力倡导的能源建设发展模式。地热产业发展成为该模式中不可或缺的组成部分。

根据 2018 年 1 月 2 日召开的京津冀协同发展工作推进会上的消息，河北雄安新区规划框架基本成熟，未来，雄安新区将建设绿色智慧新城，只有实现新能源和可再生能源 100% 替代化石能源，才能建设真正意义上的绿色智慧城市。在去化石能源工作中，首先就是全力开发可再生能源，充分利用太阳能、地热能、风能等资源。雄安地区地热田面积达 320 平方公里，地热水储量 821.78 亿立方米，可替代 66.3 亿吨标准煤，但目前开发利用量仅占可采总量的 6%，国土资源部已规划“打造全球地热利用样板”。因此，在不久的将来，地热产业将在雄安新区这个舞台上大展拳脚。

2.5 水热型地热发电和干热岩利用在新的起点上将迎来新的崛起

地热发电自 1977 年建成西藏羊八井地热电站并沿用至今，一直没有形成遍地开花的局面。当前，规划印发、技术进步等因素使停滞多年的地热发电又热起来了。云南等地已建立了一些新电站，在其示范带动下必将推动我国地热发电产业快速发展，将在分布式发电、一带一路新能源发展等发面发挥作用。相对于光电、风电的波动性对电网的冲击缺陷，地热发电更持续稳定。我国对光伏和风力发电已给出明确的上网电价政策，而地热发电尚无相关扶持政策出台，产业的发展还期待政策的扶持。

干热岩是国际社会公认的高效低碳清洁能源。2017 年 9 月我国科学家在青海共和盆地 3705 米深处钻获 236℃的高温干热岩体。这是我国首次钻获温度最高的干热岩体，是干热岩勘查的重大突破。经过中国地调局初步评价我国陆域干热岩资源量为 856 万亿吨标准煤，根据国际标准，以其 2% 作为可采资源，全国陆域干热岩可采资源量达 17 万亿吨标准煤。和传统水热型的地热相比，干热岩温度更高，能量资源更丰富。根据中国地调局初步调查结果，我国东南沿海地区，松辽平原、华北平原和青藏高原地区是干热岩将来勘查开发有潜力的地区。国际社会高度重视干热岩的勘查开发，如在美国已经初步在某些地区进行了干热岩的实验性发电。在我国，干热岩的开发特别是商业开发，目前还处于一种探索的阶段，但前景广阔。

3 新时代行业发展催生新成果

当前，我们已迈入新时代中国特色社会主义道路，继往开来，新时代，新气象，新思路，新做法。“两个一百年”为我们指明了前进的方向和目标。顺应时代发展，创新规划、思路、技术、模式等，地热行业也创造出许许多多的优秀成果，主要表现在以下几个方面：

3.1 系统集成方面

因地制宜，多能互补的“浅层地温能 +”是近年来地源热泵行业大力发展的建设模式。充分考虑到了区域自然资源条件和特点，合理调配资源开发利用，真正做到了资源的集约、节约利用，我们已总结为“四个结合”，即深浅结合、天地结合、调蓄结合、表里结合。这四种结合方式不是孤立的，而是可以相互结合的。总之要根据不同地区的资源条件，最大程度地利用好各种资源，提高资源的利用效率。

3.2 技术创新方面

为了满足地热行业的快速发展需求，大量新

技术应运而生，而技术的革新又推动了行业的进步，值得我们学习和推广。

（1）水热型地热资源的梯级利用

一般来说，高于 150℃的高温地热资源，可开采流体多属于蒸汽型，分布区域有限，主要用于发电；而对于我国大部分地区易开采的地热资源来说，都是低于 150℃中低温地热资源，可开采流体属于水热型。对于在封闭管路中循环的地热水，在被提取热量后，通常要回灌至地下，以保证地热资源的循环利用。而一些品质优良的地热水资源温度较高，在经首次提取热量后，仍保持较高的水温，40~50℃甚至更高，其中还有较多的热量，这种地热尾水如果直接回灌至地下，是能源资源的浪费。因此，对于品质较好的地热尾水，最好的做法是通过热泵系统对其再次或多次提取热量，将水温降至 20~30℃后进行回灌。这种做法称之为地热水的梯级利用。一方面，提高了地热资源的利用率，单位水量供能量增大，系统效率提升；另一方面，使地热水用途更加广泛，多种温度需求可以同时满足。因此，对高品质地热水实行梯级利用是要大力推广的一种好方式。

（2）热泵技术 + 干热型地热资源

干热型地热资源的特点是地下热层温度较高但无可开采流体。要开采这样的地热资源，我们采用新方法：从地上输水至地下热层进行充分换热，然后将热水抽取至地面，用热泵提取热水中的热量，取热后的尾水再输送至地下热层换热，如此循环。这样做的好处是，充分利用区域地热资源条件，在水资源缺乏的地区，只要地层温度满足，热储量足够，即可开采地热，并且不存在回灌和地下水资源量限制问题。目前，这种新方法在我国很多地区正在尝试，也有部分项目采用且效果良好，如西安等地。

（3）新型地埋管换热器

传统地埋管地源热泵系统的地下换热器采用单 U 或双 U 型 HDPE 管。通常根据项目不同，地下换热器埋深多在几十米至 150 米之间。由于单个换热孔换热能力有限，一般一个地源热泵项目需建设地埋管换热孔少则几十个、上百个，多则几千个甚至上万个；按换热孔间距 4~5 米计算，占地面积也很大。尤其是在建筑群密集的城市中，可用土地面积更是极为有限。在这种状况下，我们组织开展了一种新型地埋管换热器——同心套管换热器的研究，并进行试验安装。换热介质水从套管夹层中进入，夹层管程中设有螺旋纹，保证了水与管外岩土充分换热，换热后的水从套管底部内管中被抽取上来，进入热泵机组换热，换热后的水再输回套管换热器，如此循环。通过试验证明，相同地埋管埋深条件下，单个换热孔换热能力明显提升，有效减少了地埋管换热孔的建设数量。未来，研究者们将继续研究相关技术，如埋管间距控制、夹层螺纹设置、管材选择、隔热等技术，力争更加完善研究成果并快速推广应用。

另外，还有一些新的尝试，如我国北方寒冷地区地温能的利用形式，浅部地层岩土温度较低，其中的热量不能够满足建筑供暖需求，我们组织尝试突破浅层地温能 200 米的限制，从 400~500 米甚至更深层的地下岩土中寻求更多的热量源。再如一些大型地表水水源热泵项目也在推进实施，江、河、湖、海水皆可为我所用。城市再生水热能的利用，提升城市污水利用的新高度，等等众多案例，都说明，为了顺应时代的发展，研究者们正夜以继日地加快技术创新步伐，创新思路，做出前所未有的大胆尝试，推动产业向前发展，引领了世界先进技术。

3.3 区域能源供给新模式

当下，地热项目已经从过去的“单打独斗”，单个小规模项目，逐渐地发展成为集中成片的大规模建设。一些优秀的规模化应用案例很多，例如北京城市副中心、北京新机场项目，在规模上都

是世界上数一数二的。北京市地勘局已自主研发了 SGIS 智慧地热能系统集成技术，形成了包括浅层地温能开发利用设计、施工、运营、管理一套完整的智能耦合体系。首创了地上、地下立体监测联调的智慧控制系统和浅层地温能资源承载力监控体系，并将该项集成技术应用到北京城市副中心等大型项目中。

未来，在京津冀协同发展区、雄安新区、北京世园会、北京冬奥会区域、各地重点开发区等一些重大项目建设区域，地热还会崭露头角，甚至成为万众瞩目。因此，更应该思考如何让地热更好地适应区域能源供给模式，如何从资源、技术、施工、运营、资本、管理等各个环节与其他能源供给形式相互融合，如何与区域其他设施、功能相互融合，如何体现友好的人机环境，如何体现智慧化，这才是真正的高水平项目的体现。

4 应重点关注的几个问题

我国地热行业发展至今，技术可行性和实操性是成熟的，但相关细节仍然值得我们改进和完善，需要我们重视起来。

4.1 地热水回灌问题

水热型地热资源的储热介质为水，根据区域资源条件不同，有的地方地下热水量丰富，有的地方水量很少，甚至没有。但即便地下水量丰富的地区，其可开采的热水储量也是有一定限度的。深层地下水不同于浅层地下、地表水，其自然补给速度多较缓慢，一般地热项目的开采水的速度远大于其自然补给速度。若长期大量开采地下水而不进行有效补给，可开采地热资源将会越来越少，至慢慢枯竭。“可再生”也变为“不可再生”。而现在国内很多地区，对于开采的地热水，取完热后并不进行回灌，大量地下水被随意排放掉，导致地下水位急剧下降，后期甚至无水可采，山东、河北、河南等很多项目都存在这样的问题，一定要高度重视。这样粗放的开发利用方式不符合生态环境的保护，不能够做到能源循环利用，无异于杀鸡取卵，要坚决杜绝。对于水热型地热资源的开发利用，可以推广“以灌定采”的开发理念，即根据地热水的回灌量决定其开采强度，做到 100% 回灌，资源可循环。另外，政府补贴的项目必须建立地下、地下监测系统。

4.2 管理问题

有效、与时俱进的管理是推进行业发展前提。管理不完善，监管缺失等往往制约了行业进步。

（1）交叉管理

目前，国内有些地方地热资源矿业权管理属于国土部门的职能，而地下水的取水许可是在水务部门审批，多部门交叉审批、管理也限制了地热行业的发展，也是现在地热水不回灌的主要原因。

（2）地热矿业权审批

从 2011 年《国土资源部关于进一步完善矿业权管理促进整装勘查的通知》的出台开始，矿权审批程序发生了较大调整，未经提前备案的矿权不得进行审批，很多市场需求受到不同程度的制约，2015 年《国土资源部关于做好矿业权设置方案审批或备案核准取消后相关工作的通知》发布，矿权审批政策再行调整，单独的矿业权设置方案取消，纳入到“矿产资源规划”统一审批，新的“矿产资源规划”未正式发布，对市场需求的释放也会有一些影响。从矿业权设置方案的编制到矿产资源规划的修订，从政策出台到省市落地政策的实施以及审批程序的调整，往往都需要较长的周期，无形中限制了很多市场项目的实施。

（3）管理空白区

近年来，中深层干热型地热资源兴起。但国内绝大部分地区对这种取热不取水的新型地热资源没有进行管理的相关部门。如何使其合理合法应用，管理服务部门如何分工、跟进，一直是行业追寻的问题。管理上的空白也影响了其健康发展。

（4）施工监管问题

目前，系统的施工建设有相关的技术规范和标准，但在实际工程项目中，地埋管地下施工的监督管理却未有效进行，质量控制存在缺失环节，项目建成后，地下埋管属于隐蔽工程，无法检验、查看，大多项目只能靠施工方的良心工程。出现“豆腐渣”工程，损害行业声誉的事件也时有发生，不利于地热能的推广应用。

5 未来发展展望

目前，国内地热行业正处在飞速发展期，众多支持政策出台、社会大力推广、民众环保意识增强，决定了在接下来一段时期内，行业发展仍会保持高增长态势。由于新规划、政策的全面实施，预计今后将迎来井喷式的大发展。未来，地热市场广阔，“蛋糕”巨大。如何抓住这良好的契机，作为行业从业者，还应当从最基本的方面着手去做：首先，做好行业自律，踏踏实实，认认真真做好自己的每一件事，高标准、严要求、细劳作、出精品；发展眼光放长远，诚信经营，相互扶持，共同进步，单丝不成线，独木不成林。其次，要做到以“我”为主，兼收并蓄，各展所长，从业人员发挥自身专业领域特长，相互借鉴，齐头并进，共同迎接这一千载难逢的新时代。

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Reflection on Development of Geothermal Industry in New Era

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Abstract: at present, the socialism with Chinese characteristics has entered the new era, the construction in all social aspects has accomplished significant achievements, and the geothermal industry is growing steadily. In the social development situation where the ecological civilization construction is robustly advocated, the green development is carried forward, the environmental protection is promoted, and the resource saving and cyclic utilization are advanced, thanks to the implementation of some important plans and policies, the construction of a batch of key areas and major projects, as well as the

promotion of tremendous new technologies for geothermal energy development and utilization, new development opportunities are brought to the geothermal industry. Different forms of and different utilization modes of geothermal energy will be faced with a wider market and a higher industrial growth. To follow the industrial development in the new era, the geothermal industry should seize the opportunities, meet the challenges, make innovations and breakthroughs, and achieve success in the future. In such aspects as upper decision-making, project construction, technical innovation and management, this paper analyzes the situations, features and existing problems of current geothermal industrial development, and raises relevant suggestions, for the purpose of joint discussion and mutual reference.

Key words:
new era; geothermal; planning and construction; technical innovation; management

Currently, China's geothermal industry is developing rapidly, and the direct geothermal utilization (non-electric) has been No. 1 for many years consecutively in the world. In particular, in 2017, in the wake of the holding of the 19th National Congress of the Communist Party of China, the publishing of 'the Thirteenth Five-year Plan' for Geothermal Energy Development and Utilization, the construction of Beijing Urban Sub-center, and the establishment of Xiongan New Area, the geothermal development and utilization enter a golden period, which greatly inspires us and spurs us to persistently advance bravely.

Through hardships, brilliant achievements have been made in the geothermal industry, and we are so proud of them. In spite of great success, we should still stick to the original intention, spare no effort to advance bravely, and follow the industrial development trend in the new era. By virtue of this occasion, we want to share some experiences and feelings with you, for the purpose of joint discussion and mutual reference, and let us work together to make the geothermal industry big and strong, and build the Chinese Brand.

1. China's Geothermal Memory in 2017

For the Chinese geothermal workers, Year 2017 should be kept in mind. In 2017, the national guidelines, policies and plans,and implementation and construction of numerous major geothermal projects revealed an important message, namely, the geothermal development and utilization have been really valued by the State and the society. The most profound feelings are embodied in the following points:

1.1 Memory of the "19th National Congress of the Communist Party of China"

On October 18, 2017, at the "19th National Congress of the Communist Party of China", in the report, General Secretary Xi Jinping put forward accelerating the ecological civilization system reform and building the Beautiful

China”.“Carry forward the green development”, “advance the comprehensive resource saving and cyclic utilization”, “reduce the energy consumption”, “continuously implement the atmospheric pollution prevention and control”, “enhance the ecological system protection” and other key expressions show that the ecological civilization construction is promoted to a new height. China’s modernization is the modernization of harmonious co-existence between human and nature and takes the development road of “respect for nature, conformance to nature and protection of nature”. As a kind of renewable energy, the geothermal energy is characterized by clean, efficient, renewable, cyclic, large reserves, extensive distribution and local use. The reasonable development and utilization can save the resources and protect the environment, and will play a remarkable role in the ecological civilization construction. Close attention should be paid to the environmental protection in the national development, and the geothermal energy is needed in the environmental protection promotion.

1.2 Memory of “Upper Plan”

In January 2017, the National Development and Reform Commission, the National Energy Administration and the Ministry of Land and Resources jointly printed and distributed the “Thirteenth Five-year Plan” for Geothermal Energy Development and Utilization. This is the first national plan in the geothermal industry. According to the Plan, during the “Thirteenth Five-year” Plan, the newly-added heating (cooling) area of geothermal energy will be 1,100,000,000m^2, including 700,000,000m^2 newly-added heating (cooling) area of shallow geothermal energy, and 400,000,000m^2 newly-added heating area of hydrothermal geothermal energy. By 2020, the total heating (cooling) area of geothermal energy will be 1,600,000,000m^2, and the installed capacity of geothermal power generation will be about 530MW. Besides, the specific indexes will be decomposed to different provinces and municipalities. The geothermal industrial development has the national special plans, guidelines and goals, and national support and guarantee. This is a new breakthrough with milestone meanings in China’s geothermal work.

To deeply implement the spirit of the 19th National Congress of the Communist Party of China, in December 2017, 10 ministries and commissions, including the National Development and Reform Commission, the National Energy Administration, the Ministry of Finance, and the Ministry of Environmental Protection, jointly printed and distributed the Clean Heating Plan (2017-2021) in Winter in the Northern Region, which is aimed to improve the clean heating in the Northern Region and reduce the atmospheric pollutant discharge. The key areas of pollution prevention and control are Beijing-Tianjin-Hebei “2+26” key cities. Subject to the Plan, by 2019, the clean heating rate in the Northern Region will reach 50%, replacing 74,000,000t scattered fired coal (including low efficiency small boiler coal). By 2021, the clean heating rate in the

Northern Region will reach 70%, replacing 150,000,000t scattered fired coal (including low efficiency small boiler coal). The heating area of geothermal energy was 500,000,000m^2 at the end of 2016, and it will increase to 1,000,000,000m^2 by 2021.

These plans co-build a wonderful development blueprint for the geothermal industry.

1.3 Memory of "Major Projects"

In 2017, a batch of national major construction projects adopted the shallow geothermal energy and medium-deep hydrothermal geothermal energy for building heating and cooling, which undoubtedly recognizes the geothermal development and utilization technologies and embodies the geothermal advantages, namely, efficient and energy saving, in the large scale application. Take the large construction projects around us as an example:

Pursuant to the Development Program for New Energy and Renewable Energy during the "Thirteenth Five-year Plan" of Beijing, by 2020, the proportion of new energy and renewable energy utilization in the administrative office areas in the Urban Sub-center will be more than 40%, and the proportion of new energy and renewable energy utilization in the whole areas of Urban Sub-center will be more than 15%. On the one hand, the geothermal energy is the absolute main force in the realization of renewable energy index. On the other hand, by the innovated smart regulation technology of energy operation information, the intelligent coupling operation of new energy and renewable energy and conventional energy system is achieved, and the renewable energy demonstration area at the international advanced level is created, which innovates the geothermal utilization technology, and builds a good model for the global regional energy development. Thanks to the good opportunities of high-level planning, advanced thinking, and key area and project construction, the excellent experience and technologies are disseminated and the whole geothermal industrial development is promoted, providing a broader platform for the industrial development. To create the "nearly zero carbon emission area" demonstration project, Phase I Project of Core Office Area of Beijing Urban Sub-center adopts the shallow geothermal energy and medium-deep hydrothermal geothermal energy for building heating and cooling, dramatically reducing the pollutant discharge and regional energy consumption.

In the construction project of Beijing's New Airport, it has been determined that about 2,500,000m^2 airport supporting buildings will adopt the shallow geothermal energy for heating and cooling, effectively promoting the regional renewable energy utilization rate.

The geothermal energy has displayed its advantages. In the future, in the "green development" themed era, more projects will adopt this mature technology. At the same time, the regional energy smart management, internet+ new energy, heat network fusion and other innovative matters will be worth our research and attention.

2. Features of Geothermal Industrial Development in New Era

The geothermal development direction in future will be the development and utilization dominated by resolving the heating in the Northern Region. At present, the geothermal industry mainly has the following features:

2.1 The geothermal energy is "hot" unprecedentedly and "warms" the shallow geothermal energy industry nationwide.

Presently, supported by the upper plan and accepted by the general public, the geothermal industrial development may be considered No. 1 in the renewable energy heating. "Geothermal energy" concept is deeply rooted among the people and its features, such as clean, renewable and large reserves, are popular with the social public. "Geothermal energy" really becomes "hot", and it also drives the development of shallow geothermal energy industry. Refer to Fig. 1 for the heating area of shallow geothermal energy nationwide. According to the figures, the shallow geothermal energy industry is growing rapidly, and the industry is really "warmed" by "geothermal energy".

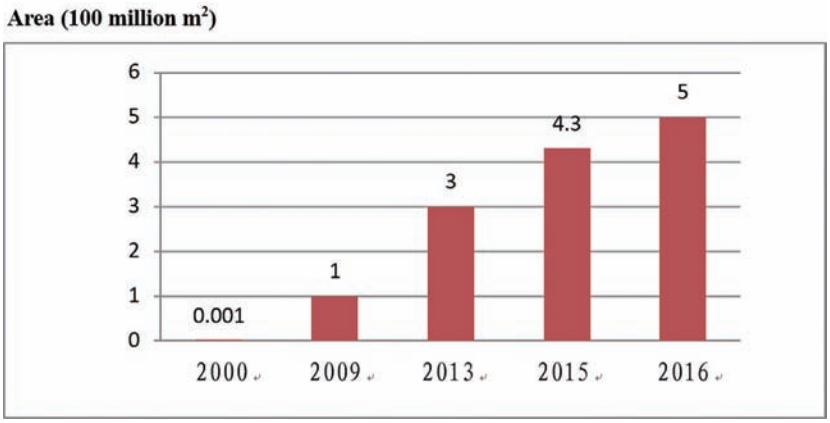

Figure 1 Application Area Statistics of Shallow Geothermal Energy In China

2.2 The shallow geothermal energy industry presents the high-speed development due to the clean heating and haze control in the Northern Region.

Currently, the haze problem is serious in winter in the Northern Region of China, especially Beijing-Tianjin-Hebei Region. The coal-fired heating in winter is an important cause for haze. In December 2016, the clean heating issue in the Northern Region was presented at the 14th meeting of the Central Leading Group for Financial and Economic Affairs. The local governments in Beijing, Tianjin and Hebei launch relevant policies and adopt the coal-to-electricity, coal-to-gas and other ways to realize the clean heating reform. As a kind of clean energy, the shallow geothermal energy heating will certainly play a more important and irreplaceable role in the current situation. In 2010, the heating area of shallow geothermal energy of Beijing was 19,570,000m^2. In 2015, it was 40,000,000m^2. However, by 2020, it is estimated that the heating area of shallow geothermal energy of Beijing will be more than 50,000,000m^2.

2.3 The encouragement policies are launched intensively and the governments at all levels positively carry out the promotion,

which is comprehensively favorable for the development of shallow geothermal energy industry.

In the past two years, the encouragement policies have been launched intensively. In September 2017, 4 ministries and commissions, including the Ministry of Housing and Urban-Rural Development and the National Development and Reform Commission of the People's Republic of China, jointly issued the Guiding Opinions on Boosting the Urban Clean Heating in Northern Heating Region. According to the Guiding Opinions, advancing the clean heating in wither in the Northern Region was an important strategic deployment proposed by the Central Government. The renewable energy heating projects, including the geothermal energy, should be robustly carried forward. In December 2017, 6 ministries and commissions, including the National Development and Reform Commission and the Ministry of Land and Resources, jointly issued the Circular on Promoting the Fire Coal Reduction and Replacement in the Northern Heating Region by Accelerating the Shallow Geothermal Energy Development and Utilization, which required accelerating the promotion of shallow geothermal energy development and utilization and robustly driving the shallow geothermal energy utilization in this Region.

The local governments also respond to the call in succession, and formulate the implementation schemes. With Beijing as an example, after the State Council published the Action Plan for Prevention and Control of Atmospheric Pollution, Beijing published the Action Plan for Clean Air from 2013 to 2017 of Beijing in 2013. In December 2013, 6 departments, including Beijing Municipal Commission of Development and Reform, printed and distributed the Implementation Opinions on Further Promoting the Geothermal Energy Development and Heat Pump System Utilization; in June 2016, Beijing Municipal Commission of Development and Reform printed and distributed the Circular on Further Specifying the Support Policies for Coal to Ground Source Heat Pump Project; in September 2016, Beijing published the Development Program for New Energy and Renewable Energy during the "Thirteenth Five-year Plan"; in February 2017, the General Office of Beijing Municipal People's Government printed and distributed the 2017 Work Program for Clean Heating in Winter of Rural Villages in Beijing. These encouragement policies show that the shallow geothermal energy system construction will be robustly developed, and the support funds will be enhanced. The subsidy amount changes from 30% to 50%, the preferential electricity price is provided, and unprecedentedly strong support is provided. Likewise, this greatly drives the market development. The users have demands and subsidies, the equipment suppliers possess thesales volume and markets, and the construction units obtain the projects and earnings. Besides, the governmental regulation achieves great effects, and the environmental protection is promoted.

2.4 The hydrothermal geothermal heating shows its capabilities due to the key area and project construction.

With the key area and project construction as an opportunity, by the comprehensive application of multi-energy complementary model and smart energy technology, creating a batch of new energy and renewable energy demonstration areas at the international advanced level is the energy construction and development model robustly advocated by the government currently. The geothermal industrial development becomes an indispensable part in this model.

According to information at the promotion meeting of coordinated development work of Beijing, Tianjin and Hebei held on January 2, 2018, the planning framework of Xiongan New Area in Hebei is basically mature. In the future, Xiongan New Area will build the green smart new city. Only when 100% replacement of fossil energy by new energy and renewable energy is realized can the green smart city be constructed really. In the removal of fossil energy, the renewable energy should be developed with all the strength and solar energy, geothermal energy, wind energy and other resources should be made full use of at first. In Xiongan Area, the geothermal fields cover an area of 320km^2, and the geothermal water reserves are 82,178,000,000m^3, which may replace 6,630,000,000t standard coal. However, the current development and utilization amount only accounts for 6% of total recoverable reserves. The Ministry of Land and Resources has planned “Create the Global Geothermal Utilization Model”. Therefore, in the near future, the geothermal industry will fulfill its potential in Xiongan New Area.

2.5 The hydrothermal geothermal power generation and hot dry rock utilization will face a new rise in the new starting point.

After the completion of Yangbajing Geothermal Power Station in Tibet in 1977, so far, the geothermal power generation has not bloomed everywhere. Presently, due to the plan printing and distribution, technical progress and other factors, the geothermal power generation which has stagnated for years is “hot” again. Some new power stations have been constructed in Yunnan and other places, which will certainly drive the rapid development of China’s geothermal power generation industry, and will play an important role in the distributed power generation, new energy development along the Belt and Road and other aspects. Compared with the power grid impact defect of photoelectricity and wind power fluctuation, the geothermal power generation is more continuously stable. China has given explicit on-grid electricity price policies for photovoltaic and wind power generation. However, there are no relevant support policies for the geothermal power generation, and the industrial development still expects the policy support.

The hot dry rock is the efficient low carbon clean energy acknowledged in the international community. In September 2017, Chinese scientists had drilled 236°C high temperature hot dry rock body at 3,705m depth of Gonghe

Basin in Qinghai. This is the hot dry rock body of the highest temperature drilled for the first time in China, and it is a significant breakthrough in the hot dry rock exploration. According to the preliminary evaluation by China Geological Survey, the resources of hot dry rock in the land areas of China are 856 trillion tons of standard coal. Subject to the international standard, per 2% as the recoverable resources, the recoverable resources of hot dry rock in the land areas nationwide are 17 trillion tons of standard coal. Compared with the traditional hydrothermal geothermal energy, the hot dry rock temperature is higher and the energy resources are richer. Based on the preliminary investigation results of China Geological Survey, China's southeastern coastal areas, Songliao Plain, North China Plain and Qinghai-Tibet Plateau Regions are potential regions for exploration and development of hot dry rock in the future. The international community attaches great importance to the exploration and development of hot dry rock. For example, the USA has carried out the experimental power generation of hot dry rock in some regions. In China, the development of hot dry rock, especially the commercial development, is still in the exploration stage presently, but its prospect is broad.

3. New Achievement Generated in Industrial Development in New Era

At present, we are forging ahead on the socialist road with Chinese characteristics in the new era. We should carry on the past and open a way for future, and have a new look, thought and practice in the new era. "Two Centenary Goals" have pointed out the advancing direction and goal for us. We should follow the development of times and innovate the plan, thought, technology and model. There are many excellent results in the geothermal industry and they are mainly embodied in the following aspects:

3.1 System integration

The multi-energy complementary "shallow geothermal energy+" according to the local conditions is the construction model robustly developedin the ground source heat pump industry in recent years. The regional natural resource conditions and features are fully considered, the resource development and utilization are reasonably deployed, and the intensive and economical utilization of resources is really realized, which is summarized by us as "four combinations", namely, "deep and shallow combination, sky and earth combination, regulation and storage combination, and exterior and interior combination". These four kinds of combination modes are not isolated, but they may be mutually combined. In a word, based on the resource conditions in different regions, various kinds of resources should be made use of to the greatest extent, and the resource utilization efficiency should be improved.

3.2 Technical innovation

To meet the rapid development requirements in the geothermal industry, tremendous new technologies arise, and the technical

improvement also propels the industrial progress, which is worth our study and promotion.

(1) Cascade utilization of hydrothermal geothermal resources

Generally speaking, for higher than 150°C hightemperature geothermal resources, the exploitable fluid belongs to the steam type in most cases, the distribution areas are limited, and they are mainly used for power generation. The easily exploited geothermal resources in most regions of China are lower than 150°C medium and low temperature geothermal resources, and the exploitable fluid belongs to the hydrothermal type. After the extraction of heat, the geothermal water circulated in the closed pipeline is often recharged back to the underground, so as to guarantee the cyclic utilization of geothermal resources. However, the temperature of some high-quality geothermal water resources is relatively high. After the extraction of heat for the first time, relatively high water temperature is still kept, and it is 40-50°C or even higher and much heat still exists. If such geothermal tail water is directly recharged back to the underground, it is a waste of energy resource. Therefore, for the geothermal tail water of relatively good quality, the best practice is the re-extraction of heat or extraction of heat for many times through the heat pump system. After the water temperature is lowered to 20-30°C, the recharging is done. This practice is called the cascade utilization of geothermal water. One the one hand, the utilization rate of geothermal resources is improved, the unit water energy supply is increased, and the system efficiency is promoted. On the other hand, the geothermal water purposes are more extensive, and multiple temperature requirements may be met simultaneously. Hence, the cascade utilization of high-quality geothermal water should be robustly promoted.

(2) Heat pump technology + hotdry geothermal resources

The hotdry geothermal resourcesare characterized by relatively high underground thermal layer temperature, without exploitable fluid. To exploit such geothermal resources, we adopt a new method: deliver the water aboveground to the underground thermal layer for full heat transfer; extract the hot water to the ground, and extract the heat in the hot water by the heat pump; re-deliver the tail water after the heat extraction to the underground thermal layer for heat transfer, and the cyclic operation is carried out. The advantages are as follows: the regional geothermal resource conditions are made full use of; in the regions with scarce water resources, as long as the formation temperature is met and there aresufficient heat reserves, the geothermal energy may be exploited; besides, recharging or underground water resource restriction does not exist. At present, this new method is being tried in many regions ofChina. Some projects have adopted this method and they have achieved good effects, for example, the project in Xi'an.

(3) New underground pipe heat exchanger

The underground heat exchanger of traditional underground pipe ground source

heat pump system adopts the single U or double U shaped HDPE pipe. Generally, the burial depth of underground heat exchanger is dozens of meters to 150m in most cases according to different projects. Since the heat transfer capacity of single heat transfer hole is limited, for the ground source heat pump project, it is required to construct dozens of or hundreds of heat transfer holes of underground pipe. Even, it is required to construct thousands of or over ten thousands of heat transfer holes. After the calculation per 4-5m spacing of heat transfer holes, the floor area is large. In particular, in the cities with dense buildings, the available land area is extremely restricted. In this case, we have organized the research on a new underground pipe heat exchanger-concentric double-pipe heat exchanger, and carry out the test installation. The heat transfer medium water enters from the double-pipe interlayer,the spiral screw thread is set in the interlayer pipe pass, and the full heat transfer between water and rock and soil outside the pipe is guaranteed. The water after the heat transfer is extracted from the inner pipe at the double-pipe bottom, and it enters the heat pump unit for heat transfer. The water after the heat transfer is re-delivered back to the double-pipe heat exchanger, and the cyclic operation is carried out. According to the test, under the same burial depth conditions of underground pipe, the heat transfer capacity of single heat transfer hole is obviously improved, and the construction quantity of heat transfer hole of underground pipe is effectively decreased. In the future, the researchers will continuously research relevant technologies, such as buried pipe spacing control, interlayer screw thread setting, pipe selection and thermal insulation, and work hard to consummate the research results and rapidly promote and apply them.

Besides, there are some new trials, for instance, the utilization form of geothermal energy in the northern cold regions of China. The shallow formation rock and soil temperature is relatively low, and the heat cannot meet the building heating requirements. We organize the trial for breaking 200m limitations of shallow geothermal energy, and seek more heat sources from the underground rock and soil at 400-500m or even deeper. Some large surface water source heat pump projects are promoted, and river water, lake water and sea water are used by us. The utilization of urban reclaimed water thermal energy, promotion of urban wastewater utilization and other cases show that the researchers are speeding up the technical innovation day and night, innovating the thoughts, and making unprecedentedly bold trials, so as to follow the development of times. They propel the industrial development and have led the world advanced technology.

3.3 New Model of Regional Energy Supply

For the time being, the geothermal project has gradually developed from the single small-scale project to the centralized large-scale construction. There are many excellent large-scale application cases, such as Beijing Urban Sub-center and Beijing's New Airport Project, and they are huge projects

in the world. Beijing Geological and Mineral Exploration and Development Bureau has independently researched and developed SGIS smart geothermal energy system integration technology, and formed a complete set of smart coupling system covering the shallow geothermal energy development and utilization design, construction, operation and management. Besides, it has initiated the smart control system of aboveground and underground stereoscopic monitoring and joint debugging, and bearing capacity monitoring system of shallow geothermal energy resources, and has applied such integrated technology to Beijing Urban Sub-center and other large projects.

In the future, in Beijing-Tianjin-Hebei coordinated development area, Xiongan New Area, Beijing International Horticultural Exposition, Beijing Winter Olympics Area, key development area in different places and other major project construction areas, the geothermal energy will also stand out conspicuously or even draw much attention from people. Therefore, we should think more about how to make the geothermal energy better adapt to the regional energy supply model, how to integrate with other energy supply forms in such aspects as resource, technology, construction, operation, capital and management, how to integrate with other regional facilities and functions, how to embody the friendly man-machine environment and how to embody the intelligentization. This is the really high-level project embodiment.

4. Several Issues To Which Close Attention Should Be Paid

So far, the technical feasibility and practical operationof China's geothermal industrial development are mature. However, relevant details still need improvement, and we should pay close attention to them.

4.1 Recharging of geothermal water

The heat storage medium of hydrothermal geothermal resources is water. Based on different regional resource conditions, there is rich underground hot water in some places, but there is little water or even no water in some places. In the region with rich groundwater, the exploitable hot water reserves are limited to a certain extent. Different from the shallow groundwater and surface water, the deep groundwater has a slow natural supplement rate. The rate of water exploitation of ordinary geothermal project is far greater than its natural supplement rate. If much groundwater is exploited for a long time, without effective supplement, the exploitable geothermal resources will be fewer increasingly, and they will be exhausted gradually. Consequently, "renewable" turns into "non-renewable". In many regions of China, after the extraction of heat, the exploited geothermal water is not recharged, and much groundwater is discharged at will. As a result, the groundwater level decreases sharply. In the later stage, no water may be exploited even. Such problems exist in many projects in Shandong, Hebei and Henan. Therefore, close attention should be paid to them. Such extensive development

and utilization modes are not in line with the ecological environmental protection, and cannot realize the cyclic utilization of energy, so they should be eradicated. For the development and utilization of hydrothermal geothermal resources, the development philosophy of "exploitation subject to recharging" may be promoted. In other words, according to the recharging amount of geothermal water, the exploitation strength is decided, and 100% recharging and cyclic resources should be realized. In addition, the aboveground and underground monitoring system must be established for the government subsidized projects.

4.2 Management

The effective management advancing with the time is the precondition for boosting the industrial development. The imperfect management and deficient regulation will often constrain the industrial progress.

(1) Cross management

Currently, in some places of China, the mining right management of geothermal resources belongs to the function of land department, but the groundwater extraction permit is subject to the approval by the water department. The multi-departmental cross approval and management restrict the geothermal industrial development and they are primary causes for not recharging the geothermal water presently.

(2) Geothermal mining right approval

From the launch of the Circular of the Ministry of Land and Resources on Promoting the Package Exploration by Further Improving the Mining Right Management in 2011, great adjustments have been made in the mining right approval procedures. It is not allowed to approve the mining right which is not filed in advance. As a result, many market demands are restricted to different degrees. After the publishing of the Circular of the Ministry of Land and Resources on Doing Relevant Work after Cancellation of Setting Scheme Approval or Filing Approval of Mining Right in 2015, the mining right approval policy is re-adjusted, the separate mining right setting scheme is cancelled, and it is brought into the "mineral resource planning" for uniform approval. As the new "mineral resource planning" is not officially published, some effects will be left on the release of market demands. From the compilation of mining right setting scheme to the revision of mineral resource planning, and from the policy launch to the implementation of provincial and municipal policies, as well as the approval procedure adjustment, it often takes a relatively long time, invisibly restricting the implementation of many market projects.

(3) Management blank area

In recent years, the medium-deephotdry geothermal resources rise. However, in most regions of China, there is no relevant department for the management of this kind of new geothermal resources in which "heat is extracted but water is not extracted". How to reasonably and lawfully apply them, and how to divide the labor and track them for the management service department are issues pursued in the industry all the time. The management blank also affects their healthy development.

(4) Construction supervision and management

At present, the systematic construction has relevant technical codes and standards. However, in the actual engineering project, the supervision and management of underground construction of underground pipe are not effectively carried out, and the quality control has deficiencies. After the project completion, the underground pipe belongs to the concealed works and cannot be inspected and checked. Most projects can only rely on the conscientious projects of the construction unit. The jerry-built projects and incidents impairing the industrial reputation happen occasionally, which is unfavorable for the promotion and application of geothermal energy.

5. Future Development Prospect

Currently, China's geothermal industry is in the rapid development period, many support policies are launched, the geothermal industry is robustly promoted by the society, and the environmental protection awareness of the public is enhanced. Therefore, for a period of time in future, the industrial development will still maintain the high growth. Thanks to the comprehensive implementation of new plans and policies, it is estimated that the blowout development will occur from now on. In the future, the geothermal market is broad and "cake" is huge. As for how to grasp this good opportunity, the industrial workers should set about the things in the most fundamental aspects: firstly, do a good job of self-discipline, do everything in a thoroughgoing and serious manner, and work meticulously and create fine projects based on tough standards and requirements; have the long-term development sight, and carry out the honest operation and mutual support to make common progress; secondly, take the initiative, incorporate things of diverse nature, and ensure that each gives full play to his strong point; the workers bring their strong points in the professional field into play, carry out the mutual learning and advance together, and jointly welcome the golden new era.

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发展终端能源消费“全清洁” 雄安打造全球地热利用样板

IN THE DEVELOPMENT OF "ALL CLEAN" FINAL ENERGY CONSUMPTION XIONGAN CREATES THE GLOBAL GEOTHERMAL UTILIZATION MODEL

作者：特邀记者 / 李晶

以“新时代的中国：雄安 探索人类发展的未来之城”为主题的外交部河北雄安新区全球推介活动目前在北京举行，在推介活动上，河北省委副书记、省长许勤介绍了“雄安新区”这座未来之城。他提到，这是一座绿色生态的未来之城，将规划构建科学合理的空间布局、塑造新时代城市特色风貌，坚持绿色低碳发展。尤其提到，终端能源消费将采用清洁能源，电力来自河北省张北地区的风电、光电，同时科学的利用雄安当地的地热资源，真正建成绿色低碳宜居新城区。

不易的终端能源“全清洁”

不过从国内或国外来看，“终端能源消费全部为清洁能源”并不是一个容易实现的目标。

以人口规模与雄安新区接近的一些国家和地区为例，340 万人口的南美洲国家乌拉圭，2015 年全年 94% 的电力供应来自风能、水能、太阳能和生物质能等清洁能源；282 万人口的德国北部城市石勒苏益格－荷尔斯泰因，2011 年实现 100% 的清洁供应；588 万人口的我国青海省，依靠风能、太阳能、水能等可再生资源，实现了在 2017 年 6 月连续 7 天 168 小时，以及 2018 年 6 月连续 9 天 216 小时的全清洁能源供电。

然而，上述国家和地区都有一个共同的特点，就是清洁能源富集。乌拉圭仅风能就可提供 38% 的电力供给，石勒苏益格－荷尔斯泰因则是世界风能利用起步最早的地区之一，我国的青海省也是清洁能源大省。

从资源禀赋来看，并不是清洁能源富集地的雄安新区，该如何实现“终端能源消费全部为清洁能源”的目标呢?

打造全球地热利用样板

实际上，雄安新区也有自己的优势能源，如分布在雄县和安新的地热就是其主要的优势能源，初步勘探可采地热资源量达到 142 亿吉焦。

数年前，原河北省雄县就曾走在全国地热能源开发利用的前列。2017 年 4 月，国家级新区雄安

新区横空出世。为建设“蓝绿交织、清新明亮、水城共融、多组团集约紧凑发展的生态城市”，雄安新区提出以地热能为主，多能互补的供暖方案，并把“打造全球地热利用样板”作为目标之一。当年8月，经地质调查发现，雄安新区地质条件优越，区内浅层低温能开发利用条件适宜，可满足约1亿平方米建筑面积供暖需要。

据《河北雄安新区规划纲要》指出，雄安新区将科学利用区内地热资源，综合利用城市余热资源，合理利用新区周边热源。2018年5月，作为雄安新区第一个建设项目，雄安市民服务中心正式开园。该园区通过1510根、深120米地埋管，从土壤中提取浅层地温能。且仅浅层地热能，就可为整个园区提供70%-75%的采暖供能来源。同时，遵循“成熟技术+系统创新”的设计理念，配合生活污水冬夏环境温差作为辅助供能来源，利用峰谷电价调节蓄能，回收空调循环水热量变废为宝等方式，实现了安全、绿色、清洁、高效的供能目标。相比单独使用电能的供能方案，在初始投资相当情况下，运行费用大幅降低，冬季用电量降低三分之二，夏季用电量降低三分之一，节约能源折合标煤超过600吨。

中科院院士陈维江为首的专家团队针对“雄安新区智慧能源战略研究”重大咨询项目给出了一份建议：雄安能源系统作为一张“白纸”，没有传统路径依赖和既有利益藩篱。而未来的雄安新区，应该建设“驱动发展型”的城市能源系统，在保障高水平能源供给的基础上，充分发挥能源驱动城市全面发展的功能作用。

非常规热源也该推广扶持

随着国家首个地热产业规划——《地热能开发利用“十三五”规划》的出台，各省陆续编制出台了本省的地热利用“十三五”规划。与此同时，中国地热能利用的提升空间也受到了广泛的关切。

可喜的是，地热能的直接利用已经发生了结构性的变化。2014年底，中国地热利用中，地源热泵、地热供暖、温泉洗浴分别占到了58%、19%和18%。地热供暖比例首次超过温泉洗浴。

中国工程院院士，国家地热能中心指导委员会主任曹耀峰，在不久前举行的“2018中能化地热能开发论坛”上就表示，地热将在传统供暖区域燃煤替代与新增供暖区域清洁取暖方面发挥重要作用。

他认为，作为可再生能源供暖的主要形式——地热，未来发展空间较大。但是，中国地热能的开发利用需要加快顶层设计。其一，要针对全国地热资源调查评价，查明水热型地热区（田）及浅层地热能的质量和数量，为合理开发提供依据；其二，需加强技术攻关，奖优罚劣，攻关、突破砂岩回灌、单井换热、干热岩开发等瓶颈技术。同时，城市污水余热、采油污水余热、工业余热、煤矿井下余热等“非常规热源”，也应该作为地热能开发利用的重要组成部分，加以推广扶持。

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In the development of "all clean"final energy consumption Xiongan creates the global geothermal utilization model

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"China in the New Era: Xiongan-A Vision for the Future of Cities" themed MFA Presenting Xiongan New Area, Hebei is held in Beijing. At the meeting, Xu Qin, Deputy Secretary of Provincial Party Committee and Provincial Governor of Hebei, introduces "Xiongan New Area", a future city. He says that Xiongan New Area is a green and ecological future city, and will plan and construct the scientific and reasonable spatial layout, build the urban feature and style in the new era and stick to the green and low-carbon development. In particular, he mentions that the final energy consumption will adopt the clean energy, the electric power will be the wind power and photoelectricity from Zhangbei, Hebei Province, and Xiongan New Area will make the most of local geothermal resources in a scientific manner, so as to really build a green, low-carbon and livable new city.

Not Easy "All Clean"Final Energy

At home and abroad, "all the final energy consumption is clean energy" is not easily achieved.

With some countries and regions whose population scale is approximate to Xiongan New Area as an example, 94% electric power supply in 2015 of Uruguay, a South American country with a population of 3.4 million, came from wind energy, hydroenergy, solar energy, biomass energy and other clean energy; Schleswig-Holstein, a northern city of Germany with a population of 2.82 million, realized 100% clean supply in 2011; reliant on wind energy, solar energy, hydroenergy and other renewable resources, Qinghai Province of China with a population of 5.88 million realized all clean energy power supply for seven days (168h) consecutively in June 2017 and for nine days (216h) in June 2018.

However, the abovementioned countries

and regions have a common feature, namely, clean energy enrichment. The wind energy alone in Uruguay may provide 38% electric power supply, Schleswig-Holstein is one of the regions which start the wind energy utilization at the earliest in the world, and Qinghai Province of China is a province with rich clean energy.

In terms of resource endowment, how can Xiongan New Area, which does not belong to the clean energy enrichment place, realize the goal of "all the final energy consumption is clean energy"?

Create the Global Geothermal Utilization Model

As a matter of fact, Xiongan New Area has its own advantageous energy. For instance, the geothermal energy distributed in Xiongxian County and Anxin County is its advantageous energy primarily, and the preliminarily explored recoverable geothermal resources are 14,200,000,000GJ.

Several years ago, the former Xiongxian County of Hebei Province was in the front rank of geothermal energy development and utilization nationwide. In April 2017, Xiongan New Area, a state-level new area, was established. To construct the "blue and green interlaced, fresh and bright, water city co-integrated, and multi-cluster intensive and compact development ecological city", Xiongan New Area presents the "geothermal energy dominant and multi-energy complementary" heating scheme, and regards "create the global geothermal utilization model" as one of the goals. In August 2017, according to the geological survey findings, Xiongan New Area has excellent geological conditions, the development and utilization conditions of shallow geothermal energy in the Area are appropriate, and the heating requirements of about 100,000,000m2 buildings may be met.

Subject to the Outline of the Program for Xiongan New Area in Hebei, Xiongan New Area will scientifically make use of the geothermal resources in the Area, comprehensively utilize the urban waste heat resources, and reasonably exploit the heat sources around the New Area. In May 2018, as the first construction project in Xiongan New Area, Xiongan Citizen Service Center was officially open. In the Park, through 1,510 pieces of 120m deep underground pipes, the shallow geothermal energy is extracted from the soil. The shallow geothermal energy alone may provide 70%-75%heating energy supply sources for the whole Park. Meanwhile, based on the "mature technology + system innovation" design philosophy, with the environmental temperature difference in winter and summer of domestic wastewater as the auxiliary energy supply source, by virtue of the peak-valley electricity price regulation and energy storage, and recycling of air conditioning circulating water heat, the safe, green, clean and efficient energy supply goal is achieved. Compared with the energy supply scheme of use of electric

energy alone, under the premise that the initial investment is equivalent, the operating expenses are greatly reduced, the electricity consumption in winter decreases by two thirds, and the electricity consumption in summer decreases by one third, and the saved energy exceeds 600t standard coal after conversion.

The expert team headed by Chen Weijiang, Academician of Chinese Academy of Sciences, raises the suggestions on the "Smart Energy Strategic Research of Xiongan New Area", a major consulting project: as a piece of "blank paper", Xiongan's energy system does not have the traditional path dependence and existing interest barrier. Xiongan New Area in the future should construct the "development-driven" urban energy system, and bring the functional role of energy driving the all-around urban development into full play on the basis of guaranteeing the high-level energy supply.

The unconventional heat source should be promoted and supported as well.

With the launch of the "Thirteenth Five-year Plan" for Geothermal Energy Development and Utilization, the first national plan in the geothermal industry, different provinces compile and launch their "Thirteenth Five-year Plan" for geothermal utilization in succession. At the same time, the promotion space of China's geothermal energy utilization draws extensive attention.

Delightfully, the structural changes have taken place in the direct utilization of geothermal energy. At the end of 2014, in China's geothermal utilization, the ground source heat pump, geothermal heating and hot spring bathing accounted for 58%, 19% and 18% respectively. The proportion of geothermal heating surpasses the hot spring bathing for the first time.

At the "2018 Zhongneng Chemical Geothermal Energy Development Forum" recently, Cao Yaofeng, Academician of Chinese Academy of Engineering, and Director of Steering Committee of the Geothermal Energy Center of China, expressed that the geothermal energy would play an important role in the fire coal replacement in the traditional heating area and in the clean heating in the newly-added heating area.

He thinks that the geothermal energy, as a major form of renewable energy heating, has a great development space in the future. However, the development and utilization of China's geothermal energy should accelerate the top-level design. Firstly, based on the national geothermal resource survey and evaluation, ascertain the quality and quantity of hydrothermal geothermal area (field) and shallow geothermal energy, so as to provide a basis for reasonable development; secondly, enhance the technological breakthrough, reward the good and punish the bad, tackle key problems and achieve breakthroughs in the sandstone

recharging, single well heat transfer, hot dry rock development and other bottleneck technologies. In the meantime, the urban wastewater waste heat, oil production wastewater waste heat, industrial waste heat, underground coal mine waste heat and other "unconventional heat sources" should be regarded an important part of geothermal energy development and utilization and they should be promoted and supported.

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Single-well circulation systems for geothermal energy transfer

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Abstract:As an alternative method of implementing environmentally friendly geothermal systems for space heating and/or cooling, groundwater has been increasingly used in open-loop ground-coupled heat-pump systems. Of various groundwater heat-pump configurations,the single-well circulation systems tend to provide the best geothermal exchange efficiency where the hydrogeological and thermogeological conditions allow for their installation. In comparison with the closed-loop systems consisting of geothermal boreholes, the single-well circulation systems may substantially reduce the number of boreholes needed, especially for large-scale geothermal applications. In small-scale applications of the single-well circulation system, the groundwater circulation supplies enough thermal energy underground that the temperature of the circulating water remains stable through the years. For district scale applications, however, further studies are needed to fully understand their sustainability and the impacts on groundwater quality from operating ground-coupled heat-pump systems.

Key words:
Ground-coupled heat-pump systems;
Single-well circulation system;
Hydrogeological and thermogeological conditions;
Geothermal exchange efficiency

Introduction

Over the last ten years, ground-coupled heat-pump systems(GCHPs) have been increasingly used as an efficient and renewable alternative for space heating and/or cooling (Lund and Boyd 2015). Such GCHPs have the advantage of using the ambient temperatures at shallow depths, reducing both fuel

consumption and greenhouse gas emission. The technology taps low-temperature (usually less than 30℃) heat energy that is stored in heat reservoirs, which are composed of soil, rock and groundwater at depths less than approximately 200 m. Unlike high-temperature geothermal energy, which is usually obtainable in areas of high magmatic activity or at depths of over 1 km, the low-temperature heat energy is derived primarily from solar energy. Typical GCHPs consist of three components: ground heat exchanger, heat-pump unit and air delivery system. In the winter, the heat pump removes heat from the heat exchanger and pumps it into the indoor air delivery system, moving heat from the ground to the building's interior. In the summer, the process is reversed, and the heat pump moves heat from the indoor air into the heat exchanger, effectively moving the heat from indoors to the ground. The heat removed from the indoor air during the summer can also be used to heat water, providing a free source of hot water. Of the three components, the ground heat exchanger plays the most important role in long-term performance of the system. The heat exchangers are composed of pipes or heat collectors installed in heat reservoirs near buildings. The underground temperature balance must be maintained through proper design of the heat exchangers to ensure energy efficiency of the entire system.

While closed-loop borehole GCHPs remain the industry standard because they can be literally done anywhere, open-loop GCHPs using groundwater as a heat exchanger have also gained momentum in an effort to increase the geothermal exchange efficiency and decrease the number of boreholes drilled. A new discipline, thermogeology, has recently been developed for the study of ground source heat and proper design of the ground heat exchangers (Bank 2009). Because of the close analogy between groundwater flow and thermal convection, many hydrogeological concepts are readily adapted to thermogeology. Depending on how the pumped groundwater is discharged, there exist four configurations of groundwater heat-pump systems (Wu et al. 2014):

- Two-well circulation system: Pumped groundwater is returned to the subsurface through injection wells some distance away from the pumping wells.
- Single-well extraction system: Pumped groundwater is not returned to the subsurface rather is discharged onto surface.
- Standing column well system: Pumped groundwater is returned to the subsurface through the same well where the intake and injection sections are not hydraulically separated.
- Single-well circulation system: Pumped groundwater is returned to the subsurface through the same well where the intake and injection sections are hydraulically separated.

Of the groundwater heat-pump systems, the single-well circulation system provides the greatest geothermal supply capacity with a low space requirement. For every meter

of borehole length, a standing column well may produce geothermal supply 10 times more than a closed-loop borehole, whereas a single-well circulation can produce geothermal supply 10 times more than a standing column well (Rybach 2015). At least two versions of single-well circulation system are being used in the world, one is the ‘‘Groundwater Circulation Well’’ system patented by Geo-En of Germany and the other is the ‘‘Aqui-Flo Geothermal Energy Transfer’’ system patented in the USA by Ever Source Science & Technology Development Co., Ltd. of China. This paper presents the general design of the singlewell circulation system and one case study demonstrating its application. Both the data and case study demonstrate that the single-well circulation systems provide the best geothermal exchange efficiency where the hydrogeological and thermogeological conditions allow for their installation.

Design description

A schematic of single-well circulation system is shown in Fig. 1. For a single-well circulation system, the geothermal well is constructed with two screen sections in the target aquifer. The deeper screen section is to facilitate pumping of the groundwater, and the shallower screen section is to facilitate returning the water back into the aquifer. The two screens are hydraulically isolated by engineering measures such as grout or clapboards. During operating the single well circulation system, a submersible pump is used to pump the groundwater with ambient temperature at a designed flow rate. The pumped water passes through a wellhead heat exchanger where the return water from the heat pump receives heat from the groundwater. After the heat pump supplies water at a temperature of approximately 50–55℃ to the fan coils for space heating, the temperature of the water is lowered to approximately 5–10℃ . The water is then injected to the upper return space of the well in a return pipe. The separation seal prevents the return water from entering the lower part of the well but help the return water to flow into the aquifer, which allows the water to return to its original temperature near the well over time. This water then flows back into the intake space of the well, thus sustaining the heat balance in the groundwater.

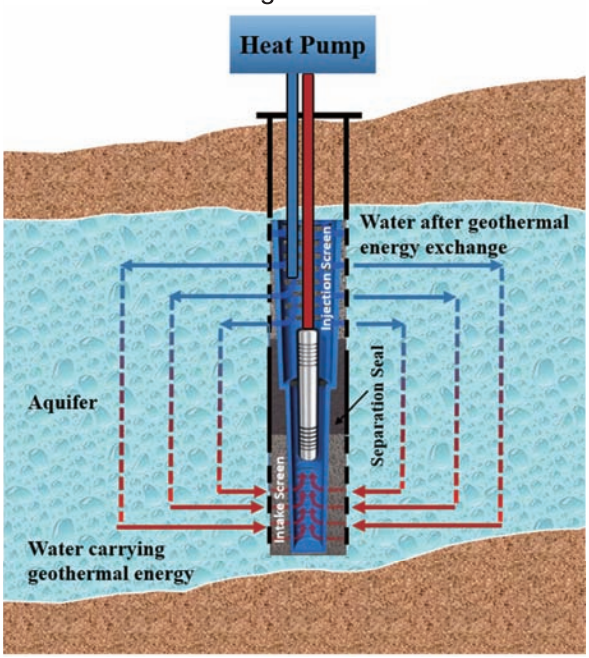

Fig. 1 Schematic of single–well circulation system for geothermal energy transfer (modified from www.geo–en.de)

A productive aquifer with a thickness ranging from 20 to circulation system. Although the Peclet number can be used to determine whether an aquifer is suitable for such a geothermal system, a general rule of thumb is that the aquifer should have a hydraulic conductivity of 10-3 m/sec or higher and flow velocity of 0.5 m/day or greater (Xu and Rybach 2003). In addition, the aquifer should have relatively shallow water table of no more than 30 m deep. Detailed discussions on hydrogeological and geothermal properties of suitable aquifers are provided in Wu et al. (2014).

An exploratory borehole is typically drilled to investigate the hydrogeological conditions prior to geothermal well design and construction. Techniques commonly used for data collection includes soil/rock description, sieve analysis of soil samples, temperature profiling, geophysical borehole logging and aquifer testing. Additional data on geochemistry, regional geology and hydrogeology, and thermal conductivity may be also needed for evaluation of environmental impacts, especially for large-scale geothermal applications.

Site-specific hydrogeological conditions determine the well specifications. Table 1 summarizes the general data from the systems constructed in the USA. Another setting for potential single-well circulation application is flooded underground mines that can be a significant source and geothermal energy. Many flooded mines can readily provide sustainable pump rates for geothermal extraction because of their great efficiency in heat exchange. The thermally spent water can then be injected into mine workings at higher elevations (Younger 2014).

Like any other GCHPs, the subsurface temperatures in small-scale single-well circulation systems are more easily maintained. With the increase in the larger-scale applications of GCHPs in which each system may consist of several thousands of boreholes or hundreds of pumping wells, maintaining thermal balance in the subsurface between periods of heating and cooling may become a challenge. Further hydrogeological and thermogeological studies are needed to understand the long-terms impacts of the large-scale GCHPs on groundwater systems. Another significant problem in maintaining thermal balance is that geothermal systems are not always built into areas where total annual heating equals total annual cooling. Systems which are cooling-dominated will increase the ground temperature, while those that are heating-dominated will decrease the ground temperature (Pertzborn et al. 2011). This annual difference will accumulate over time decreasing system efficiency requiring additional sources of heating or chilling that may negate the positive impacts of these green energy initiatives (Dunn 2013). Nevertheless, in comparison with other configurations of GCHPs, the single-well circulation system has distinct advantages including the following:

- Because of its efficiency in heat

exchange, the singlewell circulation system reduces the number of wells to be drilled significantly, approximately one tenth of the number of wells for a closed-loop system to produce the same amount of heat energy.

• Long-term monitoring in Germany and China has shown negligible effects on groundwater level and groundwater quality from operating single-well circulation systems (Ni et al. 2006).

• Because there is no actual water consumption and the water is circulated only in the vicinity of the heat exchange wells for purpose of assimilating and dissipating heat, geohazards, such as land subsidence that are often associated with groundwater abstraction can be controlled and avoided with proper placement and design of the heat exchanger wells.

Case study: application of single-well circulation system to St. Joseph's Villa, Nebraska

St. Joseph's Villa of David City, Nebraska, has been home for the elderly since 1939. A renovation that took place in 2012 included a new heating, ventilation and air-conditioning (HVAC) system. After a review of the existing system, the patented Aqui-Flo Geothermal Energy Transfer system was selected with use of the variable refrigerant flow (VRF) heat pumps. The design cooling capacity was 80 tons.

An exploratory borehole, completed in October 2012, provided the information required to complete the design of the geothermal well. Additionally, the test borehole provided sufficient detail of the aquifer to affirm that the well would be capable of providing the heat transfer necessary for the building.

The final design work of the HVAC system was completed in December 2012. The new HVAC system consisted of eight 10-ton compressors connected with refrigerant piping to remote evaporators, energy recovery ventilators that provide fresh air to the north half of the building, and a dedicated outdoor air unit that provides fresh air to the south half of the building. The project construction was completed in October 2014, and the Villa was fully transferred to the new system. Table 2 presents the design parameters of the geothermal well.

The new Aqui-Flo Geothermal Energy

Table 1 Design parameters of geothermal wells for single–well circulation systems source http://www.hyy.com.cn

Parameters	Well depth (m)	Well diameter (m)	Well casing/ screen diameter (m)	Water flow rate (m3/h)	Aquifer water temperature (℃)	Intake screen length (m)	Injection screen length (m)	Intake/ injection separation (m)	Screen type
Values	88 - 128	0.61	0.3	46 - 69	13-16	6 - 21	9-27	6 - 30	Stainless steel wire

Transfer System has been running efficiently and effectively with the VRF heat-pump system. Based on personal communication with Mr. Shengheng Xu of Ever Source Science & Technology Development Co., Ltd. of China, the Aqui-Flow Geothermal Energy Transfer system has brought the following benefits to St. Joseph's Villa.

Cost effectiveness

The new HVAC system utilizes the patented Aqui-Flo Geothermal Energy Transfer system as the heating and cooling source for the groundwater heat pumps. There is a direct connection to the ground through the energy transfer system which increases the overall efficiency of the system and provides consistent water temperatures throughout the entire year. Instead of using the traditional closed-loop ground heat exchanger with many boreholes, a single well is used to provide the entire heat rejection for both heating and cooling. The water from the single well goes through a heat exchanger in an open-loop configuration which heats/cools the building water loop which is connected to the heat pumps. The water source heat pumps use the variable refrigerant flow technology. The groundwater source heat pumps are located in a central mechanical room, and less costly refrigerant piping is installed from the heat pumps to distribution boxes and then to individual evaporators located in each room. The water source heat pumps boast a seasonal energy efficiency ratio of 23 and a coefficient of performance of 6.3 when connected to the ambient-temperature groundwater.

The single-well technology was cost-effective since it requires only one well and is capable of producing water from the aquifer and re-injecting the water back to the aquifer. The single well required very limited real estate, and it was installed in a fraction of time that would have been required for a traditional closed-loop system. In fact, without the single-well technology, it would have been very difficult to use geothermal for the heating and cooling system. The site was very tight, and there was not enough land for the standard geothermal boreholes. An estimated 96 boreholes were required for a traditional borehole system. The area for the boreholes would need to be located across the street on land owned by the Villa. Installing the standard boreholes would mean additional costs for piping and crossing the street and would also restrict the future development of the land where the boreholes were located. Utilizing the single-well technology saved an estimated $200,000 in costs and also left the property across the street open for future development.

Energy efficiency

One of the project goals was to have an efficient heating and cooling system. Table 3 shows the results of the new HVAC system and the energy saved after one-year operation.

Table 2 Design parameters of geothermal well for St. Joseph's Villa HVAC system

Parameters	Well depth (m)	Well diameter (m)	Well casing/ screen diameter (m)	Water flow rate (m3/h)	Aquifer water temperature (℃)	Intake screen length (m)	Injection screen length (m)	Intake/ injection separation (m)	Screen type
Values	128	0.61	0.3	69	13	12	27	6	Stainless steel wire

Table 3 Energy consumption of St. Joseph's Villa HVAC system

	Time frame	Electricity	Natural gas	Total energy	Energy density
	Year	Kwh/year	Therms/year	KBtu	KBtu/sq.ft.
Old system	2010 - 2013	520,545	20,479	3,824,520	104.15
New system	2015	786,993	1434	2,829,407	77.5

The existing ventilation system removed air from the resident toilet rooms. Fresh air was brought in through vents along the exterior wall and through a central makeup air unit. There was no energy recovery from the air being exhausted from the building. The new design utilized energy recovery ventilators and a dedicated outdoor air system to provide tempered air to each room. The fresh air was ducted through the corridors and was discharged to each room. The installation of the new HVAC system has resulted in an overall energy savings of 26% when compared to the previous boiler, chiller and cooling tower system.

Indoor air quality

The existing two-pipe heating and cooling presented many problems for the operation of the existing system. During the spring and fall seasons, the system needed to be changed over from heating to cooling or vice versa. The building manager needed to guess the weather patterns and determine the best time to switch the system. In the spring, the start-up of the chiller was delayed until daytime temperatures were in the 21℃. This meant that during warm spring days, there was no air conditioning, making it very uncomfortable for the residents and staff. After the chiller was started for the season, there was no longer any heating available.

Likewise, in the fall, the boiler and heating water system start-up was delayed until the nighttime temperatures were in the low 10 ℃. Heating was available for the colder days and nights, but air conditioning for the warm fall days was not available. The new HVAC system has individual VRF heating and cooling units in each space. The residents

as well as the staff can adjust the space temperature to maintain an exact set-point at all times during the year.

Operation and maintenance

When open-loop systems are used for water source heat pumps, there is a concern that the water from the well could foul heat exchangers causing a real maintenance problem. Knowing the chemistry of the water coming from the well is important so that it can be properly managed. The biggest concern is scaling since ground water is typically on the hard side, which means it contains a lot of dissolved solids. The challenge then is to keep the dissolved solids in solution so they do not plate out on the heat exchangers. There are two key factors that contribute to precipitation of dissolved solids on heat exchangers; the presence of oxygen or atmosphere and abrupt changes in temperature. The first issue is handled by making sure the well system is pressurized so that no air comes in contact with the well water. The second issue is managed by using a building heat exchanger where the initial temperature difference between the well loop and the building loop does not exceed ten degrees. The building heat exchanger is maintainable so that it can be cleaned during scheduled maintenance

With the single-well technology, maintenance of the HVAC system has been simplified since there is no longer the need to operate and maintain a cooling tower. There is no need for expensive water treatment for the cooling water nor the seasonal cleaning. Also, not using a cooling tower eliminates the possibility of legionella forming in the system. With the VRF system, there is no water circulation through the building. This has eliminated the necessary maintenance of pumps, piping, valves and controls. The VRF system capable of heating or cooling at any time and has lessened the effort of the maintenance staff by no longer needing to switch the system from heating to cooling and back to heating during the spring and fall.

Environmental impact

The single-well system uses significantly less natural gas. The consumption has been reduced from 20,479 Therms to 1434 Therms (Table 3). This represents a reduction of 95 metric tons of CO2 greenhouse gas being emitted at the local level. No natural gas is used for space heating and is only used for cooking and domestic hot water.

Conclusions

A single-well circulation type of GCHP system that combines two wells coaxially in a single borehole improves thermal efficiency of the energy transfer and provides improved environmental sustainability due to the recycling of water back to the source aquifer. The groundwater is taken at the lower screen section of the geothermal well and is fed through the inner pipe of the coaxial system to the heat pumps. After the

heat energy is extracted, the groundwater is again fed through the outer pipe into the upper screen section of the geothermal well. St. Joseph's Villa's renovation has proven the adaptability of the Aqui-Flo Geothermal Energy Transfer system. The cost-effective nature and versatility of the open-loop Aqui-Flo system provided an alternative method of implementing environmentally friendly geothermal HVAC systems. In smallscale applications of the single-well circulation system, the groundwater circulation supplies enough thermal energy underground that the temperature of the circulating water remains stable through the years. For district-scale applications, however, further studies are needed to fully understand their sustainability and the impacts on groundwater quality from operating GCHPs.

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人工流场法对静水环境条件下地源热泵系统的能效增强研究

THE RESEARCH OF ENERGY EFFICIENCY ENHANCEMENT TECHNIQUE OF SOIL SOURCE HEAT PUMP SYSTEM THROUGH GROUNDWATER ARTIFICIAL FLOW FIELD IN STATIC WATER ENVIRONMENT

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摘要：天津市滨海地区地下水位高，地下水流动性差，近似静水环境，地层天然的能量传输能力差，在一个供能期内地埋管向土层中散出的冷量 / 热量难以在短时间消散，造成冷量 / 热量在地埋管附近处持续堆积，使地源热泵系统能效降低。地下水人工流场法可通过地下水流动将地埋管周围堆积的冷量或热量较为均匀地转移到整个地埋管区域土壤中，使地埋管间的浅层地热能被充分利用，增大换热温差，提高地埋管的换热效率，从而提高地源热泵系统的能效。

关键词：人工流场；土壤源热泵；地埋管；地温场；系统能效

天津市滨海地区的地下水位高，地下水流动性较差，地下水环境近似静水环境，地层天然的能量传输能力有限，在一个供能期内地埋管系统向地层中散出的冷量/热量难以在短时间消散，造成冷量/热量在地埋管附近处持续堆积，使地源热泵系统能效降低，难以满足建筑取暖/制冷的需求[1~3]。地下水人工流场可改变静水环境下地源热泵系统能效低的困境，提高浅层地热能利用效率，进一步提高地源热泵技术的适用性[4~7]。本文对浅层地热能人工流场动态增强技术进行了分析研究。

1 研究区概况

1.1 区域概况

试验研究对象为中新天津生态城城市管理服务中心，建筑面积5174.88m^2，采用地源热泵供冷 / 供热，热泵机组制热量550kW，制冷量530kW；地埋管数量105根，深度120m，采用双U型地埋管。该工程建设时未设置监测孔。

1.2 水文地质条件

根据区域地质勘探成果，示范区100m以浅水文地质条件为（图1）：

第一弱透水层底板埋深4.3m，岩性主要为人工填土和亚黏土，渗透系数一般2.67×10^{-4}m/d。

第一含水层底板埋深在19.8m左右，岩性主要为粉砂，渗透系数一般3.46m/d。为地下咸水含水层。

第二弱透水层底板埋深在21.5m，岩性主要为亚黏土和亚砂土，渗透系数一般2.60×10^{-4}m/d。

第二含水层底板埋深27.1m左右，岩性主要为粉砂，渗透系数一般3.53m/d。为地下咸水含水层。

第三弱透水层底板埋深29.2m，岩性主要为亚黏土，渗透系数一般2.70×10^{-5}m/d。

第三含水层底板埋深49.7m左右，岩性主要为粉砂，夹亚黏土薄层，渗透系数一般3.67m/d。为地下咸水含水层。

第四弱透水层底板埋深60.5m，岩性主要为亚黏土，夹亚砂土和粉砂薄层，渗透系数一般6.70×10^{-4}m/d。

第四含水层底板埋深66.7m左右，岩性主要为粉砂，渗透系数一般3.76m/d。为地下咸水含水层。

第五弱透水层底板埋深79.2m，岩性主要为亚黏土，渗透系数一般4.30×10^{-4}m/d。

第五含水层底板埋深97.5m左右，岩性主要为粉砂，夹亚黏土薄层，渗透系数一般3.67m/d。为地下淡水含水层。

第六弱透水层底板埋深100m，岩性主要为亚黏土，渗透系数一般3.10×10^{-5}m/d。

可利用含水层累计厚度30.0~35.0m。

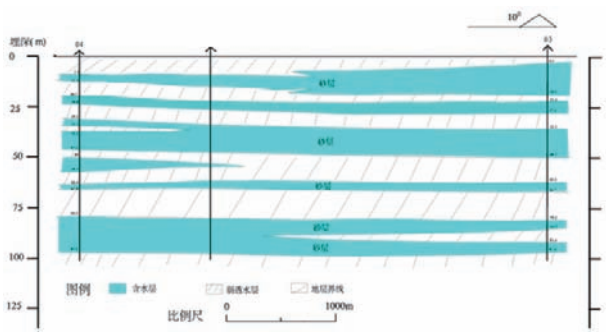


图 1 水文地质剖面简图

揭露深度段地下水主要接受大气降水和地表水渗漏补给，靠蒸发排泄，各含水层无明显的地下水流场。

本区地处滨海平原，多次海侵使浅部形成广布的咸水，根据区域资料分析，咸水底板埋深60～70m。第一含水层至第四含水层均为地下咸水含水层，水化学类型多为Cl—Na型、Cl—Na · Mg型和Cl · SO4—Na · Mg型，溶解性总

固体可大于5g/L。

第五含水层为地下淡水含水层，水化学类型由HCO3—Na型或HCO3 · Cl—Na型，溶解性总固体一般小于2g/L。

经调查，场地半径3km范围内，无同层地下水开采。

2 地源热泵系统布设

2.1 场地概况

研究对象为已建建筑，场地可供布置抽灌井的位置十分狭窄。本次共布设2口采、灌水井（井间距74m）及1口分层沉降监测标，采灌水井及分层沉降监测井单井井深均为100m。其中两眼采灌水井在地面通过管路相连，并加装调控装置，以实现水井采灌调换。采灌比为1：1（图2）。

图 2 示范工程布置图

2.2 采灌井布设

采灌水井井深100m，井径250mm，最大抽水量10m³/h。考虑变温带深度和地层固结程度，第二弱透水层（底板埋深21.5m）以上为套管，井管外采用黏土球止水；21.5m至100m为滤水管，滤水管外回填粗砂滤料（图3）。

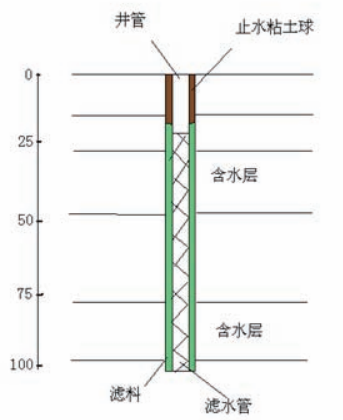


图 3 井结构简图

3 地源热泵系统运行

通过监测地埋管地源热泵系统的各项关键参数，为分析地源热泵系统运行效果提供有效依据（表1）。

表 1 地源热泵系统监测数据

编号	监测目的	监测对象	仪表类型	监测精度	监测频率/（次 · min−1）
1	计算地埋管总体换热量	地埋管总管流量	流量计	一级	1
2		地埋管总管进水温度	温度计	0.1℃	
3		地埋管总管回水温度			
4	计算系统向建筑供冷量	用户侧总管流量	流量计	一级	
5		用户侧总管进水温度	温度计	0.1℃	
6		用户侧总管回水温度			

3.1 地源热泵系统运行方案

地源热泵系统运行于2016—2017年供暖季中进行，具体见表2：

表 2 地源热泵系统运行方案

序号	日期	开始时间	结束时间	持续时间	平均流量 / ($m^3 \cdot h^{-1}$)	研究目的
1	1-10	14:05	23:05	9:00	7.7	不同持续时间、不同流量对换热及沉降影响
2	1-10	23:47	次日 4:48	5:01	8.2	
3	1-11	4:54	8:38	3:44	5.2	
4	1-14	14:02	17:02	3:00	8.1	
5	1-16	11:33	13:33	2:00	7.04	
6	2-11	16:00	20:00	4:00	8.5	
7	3-16	15:00	19:00	4:00	8.13	
8	3-18	17:00	21:00	4:00	8.43	
9	3-22	13:00	21:00	8:00	8.43	
10	3-29	10:00	22:00	12:00	8.41	不同持续时间、不同流量对沉降影响
11	4-1	10:00	14:00	4:00	10.95	
12	4-3	13:00	17:00	4:00	11.08	
13	4.6	9:30	21:30	12:00	10.89	
14	4-9	13:00	次日 1:00	12:00	10.79	

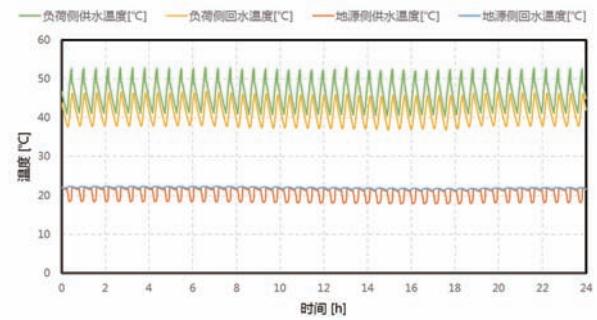


图 4 供暖季原始运行某典型日数据

3.2 实际运行效果

3.2.1无人工流场状态下运行

工程供暖季原始运行状态下，某典型日的系统运行情况，见图4。该工程原始运行呈现典型的间歇运行模式。经统计，平均约半小时运行一次。该工程供暖季的地源侧供水温度较高，运行状态下可达18~19℃，说明该工程供冷季负荷量较高，整个供冷季向地下土壤排放的总热量超过整个供暖季向地下排放的总冷量，地下土壤年平均温度逐年上升。

由于系统为间歇运行，且系统停止供热时地源侧及负荷侧循环泵持续运行，为了有效分析地源热泵系统的供能效果，取地源侧供回水温差大于1℃作为判断系统是否供热的阈值，以此分析每一段运行周期内的系统运行效果。

3.2.2人工流场状态下运行

人工流场可以强化地埋管的对流换热，在供暖季时缓解地埋管周围的冷量堆积，提高地埋管与土壤间的换热温差，进而提高地埋管的整体换热效果。以1月10日的运行数据分析为例，介绍人工流场对地源热泵供热效果影响的分析方法。

在8时左右开始上班时，由于供暖负荷增加，/地埋管周围的冷量堆积逐渐增加，地源侧回水温度逐渐下降，在该种情况下，为了保证足够的取热量，地源热泵机组将降低地源侧出水温度。在14:05分开始抽水进行人工地下水流场运行，可以

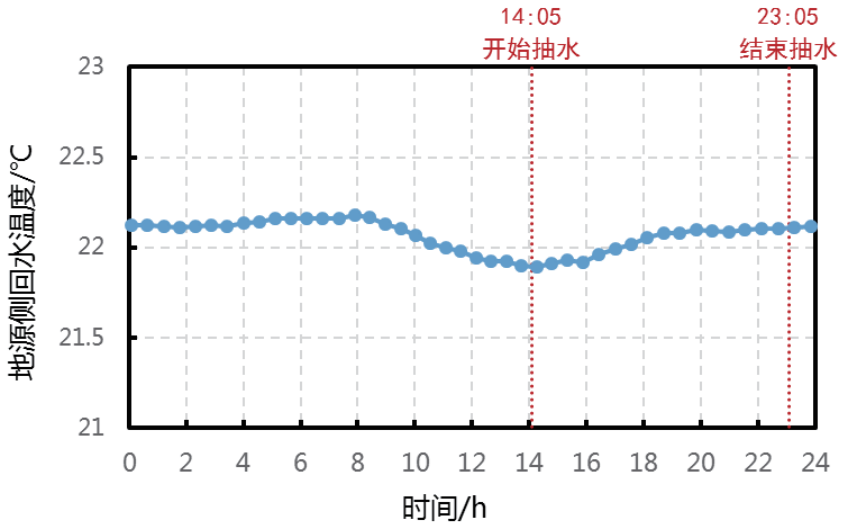
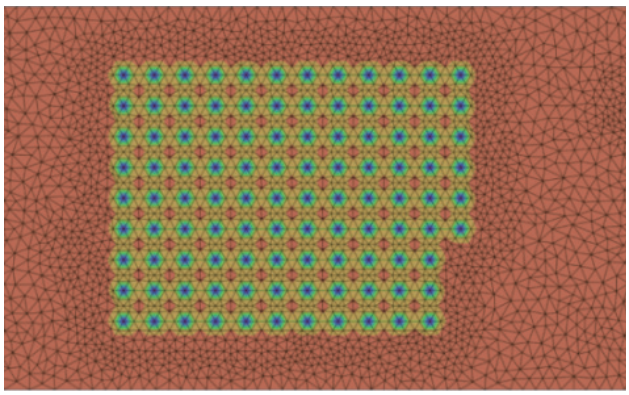
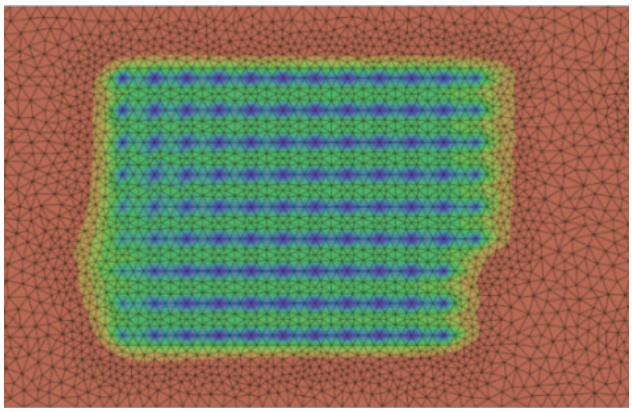


图5 1月10日地源侧回水温度曲线



（a）无人工流场



（a）有人工流场

图6 有/无人工流场模拟结束时砂层水平面温度图

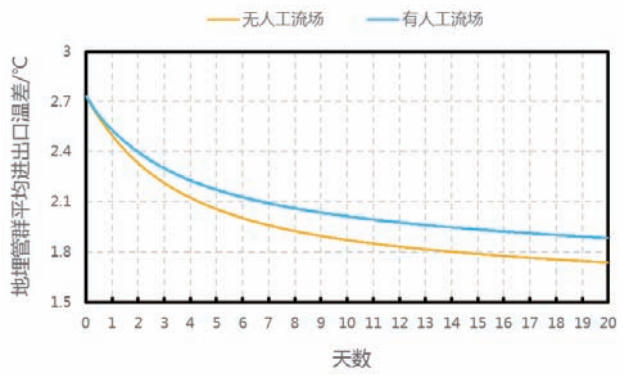
看出地源侧回水温度开始逐渐回升，说明地埋管周围的冷量堆积在一定程度上得到缓解（图5）。

4 数值模拟分析

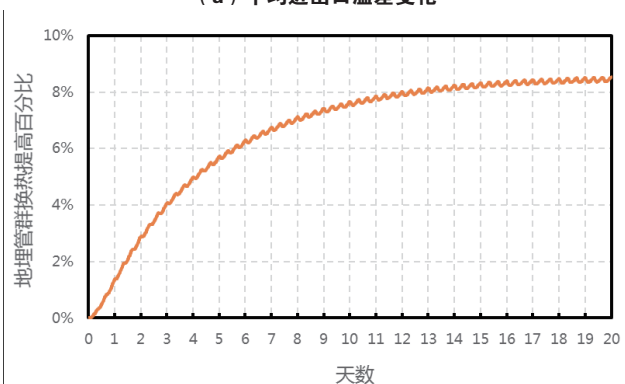
根据地源热泵系统运行情况，建立了基于示范工程地质条件下的地埋管群换热模型，分别进行有/无人工流场下地埋管的换热效果模拟。模拟计算采用FEFLOW软件，包括天然状态下及人工流场影响下的地埋管运行模拟各一组。

图6为有/无人工流场影响下，模拟运行结束时第一层砂层中间深度水平面温度分布图。总体上，在没有人工流场作用时，由于土壤的传热能力较差，地埋管放出的冷量堆积在地埋管周围，短时间内难以散出；而加入人工流场作用后，由于渗流的存在，地埋管周围的冷量堆积得以传递至地埋管之间的土壤中。

图7（a）为有/无人工流场影响下，105根地埋管平均进出口温差的变化。总体上，随着热堆积越来越严重，有、无人工流场影响下



（a）平均进出口温差变化



（b）热量提高率

图 7 有 / 无人工流场地埋管群平均进出口温差变化及人工流场下地埋管换热量提高百分比

地埋管的换热量都呈现下降趋势；但对于有人工流场的情况，由于一部分热堆积被人工流场所缓解，地埋管的换热效果得到强化。在运行初期，随着时间增加，人工流场的强化效果也显著增加，说明在冷量堆积越严重的情况下人工流场的强化效果越明显。而运行后期，人工流场的强化效果开始趋于平稳（图7（b））。

运行结束时人工流场强化下每一根地埋管的换热量提高比例，见图8。靠近左侧水井和右侧水井的地埋管换热强化最为明显。经计算，在运行结束时，105根地埋管的平均进出口温差提高了8.53%，其中强化效果最好的单根地埋管（最靠近左侧水井的地埋管）平均进出口温差提高了11.50%。

5 结论

（1）在供暖季运行时，人工地下水流场可以在一定程度上缓解地埋管换热器周围的冷量堆积，提高地埋管换热器的回水温度，并提

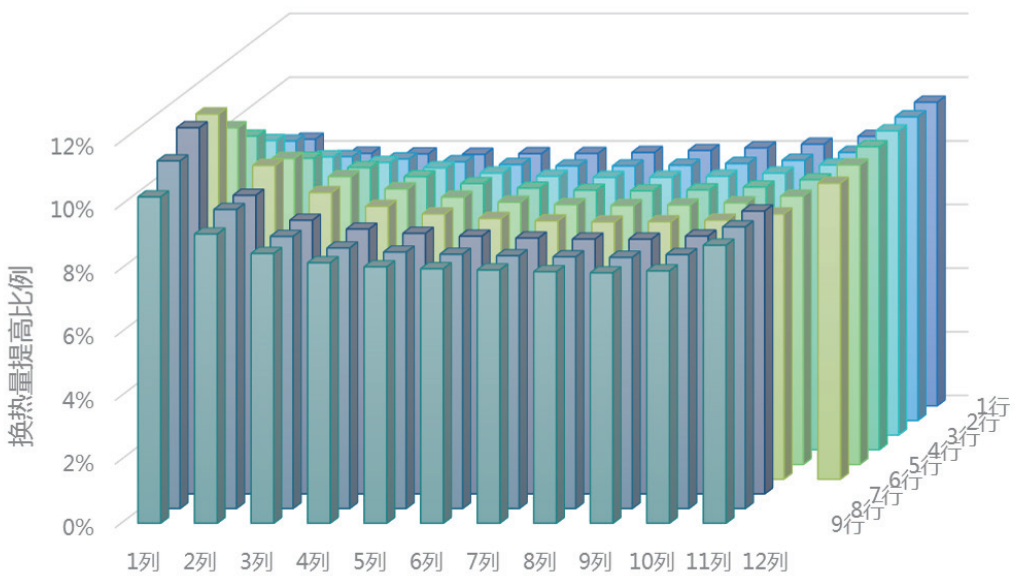


图 8 各根地埋管换热量提高比例

高地源热泵系统的能效水平。

（2）实际运行数据与模拟数据相比，人工流场的强化效果有一定程度的降低，主要是由于该场地地埋管采用原土回填，钻孔内较为密实，渗透性较差，人工流场无法直接作用于地埋管；此外，由于场地实际条件限制，无法进行抽灌井井位的优化设计。若可对该两项因素进行优化设计，可以进一步提高人工流场的强化效果。

（3）地下水人工流场不同于地下水源热泵技术，其以较低的抽水量（小于10m^3/h），与土壤源热泵技术相结合，起到了变浅层地热能静储量为动储量，提高地源热泵系统能效的作用，值得在条件适合的区域大力推广。

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地热能增长强劲 太阳能大幅下降 生物质能受青睐
清洁供暖热源呈现多元化

CLEAN HEATING SOURCES PRESENT DIVERSIFICATION

近日，记者从国家节能中心了解到，中国、丹麦正联合为陕西省铜川市提出区域能源及节能改造综合性规划方案，预计在6月底前完成对数据资料的分析和完善，改造完成后，将作为中丹清洁供热合作的典型案例进行推广。

近年来，国家高度重视清洁供暖，相关政策频出，并构建了从中央到地方的奖励体系，行业多位专家表示，我国清洁能源供暖仍任重道远。

市场巨大

“在供热供暖领域，清洁能源替代污染的散煤燃烧是解决大气污染的重大举措。我国积极推进可再生能源清洁供暖，启动了一批风电供暖示范工程，加大生物质能供热技术项目推广应用,启动了一批地热、风能供暖项目。”国家能源局新能源司副司长梁志鹏在“2018 中丹可再生能源清洁供热高峰论坛”上表示。

风电供暖早在7年前在吉林进行试点，已在新疆、山西、内蒙古等地已经开展了众多风电供暖项目，建立了政府、电网企业、风电企业和供暖企业四方交易机制，全国风电供热面积总计达500万平方米。

生物质能是为中小城市提供供热，解决散煤污染的重要措施。今年1 月，我国启动了全国“百个城镇”生物质热电联产县域清洁供热示范项目，136 个示范工程供暖面积将达到9000万平方米。

地热供暖包括地热水的直接供暖，还包括地源热泵、水源热泵和空气源热泵，雄安新区已成为地热供暖重要试点，北京周边的农村也在大量推广空气热泵。

按照10 部委联合下发的《北方地区冬季清洁供暖规划（2017—2021 年）》，我国清洁取暖率要在2019年达到50%，2021年达到70%，其中可再生能源供暖的目标是地热10亿平方米、生物质21亿平方米、太阳能5000万平方米。

国家发改委能源研究所相关报告显示，我国可再生能源供热“量大面广，市场巨大”，2017年我国可再生能源供热利用量为7484万吨标准煤，其中太阳能达到5734万吨标准煤，

地热达到1250万吨标准煤，生物质能500万吨标准煤。“

地热能成为供热市场增长的主力，太阳能自2014 年市场连续下滑，年均降幅超过15%，生物质能近两年来有所增长，但总体来讲，与目标差距较大。”国家发改委能源研究所相关人士告诉记者。

提高能效是关键

“供热是人民生活和众多生产活动的基本能源需求，在全球终端能源消费中供热占50%左右。”中国生物质能源产业联盟理事长陈小平告诉记者，全球越来越多的国家和地区将可再生能源供热纳入地区能源发展的总体战略和规划。

丹麦是世界上能源效率最高的国家之一，区域供热被视为丹麦绿色转型的基石，2013 年起，中丹两国政府就在清洁供热方面进行了密切合作，签署系列备忘录和合作纲要，推动清洁供暖发展。

“63%的丹麦家庭通过区域供热采暖并获得热水，约60%的电力来自热电联产。区域供热和热电联产系统的高效性和灵活性，是丹麦2050 年摆脱对化石燃料依赖的关键。”丹麦能源气候和建筑部长Lars Chr.lilleholt 认为，不同供热方案的综合分析显示，区域供热在许多地域是最好的解决办法，丹麦还因此通过了相关供热法案。

“区域供热和热电联产的广泛使用，是提高能源利用效率、减少能源消耗、降低碳排放的重要手段。”丹麦能源公用事业与气候变化部相关人士介绍，德国也约有14%的用户在区域供热系统中，并将继续扩建相关基础设施。

国家节能中心数据显示，我国北方地区城镇采暖面积达120亿平方米，其中城镇集中供热面积为71亿平方米，采暖用能超过1.8 亿吨标准煤（燃煤约占90%）。“北京冬季供暖大部分仍旧是集中供暖，按平米收费，节能的热情自然不会太高。”丹佛斯供热事业部中国亚太及印度区总裁于泳溟坦言，我国仍旧以集中供暖为主，但在努力推进供热计量改革。

如何提高能效？“需要针对性的解决办法，一些供暖技术已具备竞争力，但仍需要政策支持。好产品是基础，系统设计是关键，要能与常规能源系统互补运行，实现经济性的优化和准确的热力计量。”一位不愿具名的人士告诉记者。

生物质受期待

“从生物质能特性以及国外实践来看，清洁供热是生物质能的最优方向，无论是生物质热电联产，还是以生物质原料、成型燃料、生物质燃气等为燃料的锅炉供热，生物质能具有先天的优势。”陈小平分析。据测算，中国可再生能源潜力可达30亿吨标准煤以上，单是可作为能源利用的农作物秸秆及农产品加工剩余物、林业剩余物和能源作物、生活垃圾与有机废弃物等生物质资源年供热潜力将折合4.6亿吨标准煤。

近两年，生物质能利用率也呈上升趋势。今年一季度，全国生物质发电新增装机99万千瓦，累计装机达到1575万千瓦，同比增长24%；发电量178.6 亿千瓦时，同比增长19.1%。

“国家有关部门始终没有明确生物质发电、供热行业的排放标准，造成一些项目审批工作困难。”中国产业发展促进会生物质能产业分会副秘书长张大勇告诉记者，生物质仍旧面临排放标准不明、依赖发电补贴、供热盈利模式尚处探索阶段等问题。

针对近期引起光伏行业“巨震”的“531新政”，张大勇认为这是一个“警示”，生物质能源要突出环保民生属性,亟需加快由单纯发电转向生物质热电联产或生物质供热（冷）方向转变，再向综合能源服务方向升级，向供热为主、发电为辅的运营模式转型。“期待生物质能在清洁供热、大气污染防治、精准扶贫和解决民生问题上有更大作为，北欧四国的生物质能供热经验值得我们学习和研究。”他说。

选自《中国能源报》

地热作为非化石能源的后起之秀，正在表现出强大的发展潜力

我国地热供热发展路线

DEVELOPMENT ROUTE OF CHINA'S GEOTHERMAL HEATING

作者：罗佐县 宫昊 梁海军（中国工程院《中国地热产业规划与布局战略研究》项目组）

2017年气荒的出现为可再生能源供热提供了施展身手的空间。在此形势下，地热受重视程度正在进一步提升，北方地区清洁取暖规划对地热在北方地区清洁取暖中作用的发挥寄予厚望。地热供热在北方做成功了，南移也就有了底气和资本。预计未来地热供热事业的发展将沿着浅层深层并举，南北结合，通过发挥示范工程领衔引导功能实现由点到面推进的道路前行。

地调局的最新资源评价结果显示：全国地热资源年可开采量折合标煤26亿吨。其中中低温水热资源年可开采量折合标煤18.65亿吨，主要分布在华北、苏北、松辽、江汉等大中型盆地，每年可采资源量折合标煤18. 28亿吨。高温水热型资源主要分布在西藏自治区、云南、四川和台湾省。

全国336个地级以上城市浅层地热能资源每年可开采量折合标煤7亿吨，可用于建筑物供暖和制冷。336个地级以上城市80%以上的土地面积适宜利用浅层地热能，可实现建筑物夏季制冷面积326亿平方米，冬季供暖面积323亿平方米。全国适宜开发浅层地热能的地区主要分布在中东部，包括北京、天津、等13个省（市）。

此外，干热岩开发潜力巨大，我国干热岩资源总量初步评估折合标煤达856万亿吨。若按照国际通用规则，开发利用其总量的2%，可利用规模亦达17万亿吨标煤。

资源勘查取得进展的同时，我国地热开发利用力度也在逐年加大，地热资源利用量连续多年位居全球之首。数据显示，2014年我国地热资源直接利用量达到48435GW，是美国地热直接利用量的2倍多。在地热直接利用构成中，用于供热和制冷的地源热泵利用方式占58%，水热型地热供暖占19%，温泉洗浴占18%。2014年，我国水热型地热供暖比例首次超过温泉洗浴，反映出我国地热资源能源化利用步伐正在加快。

浅层地热利用方面，截至2014年底全国浅层地热能供暖制冷面积达3.92亿平方米。地源热泵机组总装机容量达11.78GWt，开发利用年增长率远高于世界上其他国家的增长速度。目前全国除港、澳、台地区外，31个省、自治区、直辖市均有开发浅层地热能的地源热泵系统工程项目在运营，应用浅层地热能资源进行供暖和制冷

的地源热泵项目在中国已经超过7000个，这些项目多集中在华北和东北地区，建筑物类型主要集中在办公楼、宾馆、医院、商场、学校和住宅等。近年来长江及珠江流域附近城市地源热泵特别是江水源热泵发展迅速。

从地热供热技术路径看，首先是地热供热应该走浅层地热供热与中深层供热齐头并进道路。具体思路是有中深层资源的地区，在确保回灌条件下应优先开发中深层资源，比如中国石化在河北雄县的地热资源开发就做的非常成功，目前已在城区实现地热供暖面积600多万平方米，实现地热供暖零排放，零污染，取热不取水。目前这种模式在雄县周边的农村地区也有一定的推广和尝试。中石化在雄县地热开发取得成功之后计划在“十三五”时期在全国再建20个无烟城。在中深层资源不具备的地区，可考虑大力推广浅层地热能开发利用。浅层地热能分布广泛，不仅涵盖土壤热源，还包括地表水、城市污水、江河湖泊水源一级工业余热等热源，具有大面积推广利用的资源基础。过去一致认为浅层地热开发利用在我国的适宜区主要在中东部，但是近年国内一些企业先后在西藏、黑龙江等极寒地区也取得了浅层地热能开发突破，这些突破和进展对今后极寒地区浅层地热能开发有重大的示范意义。

其次是地热供热在区域布局方面将表现出南北结合，由北向南推进特点。目前的发展态势是不仅北方地区冬季需要供暖，传统的夏热冬冷地区供暖呼声也日益高涨。进入本世纪以来，南方屡发雨雪冰冻天气使得南方地区加强冬季供暖的呼声日益高涨。目前在南方部分城市已经开始了地热集中供暖。比如南京一些小区的冬季供热就是依靠水源热泵方式，水源是长江水。地热资源分布广泛，特别是浅层地热资源可以大面积利用。随着地热在北方地区清洁取暖中的作用的发挥，地热的供热区域将不断扩大，由北向南。

再次是发展地热供热应重视示范工程的引领功能，这是技术路线。地热供热目前有蓬勃发展之势，但发展规模毕竟较小，尚处于起步阶段，因此应有意识的树立一些示范工程并将其发展模式予以推广，比如雄县模式。从经济角度看，地热开发利用目前面临的最大挑战是初投资高，投资回收期长，但运行起来则具有运行成本低的优势。因此，发展地热供热需要从政策、技术创新、管理方面入手，结合地热供热的特点，为其发展创造适宜的生存“土壤”。

地热作为非化石能源的后起之秀，正在表现出强大的发展潜力
新时代地热资源勘查开发问题研究

RESEARCH ON EXPLORATION AND DEVELOPMENT ISSUES OF GEOTHERMAL RESOURCES IN NEW ERA

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1　我国地热资源潜力与节能减排分析

地热能源主要来自地球深处，资源量巨大、分布广泛。每年自然释放的地热能相当于全球耗电量的5倍。蔺文静等（2012）和Wang et.（2013）估算了我国大陆3～10km干热岩资源量约为2.5×10^{25}J，相当于860万亿t标准煤，按2%的可开采资源量计算，相当于我国目前能源消耗总量的5200倍左右。王贵玲等（2017）对我国浅层地热能和中深层水热型地热资源潜力进行了潜力评价并提出：全国336个地级以上城市浅层地热能资源每年可开采量折合标准煤7亿t，可替代标准煤11.7亿t/a，节煤量4.1亿t/a；水热型地热资源量折合标准煤12500亿t，每年地热资源可采量折合标准煤18.65亿t，发电潜力为996万kW。目前已查明全国出露温泉2334处，备案地热开采井5818眼。

据统计和测算：1t煤炭燃烧平均会产生11kg烟尘、8.5kg二氧化硫、7.4kg氮氧化物。我国每年煤炭能源消耗量为36.1亿t，煤田火区自燃消耗资源量为3000万t，总计每年消耗煤炭资源量36.4亿t。产生的烟尘、SO_2、NOx污染物分别为4000.4万t、3094万t、2693.6万t。

地热资源开发利用可以减少温室气体排放，节能减排效果显著。据相关公式和经验测算：10000m^{2}公用建筑物采用地热能供暖，每季可减少CO_2排放350～400 t；减少SO_2排放２～４ t；减少氮氧化物排放0.9～1.2 t；减少粉尘排放1.0～1.5 t 。按照目前中国地热资源量计算（不包括干热岩）：每年可减少CO_2排放量高达24亿t,其中浅层地热能开发利用可减少CO_2排放６亿t，中深层水热型地热资源开发利用可减少CO_2排放18亿 t 。

开发利用深部地热资源，不但可以替代传统化石类能源、节能减排，更重要的是可以有序控制地下能量的释放（地震、火山喷发及地气无序溢出），起到减震防灾作用。

2　地热资源应用领域

目前，浅层地热能主要用于建筑物供暖制冷，中深层水热型地热资源主要用于城镇供暖、温泉度假、种植养殖等。我国水热型地热资源多数情况用于温泉度假、种植养殖和生活热水，用于建筑物供暖占32.7%，地热发电仅占0.5%。在地热发电和城镇供暖方面所占比例远远低于欧美地热发达国家。

地热清洁能源供暖制冷将替代传统的化石类（煤炭、石油、天然气）供暖方式，不但可以加速能源结构调整和优化、节能减排，还可以推进新型的能源产业发展。

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浅层地热能开发利用方面，美国、瑞典、瑞士、德国、加拿大、奥地利、法国和荷兰等欧美国家发展迅速，并且效果显著。在地热供暖方面，冰岛74%以上建筑物实现地热直接供暖，受惠人口占全国的85%，土耳其30%以上建筑物也全部采用地热供暖。

浅层地热供暖制冷系统，需要大量的热泵机组、金属和新型塑料管材及辅助设备安装。同时，地下能源交换系统需要水文地质勘查和大量的钻井（钻孔）工程。地热产业发展同时，势必会带动适合200m左右轻便钻机和中深层地热钻机及配套设备、钻具等制造产业的快速发展。

中深层水热型地热水质中富含各种矿物质，特别是河南省多数地区地热水中富含锶、硒、偏硅酸等。在地热资源梯级或综合开发利用中，常常用地热水种植养殖特色农产品和水产品。冬季地热尾水可大面积用于大棚室内种植养殖，形成新型的特色农业和观光农业产业，如富锶和富硒瓜果蔬菜、冬季大棚蔬菜花卉种植养殖和观赏。

地热水质富含锶、偏硅酸、氟、氡、铁等几十种对人体有益的矿物质，具有一定的疗养、治疗功能和保健作用。目前世界各地均在利用地热温泉作为品牌带动当地旅游、度假、养老、房地产和餐饮等产业。在我国各省发展不均衡，普遍存在着资源浪费（无序排放）和单一利用，缺少品牌和地热（温泉）文化。

地热发电方面，根据世界地热大会报告数据，全球地热资源利用方式中，地热发电利用占利用总量的17%。2012年全球地热发电装机容量为11446MW，中国仅为24MW，截至2015年底，我国地热发电总装机容量也仅为27.88 MW，居全球第18位，占全球地热发电装机容量的0.2%，可见与地热发达国家相比有较大差距。20世纪70年代初，我国先后在广东丰顺、山东招远、辽宁熊岳、江西温汤、湖南灰汤、广西象州、河北怀来等地建成中低温试验性地热站，但目前除广东丰顺地热站外，其余均停止运行。高温地热发电方面，西藏羊八井地热发电站是唯一亮点，在国家的大力扶

持下，该高温地热发电站20世纪70年代顺利建成投产并运营至今。

3 结语

地热是大自然馈赠给人类的宝贵资源和清洁能源，在生态文明建设和大力推进清洁能源开发利用新的形势下，开发利用地热清洁能源不仅可以优化我国的能源结构、实现节能减排、减少雾霾和污染，而且还可加速钻井和供暖制冷设备制造业、各类监测仪器和仪表业、特色生态农业、旅游度假休闲等产业的发展。新时代大力开发利用地热清洁能源意义重大，与此同时，怎样在保护中科学、合理、持续开发利用也是目前亟待解决的问题和新的课题。

地热资源开发利用新时代从雄安起航

NEW ERA OF GEOTHERMAL RESOURCE DEVELOPMENT AND UTILIZATION SETS SAIL FROM XIONGAN

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为实现更快的技术进步和更大范围的推广应用，建议将地热资源利用纳入大气污染防治的总体规划之中。采取必要政策措施与资金扶持，引导地方加大推广力度，出台优惠政策，鼓励各类企业积极参与，提升开发效率和水平，逐步形成和发展绿色地热能源产业。与化石能源相比，地热能具有强大的社会经济与环保优势，其利用过程中基本不排放污染物，也不会排放大量二氧化碳。与太阳能和风能相比，地热能是一种连续稳定的能源，一年365天、每天24小时稳定存在。而且地热利用效率高，可以做到“热电联产”，同时供应暖气和热水甚至冷能。地球的地热总能量虽然巨大，但其分布很不均匀，要想加以经济合理的有效利用，需要找到资源聚集地，进行清晰的地热资源成因模式研究、准确的地热资源储量评价研究，不断开辟新的资源储备。这是地热资源规模化可持续利用的基础。

冬季是华北地区雾霾频发的时期，清洁取暖是从源头上治理雾霾的关键一环。华北地区地热资源丰富，其中京津冀地区最为丰富。“大华北要看京津冀，京津冀要看雄安新区”，雄安新区的地热是如何形成的？资源量多大？能满足多大规模供暖需求？是不是可再生的？如何可持续？会不会污染环境？

21 世纪以来，我国集中开展了大型岩溶热储评价与开发关键技术研究。理论模型和现场实践结果均表明，华北地区广泛分布的碳酸盐岩储层中发育的大型岩溶热储，规模大，地热资源品质优，可以实施采灌平衡的大规模开发利用，属世界罕见，可以支撑地热供暖形成产业，替代燃煤，缓解该地区雾霾。

中科院的地热团队在华北地区开展了长期的地热研究。“六五”计划期间（1981 年—1985 年），开展了系统的地温测量和大地热流测试，收集整理了石油勘探的地热资料，圈划出相对高温区域，开展地温场的数学模拟，探讨了该地区的构造—热演化特点。20 世纪90 年代，开展了冀东油田地热资源研究。“十一五”期间（2006

年—2010 年），开展了华北地区深部煤矿山热害防治研究，针对煤层与碳酸盐岩热储组合结构，研究热量聚集与热害形成机理与分布特点。“十二五”期间（2011 年—2015 年），开展了渤海湾盆地二氧化碳地质封存中的地热问题研究、典型热储成因分析与开发利用技术研究、大型岩溶热储对规模化开采的响应研究。此外，还有“华北克拉通破坏的地热模型制约”等基础性研究工作。

基于长期的研究，发现雄安新区地下蕴藏着极其丰富的地热资源。仅就地下3000 米以浅的经济深度而论，就有三类地热资源和热储层可供利用。第一类是浅层地热能（位于地下200 米以浅），可与地源热泵技术相结合，达到节能目的。地源热泵供暖效率通常比普通空调高4倍，比空气源热泵高2倍。此类地热资源的利用，采用地埋管换热方式，不破坏环境，节电、节煤效果显著。雄安新区浅层地热能在地下空间合理调配的基础上比较适合利用。第二类是砂岩热储（位于地下200 米至3000 米深度范围内），可以采用抽水加回灌的方式利用，可用于供暖或供热，替代燃煤，减缓雾霾。不过，此类热储层有一定局限性，主要缺点是有一些地区回灌比较难，平均只有30%回灌率，即每开采100立方米热水，只有30立方米左右可以顺利回灌到地下。剩下的部分，若排放到地表水体，则会带来污染，达不到清洁能源的要求。因此，此类资源应该慎用，可以实行以灌定产的政策加以调控。第三类是碳酸盐岩热储（位于地下1000米至3000米深度范围内），其中的中、晚元古界岩溶（喀斯特）特别发育，形成大型岩溶热储，可用于供暖或供热。在雄安新区，广泛分布着元古界雾迷山组白云岩热储，总厚度可达数千米，千米深处的温度在60摄氏度以上。其最大优点是出水量大，尾水可以100%回灌到地下，实现循环利用。

雄安新区以上三种类型地热资源都很丰富，如何持续开发利用呢？需要依靠先进的地热开采关键技术及示范工程。

地热资源开发利用技术经历了两代演变。第一代技术的基本特征是直采、直供、直排，但由于环保水准很低，现已放弃不用。第二代技术是采灌结合、用热不用水，环保水准很高，已经得到各地政府的重视和推广应用。在我国，浅层地热能的利用技术比较成熟。只要抓好严格监管等工程质量控制措施，大部分地方可以使用。实践中，一般鼓励地埋管模式的土壤源热泵系统，限制需要抽水的地下水源热泵系统，以保护珍贵的地下水资源。对于中深层砂岩热储，在回灌条件好的地方，普遍采用第二代技术，回灌技术也在不断进步中。对于基岩中的岩溶热储，逐步形成了规模化、产业化的地热开发利用技术体系，并进行了应用实践。

雄县地热供暖示范工程基于政产学研用相结合的方式，首次实现了地热利用高效率和接近零排放高水准的清洁能源利用双重目标，迄今已经平稳运行了8年。2014年年初，国家能源局开始把雄县地热供暖的示范项目向北方地区推广。

在过去20年里，我国地热资源直接利用总量

一直处于世界第一的位置，目前还比美国高1倍以上。同时，一般供热系统的主体设备都是国产化的，因而技术基础较好。在尾水回灌技术上，通过持续探索，形成了可支持规模化开发利用的热储回灌技术系列。雄县地热田回灌始于2010年，地热尾水的回灌避免了地表排放带来的污染，也有效地减缓了热储压力的下降。

雄安新区地热开发如何可持续？采灌井的合理布局和最优井距是地热田优化开采极为关键的两方面内容，关系到企业的生产成本和热田的使用寿命。为此，研究团队建立了一套用于评价热田合理布局和最优井距的方法，雄县地热田在对井模式下，采灌井最优井距为400 米。

为实现更快的技术进步和更大范围的推广应用，建议将地热资源利用纳入大气污染防治的总体规划之中。采取必要政策措施与资金扶持，引导地方加大推广力度，出台优惠政策，鼓励各类企业积极参与，提升开发效率和水平，逐步形成和发展绿色地热能源产业。

同时，进一步加强地热资源勘查，查清更深层地热储层发育状况和地热资源开发利用条件。在雄县模式的基础上，雄安新区应该立足于高起点、高标准、高水平的地热资源开发利用；在容积率比较低的住宅区，可采用浅层地热能供暖，地源热泵是新型节能技术，在地下空间合理协调的前提下，应该充分加以利用；在集中办公区域宜采用中深层地热能供暖。

依托地热，多能互补。一方面，加强地热系统运行的长期动态监测和定量化热储模拟；另一方面，对于砂岩热储和岩溶热储开发利用条件稍差的地方，开展储层改造技术研发和试验。同时，鼓励探索以地热能为主体，多种清洁能源融合的“地热+”第三代技术的研发与应用示范。

探访湖北省最大可再生能源建筑应用项目

——巧用地热能 让家冬暖夏凉

VISIT TO THE LARGEST RENEWABLE ENERGY BUILDING APPLICATION PROJECT IN HUBEI PROVINCE

——MAKE HOME WARM IN WINTER AND COOL IN SUMMER BY GEOTHERMAL ENERGY

太阳能、地热能等可再生能源，因其高效、绿色、无污染的优点，正在我省建筑节能领域快速推广。省住建厅统计，2017年，全省新增可再生能源建筑应用面积1800多万平方米，今年计划再新增1600万平方米。

可再生能源用起来怎样？5月3日，湖北日报全媒记者来到全省最大可再生能源建筑应用项目——江汉油田地热供暖改造项目一探究竟。

12 座地热站上岗 可替代 3.77 万吨煤

江汉油田职工小区冬季供暖，总供暖面积达548.13万平方米。为此，江汉油田备有供暖锅炉房20座、锅炉44台，其中大部分是燃煤锅炉。2016-2017年供暖季，共消耗原煤8.22万吨、天然气406万方，排放污染物数量非常可观。去年7月，开始建设江汉油田矿区530万平方米供暖改造项目。如今，一期项目建设的12座地热站替代了14 座燃煤锅炉房。

5月3日，记者来到华美小区锅炉房旧址，这里的燃煤锅炉已被拆除，取而代之的是一套“地热+水源热泵系统”，各种复杂的管道填满了屋子，这个地热站已于去年投入供暖，目前处于检修阶段。这套系统从700米深的地下取水。出水温度有33℃，地下水的热量被板式换热器置换出来后，以12℃左右又回到地下，热量源源不断地传导到内部循环系统，被水源热泵吸收，再传送到

用户循环系统。这套系统只取热不取水，封闭式生产，不产生污染。热泵另一头连着独立的供热管道，管道里的循环水流进热泵，提热到60℃左右后输送至千家万户。“以前供暖锅炉房就在小区附近，冬天烟囱冒烟，居民很受影响。”家住石南小区的文春华说。2017 年冬季，她家里用地热供暖的效果很好，只穿秋衣都不冷，而居民区里的烟囱少了，空气质量变好了。

据项目设计单位测算，一期改造项目供暖面积为235.66万平方米，涉及910多栋住宅和部分公用建筑，受惠居民超过2.2万户，每年可替代标煤3.77万吨，减排二氧化碳9.43万吨、二氧化硫905吨、氮氧化物264吨。待二期项目完成后，减排量将更多。

南方的冬季湿冷难耐，南方人经常羡慕北方人能享受“集中供暖”。地热供暖效果好又环保，能否大范围推广？“潜江的地热资源丰富，便于利用。”潜江市建材发展与建筑节能办公室相关负责人表示。而且，江汉油田的职工小区原本就有供暖管道，新建的地热站只要接上这些管道即可，部分站房地面建筑可充分利用，省去了很多工程量，这也是项目建得快、投运得快的重要原因。

江汉油田地热供暖改造后，取暖成本会不会提高呢？据了解，江汉油田的供暖费用，原先均由企业承担，随着国有企业“四供一业”（供水、供电、供热、供气）分离移交工作逐步展开，今后供暖按户收费是大势所趋，地热供暖节能30%左右，综合效益物有所值。

节选自《湖北日报》

我国地热能开发利用情况及发展趋势分析

ANALYSIS OF CHINA'S GEOTHERMAL ENERGY DEVELOPMENT AND UTILIZATION AND DEVELOPMENT TREND

作者：胡甲国（中国石化集团新星石油有限责任公司）

0 引言

地热能是指能够经济地被人类所利用的地球内部的热能，其总量丰富、能量密度大、分布广泛，具有绿色低碳、适用性强、稳定性好等特点，与风能、水能等其他新能源相比，受外界因素影响小，是一种发展潜力巨大的可再生能源。在能源革命、大气污染治理、北方清洁供暖的大背景下，地热能作为一种极具竞争力的清洁可再生能源，将发挥日益重要的作用。

1 开发现状

资源情况

我国地热能资源丰富，据国土资源部2015年发布的数据，4000 m 以浅水热型地热资源量折合标准煤为12500亿t，年可采资源量折合标准煤为18.7亿t；全国336个地级以上城市浅层地热能资源每年可开采量折合标准煤为7亿t，干热岩资源折合标准煤为856万亿t 。

浅层地热能开发情况

我国浅层地热能开发利用起步较晚。近几年，我国开始大力推进浅层地热能的开发利用，据调查研究，目前我国大多数省市都有浅层地热能开发利用项目，项目主要集中在东北、华北等地，其中山东、河北、辽宁、河南、北京、天津等省市约占80%。截至2016 年底，全国利用浅层地热能的建筑物面积已达4.78 亿m^2。

经过多年的努力，我国地热能直接利用取得了可喜的成绩。截至2015年底，我国地热能年利用量折合标准煤2000万t，占一次能源消费的0.465%，排名世界第一。我国地热能直接利用发生了结构性的变化，地热供暖取代温泉疗养成为地热开发利用的最主要方式，地热资源属性得以彰显，供暖将成为地热能未来主要的发展方向。

2 开发建议

1) 地热能勘察是为民生工程服务，建议采用

由政府组织、企业实施、固定财政支出的渠道，齐心协力将地热能勘察清楚，为地热能大规模开发打下坚实的基础。

2) 建立地热产业准入制度及地热能勘察开发和保护制度，完善地热产业技术标准，规范地热产业的投资行为，对地热能的开发、利用进行立法，严格监管。

3) 地热能是清洁能源，地热能供暖费价格不应低于采用清洁能源的锅炉的供暖价格；同时地热能供暖应享受政府对供热企业的补贴，补贴不应低于清洁能源供暖企业。

4) 地热能是一种可再生能源，对于地热发电项目，相关部门需按照可再生能源电价的相关要求，对地热发电上网电价给予补贴。对于地热能供暖制冷的项目，运行电价参照居民用电价格执行；实行分档计量的，按最低档价格计费。

5) 对于完全回灌的地热能开发项目，采用减免税费的办法调动地热产业的积极性，在保护水资源的同时，提高项目的盈利能力，推进地热产业持续健康发展。

3 地热前景

在中央财经领导小组第十四次财经会议上，习近平总书记指出，推进北方地区冬季清洁取暖，尽可能利用清洁能源，加快提高清洁化供暖比重。李克强总理作政府工作报告时指出，2017 年要坚决打好蓝天保卫战，全面推进污染源治理。根据《锅炉大气污染排放标准》《火电厂大气污染物排放标准》计算可知，采暖锅炉污染物排放量是电厂锅炉的数倍，散煤直燃的污染物排放量更是工业燃煤的十几倍，燃煤供暖污染严重。打好蓝天保卫战，需加快解决燃煤污染问题，全面实施散煤综合治理。地热替代燃煤锅炉和散煤供暖，几乎不产生污染物，为贯彻落实习近平总书记关于“推进北方地区冬季清洁取暖”重要讲话精神和2017 年政府工作报告“坚决打好蓝天保卫战”重点工作任务提供了一条重要路径。

4 结论

大力发展可再生能源，促进我国能源结构优化调整，是我国未来能源发展的主要方向。地热能作为一种极具竞争力的可再生能源，随着《地热能开发利用“十三五”规划》的出台及“北方地区清洁取暖” 工作的推进，地热能将在我国能源转型中发挥越来越重要的作用。

北京五大重点功能区 2018 年将新增热泵供暖面积 400 万平方米

NEWLY INCREASE OF 4,000,000M² HEAT PUMP HEATING AREA IN 2018 IN FIVE KEY FUNCTIONAL AREAS OF BEIJING


北京市发展和改革委员会
BEIJING MUNICIPAL COMMISSION OF DEVELOPMENT AND REFORM
政务信息 政民互动 办事服务 查询服务
关于印发北京市2018年能源工作要点的通知
2018年04月25日
各区人民政府，市政府各委、办、局，各能源企业：
经市政府同意，现将《北京市2018年能源工作要点》印发给你们，请结合实际认真贯彻落实。
特此通知。
北京市能源与经济运行调节工作领导小组办公室

2018 年 4 月 25 日，北京市能源与经济运行调节工作领导小组办公室印发《北京市 2018 年能源工作要点》，指出 2018 年北京市将持续推进农村“煤改清洁能源”工程，完成 450 个村庄和 502 个村委会、村民公共活动场所的“煤改清洁能源”任务，开展山区村庄“煤改清洁能源”工作试点，基本实现全市平原地区无煤化。

同时，北京市 2018 年还将大力发展可再生能源，提升可再生能源利用规模，以城市副中心、北京新机场临空经济区、怀柔科学城、冬奥会、世园会五大重点功能区为重点，推动国际一流的新能源高端示范区建设。推进热泵系统供暖，新增热泵供暖面积 400 万平方米。

研究完善北京市热泵利用政策，进一步促进规模化应用水平。建成北京城市副中心行政办公区启动区地热“两能”供暖制冷系统，可再生能源比重力争达到 40% 以上。实施清洁供暖惠农工程，推进地源热泵等技术在农户、村民公共活动场所、公共文化设施等场所的应用，鼓励整村实施新能源供暖系统改造，力争建成 20 个新能源供暖示范村。

坚决打好污染防治攻坚战 推动生态文明建设迈上新台阶

RESOLUTELY FIGHT AGAINST THE POLLUTION PREVENTION AND CONTROL, AND DRIVE THE ECOLOGICAL CIVILIZATION CONSTRUCTION TO A NEW STAGE

日前，全国生态环境保护大会在北京召开。中共中央总书记、国家主席、中央军委主席习近平出席会议并发表重要讲话。他强调，要自觉把经济社会发展同生态文明建设统筹起来，充分发挥党的领导和我国社会主义制度能够集中力量办大事的政治优势，充分利用改革开放 40 年来积累的坚实物质基础，加大力度推进生态文明建设、解决生态环境问题，坚决打好污染防治攻坚战，推动我国生态文明建设迈上新台阶。

习近平在讲话中强调，生态文明建设是关系中华民族永续发展的根本大计。中华民族向来尊重自然、热爱自然，绵延 5000 多年的中华文明孕育着丰富的生态文化。生态兴则文明兴，生态衰则文明衰。党的十八大以来，我们开展一系列根本性、开创性、长远性工作，加快推进生态文明顶层设计和制度体系建设，加强法治建设，建立并实施中央环境保护督察制度，大力推动绿色发展，深入实施大气、水、土壤污染防治三大行动计划，率先发布《中国落实 2030 年可持续发展议程国别方案》，实施《国家应对气候变化规划（2014 – 2020 年）》，推动生态环境保护发生历史性、转折性、全局性变化。

习近平指出，新时代推进生态文明建设，必须坚持好以下原则。

一是坚持人与自然和谐共生，坚持节约优先、保护优先、自然恢复为主的方针，像保护眼睛一样保护生态环境，像对待生命一样对待生态环境，让自然生态美景永驻人间，还自然以宁静、和谐、美丽。

二是绿水青山就是金山银山，贯彻创新、协调、绿色、开放、共享的发展理念，加快形成节约资源和保护环境的空间格局、产业结构、生产方式、生活方式，给自然生态留下休养生息的时间和空间。

三是良好生态环境是最普惠的民生福祉，坚持生态惠民、生态利民、生态为民，重点解决损害群众健康的突出环境问题，不断满足人民日益

增长的优美生态环境需要。

四是山水林田湖草是生命共同体，要统筹兼顾、整体施策、多措并举，全方位、全地域、全过程开展生态文明建设。

五是用最严格制度最严密法治保护生态环境，加快制度创新，强化制度执行，让制度成为刚性的约束和不可触碰的高压线。

六是共谋全球生态文明建设，深度参与全球环境治理，形成世界环境保护和可持续发展的解决方案，引导应对气候变化国际合作。

习近平强调，要把解决突出生态环境问题作为民生优先领域。坚决打赢蓝天保卫战是重中之重，要以空气质量明显改善为刚性要求，强化联防联控，基本消除重污染天气，还老百姓蓝天白云、繁星闪烁。要深入实施水污染防治行动计划，保障饮用水安全，基本消灭城市黑臭水体，还给老百姓清水绿岸、鱼翔浅底的景象。要全面落实土壤污染防治行动计划，突出重点区域、行业和污染物，强化土壤污染管控和修复，有效防范风险，让老百姓吃得放心、住得安心。要持续开展农村人居环境整治行动，打造美丽乡村，为老百姓留住鸟语花香田园风光。

习近平强调，要提高环境治理水平。要充分运用市场化手段，完善资源环境价格机制，采取多种方式支持政府和社会资本合作项目，加大重大项目科技攻关，对涉及经济社会发展的重大生态环境问题开展对策性研究。要实施积极应对气候变化国家战略，推动和引导建立公平合理、合作共赢的全球气候治理体系，彰显我国负责任大国形象，推动构建人类命运共同体。

地热是北方地区清洁取暖的有效补充

GEOTHERMAL ENERGY IS AN EFFECTIVE SUPPLEMENT TO CLEAN HEATING IN NORTHERN REGION

地热是一种清洁可再生能源，地热是来自地球内部核裂变产生的一种能量资源。地球是一个庞大的热库，蕴藏着巨大的热能，这种热量渗出地表，于是就有了地热。地热能是一种清洁能源，是可再生能源，其开发前景十分广阔。党的十九大报告指出，我国经济已由高速增长转变为高质量发展。高质量发展要更好地满足人民日益增长的美好生活需要，北方地区清洁取暖是美好生活需要的具体表现形式之一。

北方地区冬季取暖有多种方式，包括燃气集中供暖、燃煤集中供暖、散煤燃烧以及电能、太阳能、空气能、空气源热能、地热等分布式采暖等方式，而散煤燃烧和不清洁燃煤集中供暖是造成北方地区雾霾严重的重要原因。

清洁取暖包括清洁燃煤、电能、太阳能、空气能、空气源热能、生物质能、地热等多种方式。地热是一种清洁可再生能源，地热是来自地球内部核裂变产生的一种能量资源。地球是一个庞大的热库，蕴藏着巨大的热能，这种热量渗出地表，于是就有了地热。依据地热资源的埋深及存在形式可分为浅层地热资源、水热型地热资源和干热岩地热资源。浅层地热能即地下二百米以浅，储存在岩石、土壤中或地下水里的热能。它是地球内部的热和太阳辐射的热两相平衡的结果，在这个范围内，温度基本是恒定的，既可供暖，也可制冷。

水热型地热资源是以蒸气为主的地热资源和以液态水为主的地热资源的统称，根据其温度可分为高温 (>150℃)、中温 (90℃ ~ 150℃)、低温 (<90℃) 三种类型。热干岩型地热资源是蕴藏在热干岩体中的地热资源，储热岩体中不存在热水和蒸汽，埋深三千米以上。其温度可达到数百摄氏度，但是由于地表缺乏大气降水，或者因为其本身的透水能力太差，不能形成水热型地热资源，而岩体所蕴藏的大量热能目前还难以直接利用。

我国地热资源十分丰富，地热资源总量占世界的 7.9%，可采储量相当于 4626.5 亿吨标准煤。据国土资源部中国地质调查局统计，截至目前，我国 337 个主要城市浅层地热能可开采资源量折合标准煤七亿吨，相当于全国用于供暖制冷总能源消耗的 60%以上；可实现建筑物供暖制冷面积 320 亿平方米，相当于现状总面积的两倍以上。

截至 2015 年底，我国年利用浅层地热能对建筑物供暖制冷面积为 3.92 亿平方米，其中京津冀 8500 万平方米，约占全国的 20%，是我国浅层地热能开发程度最高、用于建筑物供暖制冷规模最大的地区。

汪集暘院士为你讲述地热能的“前世 今生 未来”

ACADEMICIAN WANG JIYANG EXPOUNDS THE PAST, PRESENT AND FUTURE OF GEOTHERMAL ENERGY FOR YOU

中国科学院院士、中国地源热泵产业联盟名誉理事长汪集暘院士于北京大学建筑与景观设计学院，开展了题为“地热——一种地球本土的未来能源”的学术报告。报告围绕地热的概念、开发地热的原因、国内外地热开发利用现状、地热开发利用方向、以及未来展望几方面内容展开。

汪院士讲述了其研究领域为地下水，并由地下凉水（水资源）转为地下热水（地热资源），指出二者并无本质区别，都来自于大气降水，只是降水循环深浅不同，我们应将地球水圈视为整体，不应把地表水与地下水完全隔离开来。

1. 地热的概念

首先，汪院士提出了地热既是地球的本土能源，又是地球的未来能源。能源是人类赖以生存不可或缺的生活资料，人类的能源利用经历了从薪碳、木材到煤炭、石油、天然气的过程。核能和可再生能源将逐渐成为主要能源，是能源界目前较为一致的看法。在可再生能源中，太阳能、风能、生物质能、海洋能都来自于太阳，只有地热是蕴藏于地球内部的热量。据研究显示，地球还有 46 亿年的生命，正处于其壮年期，仍在发生发展中。

2. 开发地热的原因

汪院士介绍了地热能具有资源量大、稳定、能源利用效率高等优点。相较于太阳能、风能等发电方式，地热发电在成本上具有竞争力，二氧化碳减排优势明显。地热在未来能源结构中贡献非常突出。根据曹耀峰院士统计，按照《国家能源十三五规划》，我国非化石能源占比将从 2015 年的 12%，提高到 2020 年的 15%。届时，在可再生能源 3 个百分点的增幅中，地热发电与非电直接利用可以占到 1/3，与太阳能、风能等非化石能源并列，“三分天下有其一”。

3. 地热开发利用现状

水热型地热资源类型依据水温划分为低温（< 90℃）、中低温（90℃ -150℃）和高温（> 150℃）地热资源。一般而言，高温水热型鼓励用于发电，中低温水热型建议非电直接利用。从全球来看，高温水热型地热资源主要分布于意大

利、墨西哥、印尼、冰岛、菲律宾、日本、美国，主导了全球高温地热发电增长。我国以中低温水热型地热资源为主，高温水热型主要分布于滇藏、环太平洋带等区域。

根据国际地热协会（IGA）2015 年最新统计数据显示，全球地热发电总量为 12.6GW，尽管与太阳能、风能发电量相比不算很大，但对于具有高温地热资源的国家而言却十分重要。

我们国家对于地热开发利用非常重视，20 多年来地热直接利用量一直占据世界第一。地热能的利用能够为冬季取暖、夏季制冷提供清洁能源，有助于节能减排和雾霾治理。我国雾霾成分与成因都非常复杂。本质上讲，燃煤是罪魁祸首，应大力开发地热取代燃煤，通过源头控制以减少污染物排放。

京津冀地区是雾霾治理重点区域，作为国家级新区，雄安新区的能源建设备受重视，确定了雄县地区以地热为主的集中供热以代替燃煤的雄县模式。一方面，该地区地热资源得天独厚，异常丰富；另一方面，该地区也基本是雾霾最严重的地区。雄县模式的建立，推动了该地区大型岩溶热储的规模化可持续利用。许多国外学者参观到访后，在国际会议上表示中低温的地热利用要到中国雄县去看。

4. 地热开发利用方向

根据我国地质条件与开发利用情况，其提出了地热能开发利用应遵循的几项原则。总体而言，是梯级开发、综合利用，从高温到低温，吃干榨净。

第一，“热”、“电”并举，以“热”为主。我国以中低温地热资源为主的条件、雾霾治理的需求与东部供暖的大量刚需，决定了其主要利用方式为直接利用。第二，“深”、“浅”结合，由“浅”及“深”。浅层地热能通常位于地表以下 200m 深度范围内；中低温水热系统深度大概在 200m ~ 3km，既有水又有热；高温地热能大概分布在 3km 以上，有热无水，称为干热岩，这部分地热资源量大但很难取。我国 3km 内水热系统尚有很大利用空间，应该结合我国地质、地热等资源条件与实际需求等实际情况进行合理利用。第三，“东”、“西”兼顾，“西”电“东”热。高温地热资源主要分布在西部，东部以中低温为主，不宜用于发电。第四，“干”、“湿”有度，先“湿”后“干”。先将湿的水热型地热系统用完后，再开辟其他类型。

国家发改委、能源局及国土资源部于 2017 年 2 月联合发布了《地热能开发利用“十三五”规划》，以推动地热能规模化开发利用。提出京津冀北方城镇推广中深层地热集中供暖，长江中下游地区推广地源热泵供暖制冷应用，以及推进西藏高温地热发电项目建设和中低温地热发电试验。

此外，我国东部包括大庆油田在内的一批油田，虽已进入开发后期，但其中隐藏着大量的地热资源，开发潜力巨大，油田可变热田。

5. 展望

报告最后，汪院士展望了未来新能源和可再生能源的发展方向。强调了地热是非常宝贵的地球本土能源与极有希望的未来能源，一定要大力开发、科学开发。提出并倡导发展“地热 +”的概念，即应将地热能的开发利用与太阳能、风能、生物质能、海洋能结合，做到“天”（太阳能）“地”（地热能）合一、“动”（风能）“静”（地热能）结合，综合开发利用、多重互补。当前地热开发利用已进入了新阶段。瑞士学者于目前所做研究中，提出了“地球电池”的构想，试图将地下热水储层变成能够储存能量的储热层，并依据我国弃风弃电数据制图，指出了这部分能量可以储存于地下热储层或含水层以备用。由此可见，地热能作为未来能源的前景不可估量。

大力推进低温绿色储粮技术革新

ROBUSTLY PROMOTE LOW TEMPERATURE AND GREEN GRAIN STORAGE TECHNICAL RENOVATION

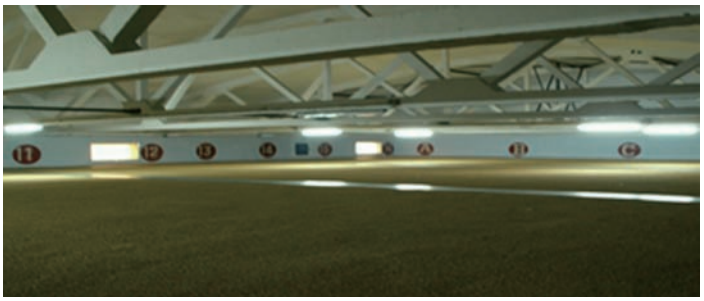
四川省紧紧围绕粮食供给侧结构性改革，大力实施低温绿色储粮工程，打造低碳环保的粮食仓储体系，着力提高粮食供给质量，有力促进了粮食流通产业转型发展。

聚焦问题，找准路径

牢固树立和践行绿色发展理念，立足粮食供给侧结构性改革需求，运用浅层地能、水冷、风冷等绿色储粮新技术，大规模推进低温绿色储粮技术运用，形成了“民生优先、技术多样、标准健全”的多层次、宽领域、结构配套、功能完善的低温绿色储粮体系。

精准发力，稳步实施

从 2010 年起，先后开展综合控温储粮、浅层地能低温储粮技术应用试点，逐步明晰适合四川储粮生态条件的低温储粮技术路线。出台《四川省粮食低温储备库建设规划》，从 2014 年起，投资 50 亿元（其中省级财政补助 14 亿元），计划用 5~7 年时间建设粮食低温储备库 173 个、总仓容 607 万吨，占全省有效仓容的 50% 以上。四川省委、省政府将低温绿色粮库建设作为“粮安工程”的重要组成部分，纳入“省长工程”。目前，已落实省级财政资金 11 亿元，启动建设项目 144 个。



储粮仓内降温作业

注重实效，强化应用

及时组织有关市（州）、企业深入开展低温技术应用研究，通过粮情数据收集、样本分析比对、能耗在线监测、经济效益分析等，初步形成四川低温粮库技术应用经验。拓展延伸，融合发展。注重低温储粮对粮食行业上下游产业的引导、带动和支撑，通过对一二三产业资源的整合，初步构建“产购储加销”一体化的全绿色产业链，推动了粮食产业转型升级，提高了粮食产业发展的质

量和效益。低温绿色储粮效益逐步显现，主要体现在：防止污染，利于环保。低温仓的用药量大幅度减少，有效避免粮食储藏过程中使用化学杀虫药剂对粮食和环境产生的污染。减少粮损，利于保持品质。低温技术大幅度减少粮食水分和干物质损失，同时保持了粮食的新鲜度和营养价值。为企业增效，利于发展。每吨粮食可增加 100 元以上的综合收益，提高了粮食仓储企业效益和粮食供给质量，产生了良好的社会效益。

恒有源地能热泵技术在绿色储粮系统中的应用

恒有源单井循环换热地能热泵技术成功应用于绿色储粮系统。在南方已有几个万吨级绿色储粮项目采用，取得了显著成效：

1. 实现了节能与环保的统一

采用恒有源技术的低温储粮系统比谷物冷却机（国家标准 0.5 kW · h/t · ℃）节能 60% 以上。单位能耗仅为 0.20 kW · h/t · ℃，运行中没有任何污染物产生。系统的能效比达到了 3.05。

2. 减少了粮食水分损耗，提高了储粮的质量

传统机械通风是通入自然冷空气，湿度无法控制和调节。且在与外界空气的对流循环过程中，不可避免的会带走部分粮食水分。恒有源低温储粮系统通入的冷风是利用仓内回收的空气进行制冷。由于是封闭内循环，保水效果好。

3. 经济效益显著

以 15 年计算设备投资分摊，3 年可收回投资。

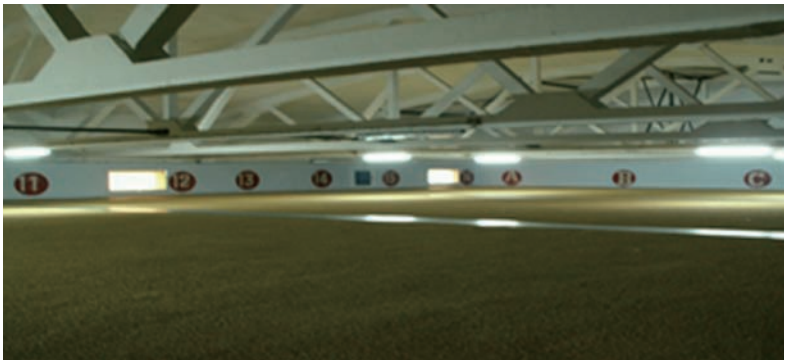
恒有源单井循环换热地能采集井和可移动的热泵装置

Robustly Promote Low-temperature and Green Grain Storage Technical Renovation

Sichuan Province closely centers around the structural reform in the grain supply side, robustly implements the low-temperature and green grain storage project, creates the low-carbon and environmentally-friendly grain storage system, and exerts great efforts to improve the grain supply quality, which strongly facilitates the transformation and development of grain circulation industry.

Focus on the problems and pinpoint the path

Firmly build and fulfill the green development philosophy, and, based on the structural reform requirements in the grain supply side, by the shallow geothermal energy, water cooling, air cooling and other new green grain storage technologies, boost the application of low-temperature and green grain storage technology on a large scale, and form the multi-level, wide-ranging, structurally-supported, and functionally perfect low-temperature and green grain storage system characterized by “people's livelihood priority, diversified technology and sound standard”.



Cooling Operation in the Grain Warehouse

Accurately exert the efforts and steadily conduct the implementation

From 2010, the pilot application of comprehensive temperature control grain storage and shallow geothermal energy low-temperature grain storage technologies has been carried out successively, and the low-temperature grain storage technical route meeting the grain storage ecological conditions in Sichuan is gradually specified. The Program for the Construction of Low-temperature Grain Reserve Warehouse of Sichuan Province has been launched. From 2014, RMB 5 billion (including RMB 1.4 billion provincial financial subsidies) will be invested, and it is planned that 173 low-temperature grain reserve warehouses will be constructed in 5-7 years, with the total capacity of 6,070,000t, accounting for more than 50% of effective capacity of the whole province. The Provincial Party Committee and the People's Government of Sichuan regard the construction of low-temperature and green grain warehouse as an important part of "grain security engineering", and bring it into the "Provincial Governor Engineering". At present, RMB 1.1 billion provincial financial funds have been implemented, and 144 construction projects have been started.

Pay close attention to the actual effects and enhance the application

Organize in time relevant cities (prefectures) and enterprises to deeply conduct the researches on low-temperature technical application, and preliminarily form the low-temperature grain warehouse technical application experience of Sichuan through the grain information and data collection, sample analysis and comparison, online energy consumption monitoring and economic benefit analysis; carry out the expansion and extension and integrative development; pay close attention to the low-temperature grain storage's guidance, promotion and support for the upstream and downstream industries in the grain industry, and initially establish the "production, purchase, storage, processing and marketing" integrated all green industrial chain through the integration of resources in the primary industry, secondary industry and tertiary industry, which drives the transformation and upgrade of grain industry and improves the quality and benefit of grain industrial development; the low-temperature and green grain storage benefits gradually appear, and they are mainly embodied in:

pollution prevention and beneficial for environmental protection; the used chemicals of low-temperature warehouse are greatly reduced, and the grain and environmental pollution due to the use of insecticide during the grain storage process is effectively avoided; the grain losses are decreased and it is favorable for maintaining the quality; the low-temperature technology drastically reduces the grain water and dry substance losses, and retains the grain freshness and nutritional value; it increases the benefits for the enterprise and it is favorable for the development; more than RMB 100 comprehensive earnings may be increased for each ton of grain, the grain storage enterprise's benefits and grain supply quality are improved, and good social benefits are achieved.

Application of Ever Source's geothermal energy heat pump technology in the green grain storage system

Ever Source's single well cyclic heat transfer geothermal energy heat pump technology is successfully applied in the green grain storage system. In the south, there are several 10,000t green grain storage projects adopting this technology, and they have achieved remarkable effects:

1. Realize the energy saving and environmental protection unification

The low-temperature grain storage system by Ever Source's technology saves more than 60% energy compared with the grain cooler (national standard 0.5 kW·h/t·°C). The unit energy consumption is only 0.20 kW·h/t·°C, and there is no pollutant during the operation. The energy efficiency ratio of the system is 3.05.

2. Reduce the grain water loss and improve the grain storage quality

In the traditional mechanical ventilation, the natural cold air enters, and the humidity cannot be controlled or regulated. Moreover, during the circulation with the external air, some grain water will be taken away inevitably. However, the cold air in Ever Source's low-temperature grain storage system is refrigerated by the air recycled in the warehouse. Since it is the closed internal circulation, the waterretaining effect is good.

3. Remarkable economic benefits

If the equipment investment apportionment is calculated per 15 years, investment may be recovered in 3 years.

Ever Source's Single Well Cyclic Heat Transfer Geothermal Energy Collection Well and Mobile Heat Pump Device

增强型地热工程国际最新研究进展与开发前景展望

AN UPDATE OF GLOBAL REVIEW AND DEVELOPMENT PROSPECTS OF ENHANCED GEOTHERMAL SYSTEMS

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摘要：增强型地热工程（Enhanced Geothermal Systems, EGS）是指通过水力压裂等工程手段在地下低渗透性高温岩体中形成具有经济价值的可持续开发人工地热系统。EGS 的研究与开发已有 40 余年历史，截至 2018 年初，已有 11 个国家开展了 47 个 EGS 工程。我国目前尚未建成 EGS 示范工程，实现干热岩的商业化开发仍面临高温钻探、储层改造、系统维护等方面的技术挑战。本文总结了世界最新的 EGS 工程研究进展，分析不同地质背景下 EGS 工程的实践经验及发展趋势，对比我国近几年干热岩资源勘探情况，为我国 EGS 工程的建设和推广提供参考借鉴。

0. 前言

随着经济社会的快速发展，传统化石能源日渐短缺且引起了不可忽视的环境污染。干热岩因其储量巨大、分布广泛、清洁稳定，符合现代工业社会的需求，已成为各个国家积极开发和研究的战略型资源。基于干热岩资源开发技术提出的增强型地热系统 (Enhanced Geothermal System, EGS)，已经历 40 余年的研究，在理论研究和工程实践中取得了重要成果，积累了丰富经验。

干热岩 (Hot Dry Rock, HDR) 一般指赋存于地下 3-10 km、温度在 150-650℃的具有经济

开发价值的高温岩体。2018 年 5 月在北京召开的能源行业地热能专业标准化技术委员会一届二次会议上通过的《地热能术语》中则将干热岩的界定温度提高至 180℃以上。随着地球向深部的地热增温，只要达到一定深度在任何地区都可以开发出干热岩资源，而不受传统水热型地热资源的地质条件限制。保守估计，地壳中干热岩所蕴含的能量相当于全球所有石油、天然气和煤炭所蕴藏能量的 30 倍。中国地处欧亚板块的东南边缘，大地构造环境处于太平洋、菲律宾、印度几大板块的挤压环境中，为干热岩资源的形成提供了优越地质条件。据测算，我国地下 3-10 km 范围内干热岩资源折合标准煤 860 万亿吨，高于美国干热岩资源量（570 万亿吨标准煤），埋深 3.5-7.5 km、温度介于 150-250℃间的干热岩资源折合标准煤 215 万亿吨，相当于目前年度能量消耗总量的 4.8×104 倍（2017 年中国能源消费总量 44.9 亿吨标准煤）。

基于干热岩的概念，美国最先提出通过人工压裂等储层改造手段从干热岩体中经济地采出高温热能的增强型地热系统。自 1973 年美国在 Fenton Hill 开展了首个干热岩开发试验项目以来，40 多年间的技术测试和改进验证了 EGS 概念的可行性，日趋完善的勘探开发技术也逐渐打破地质条件的限制，向着更具普适性的地热资源发展。EGS 将成为地热资源的主要开发方式，预计 2050 年全球 EGS 的装机容量将超过 70GWe。

但目前成功运行的 EGS 项目屈指可数，实现 EGS 的商业化运行仍面临技术、经济的巨大挑战。中国幅员辽阔，干热岩资源的地质成因模式类型多样。因此，结合场地的地质条件特点，因地制宜开发是我国成功建设 EGS 工程的关键。本文根据不同地质背景的干热岩资源的最新开发利用现状及研究进展，总结了不同地质条件下 EGS 工程建设、运行、维护的实践经验，分析干热岩资源开发的前景，为我国未来 EGS 工程成功开发提供参考建议。

1. 增强型地热工程开发现状

1.1 美国 Newberry EGS 工程

2010 年，AltaRock 公司在位于俄勒冈州中部的 Newberry 火山启动了 EGS 工程，以利用新近火山地带较高的地温。2012 年，项目完成了场地勘查和微震监测网络布设，钻成 3067 m 深的回灌井 NWG 55-29，井底温度高达 331 ° C。2012-2014 年对该井进行了水力压裂。前期的实践经验表明水力压裂过程中裂隙总是沿着最小水力剪切压力的原生裂隙打开，难以在储层中形成新裂隙，导致储层改造效率低。为有效增加单井的产热率，Newberry 项目提出借助热降解隔离材料（Thermal degradable zonal isolation materials，TZIM）进行多层水力压裂的储层改造方案。所使用的热降解隔离材料是一种颗粒状或纤维状的暂堵剂，可在一定温度区间内分解为无毒无害的可溶物。在压裂的过程中首先利用较小的注入压力刺激原生裂隙张开，然后注入 TZIM 进行封堵，再加大注入压力，形成新裂隙，从而实现储层的多级次刺激。压裂结束后，升高井筒温度，使 TZIM 降解，并回收。2014 年 8 月开展了为期 4 周的水力压裂，总注水量达 9500 m3，最大井口压力达 19.5 MPa。在水力压裂的最后阶段注入了 TZIM，测温记录显示至少对两个断裂流动区形成了封堵，并额外形成了一至两个断裂区。微震监测及水力试验结果显示，成功完成约 1.5 km3 的储层改造，回灌指数从 0.009 提升至 0.045 (L/s)/bar。由于资金问题，该项目未按原计划施工深部开采井，而是提出开发超高温地热资源的新思路。

1.2 澳大利亚 Paralana EGS 工程

澳大利亚南部的花岗岩含有丰富的放射性元素（如铀、钍），且形成一定规模的浅层高温储层。2003 年，Geodynamics Limited (GDY) 公司在阿德莱德启动了 Habanero 项目。该项目开展了多次水力压裂和井间试验，且建立了二元发电厂，由于未实现经济效益，已停滞。但在项目的场地选址、钻探、储层改造、测试评价的各个阶段积累了宝贵经验，为未来 EGS 工程的建设提供了参考。

1.3 法国 Rittershoffen EGS 工程

1987 年法国在上莱茵地堑（The Upper Rhine Graben，URG）开展了 Soultz EGS 项目，拉开了中低温沉积盆地型干热岩资源研究的序幕。该项目于 2009 年建成了装机容量 1.5 MWe 的 ORC 二元电站，首次实现了 EGS 的商业发电。借鉴 Soultz 项目的成功经验，2011 年在其东侧 6 km 处的 Rittershoffen 地区启动了以花岗岩基底断层区为目标层位的 EGS 项目。2012 年 9-12 月项目完成了 2580 m 深的钻井 GRT-1，并开展了相关的水力试验及微震测试，以确定 GRT-2 井钻入断层区。2014 年完成 3196 m 深的 GRT-2 生产井。GRT-1 井初始水力连通性较差，经过水力压裂、热刺激和化学刺激注入能力提高近 4 倍，与 GRT-2 井组成产流量 70 L/s/、产流温度 170℃的地热井对。2016 年该项目实现全面运行，为距场地 15 km 处的淀粉制造厂提供 24 MWth 的工业热能，成为法国首个提供高温热水的 EGS 工程。该项目建成了由 17 个测站组成的微震监测网络，且利用基于地震波峰移动的自动监测软件 Waveloc，实现了对场地微震活动的探测，采集和定位的综合记录 [ ]。沉积盆地型干热岩分布普遍，尽管温度条件较差，但通过供暖可实现工业农业多领域的广泛应用。

1.4 韩国 Pohang EGS 工程

干热岩资源的开发利用为缺乏近代岩浆活动和强烈构造运动成因的高温地热资源的国家和地区带来了新的发展机遇。2010 年 12 月韩国在 Pohang 启动了首个 EGS 项目，旨在通过开发沉积盆地型干热岩资源弥补其高温地热资源的匮乏。石油钻井资料显示 Pohang 地区地温梯度达 48.8℃ /km，大地热流 89 mW/m2。项目先后完成了 4,127 m 深的 PX-1 井和 4,348 m 的 PX-2 井。2016 年在 PX-2 井底 140 m 的裸孔段进行了首次水力压裂，期间监测到震级最高的微震事件为 1.4ML，相比于前期的 EGS 项目诱发地震问题得到了缓解。项目后续还将进行 PX-1 井的水力压裂，并设计完成第三口干热岩钻井，以建成装机容量 1 MWe 的 EGS 电站。

2. 我国增强型地热工程前景展望

我国的干热岩研究起步较晚，但随着国家支持力度的增加，在干热岩资源靶区筛选定位、高温深部钻探、地下多组分、多向流体反应溶质运移模拟等方面取得了突破性的研究成果。2012 年，国家“863”项目“干热岩热能开发与综合利用与综合利用关键技术研究”启动，开启了我国对干热岩的靶区工程测试及人工压裂工艺等系统的研究。2013 年，中国地质调查局出台了《全国干热岩勘查与开发示范实施方案（2013-2030）》，首次对中国干热岩勘查与开发工作进行了规范指导。2014 年，中国地质调查局与青海省共同组织开展了青海德贵、共和盆地干热岩勘查工作。2014 年首次在青海省贵德盆地地下 3000 m 钻获 151℃的干热岩。随着高温钻探技术的发展成熟，钻探深度也逐渐增加。2017 年在共和县恰卜恰镇东南完成的 GR1 干热岩勘探孔再获温度新高，3705 m 深的孔底温度高达 236℃，实现了我国干热岩勘查与示范场地上的新突破。2018 年 3 月在海南

琼北，4387 m 深钻遇 185℃的高温花岗岩。目前在青海共和县恰卜恰镇施工的 GR2 干热岩钻井已钻至地下 4200 m，孔底温度高达 190℃，将继续加深至 5000 m。

2017 年《地热能开发利用“十三五”规划》的发布，为我国干热岩资源的开发利用指明了发展方向，为政产学研用联合创新提供了政策支持。随着我国“深地探测”计划的推进，青海贵德、共和等地实现了干热岩勘察的突破，为建立增强型地热工程提供了实践平台。

3. 结论与建议

纵观世界各国干热岩资源开发的实践经验及最新研究进展，为实现我国干热岩资源的高效开发利用，提出以下建议：

1. 查清资源靶区的地质条件，因地制宜建立 EGS 示范工程；

2. 加大对干热岩地热资源研究的投入，鼓励企业、科研机构对 EGS 工程建设中的钻探、储层激发、动态监测等关键技术形成研发联盟，建立数据资源共享平台，总结出一套适用于我国干热岩资源的开发体系。

3. 与其他可再生能源相比，干热岩资源具有储量大、分布广的特点，开发资源类型开发也逐渐由早期地表热显示明显的火山型干热岩转变为地质条件更稳定的沉积盆地型干热岩，具有更强的推广前景。

4. 非常规超高温地热系统的出现，为实现地热资源的商业开发提供了新思路，与传统干热岩相比具有更高的经济效益。

借鉴世界各国积累的增强型地热工程研究经验，随着研究力度的加强，我国有望凭借干热岩资源的开发利用在可再生能源方面取得长足进步和跨越式发展。

敬告读者

TO INFORM THE READER

《中国地热能》是由中国地热能出版社主办，北京节能环保促进会浅层地（热）能开发利用专业委员会协办的科技期刊，于香港公开发行，双语季刊。我们的办刊宗旨是为政府制定能源政策提供参考建议，为地能开发企业提供宣传平台；为设计者、大众提供交流空间；推广浅层地热能利用经验，展示应用实例。

2018 年，我们始终不忘读者的期待，用心用力办好期刊。毫无疑问，优化空气、节能减排、治理雾霾是当前摆在全体中国人民面前一个重大课题，我们期望《中国地热能》这本小小的期刊能够为攻克这一难题贡献微薄之力。

立足长远，着眼当前，在继承中创新，在变革中发展。自创刊以来，期刊一直得到了业内专家学者和广大读者的热情支持，在此致以我们的衷心感谢。大家的关注是我们的追求，大家的支持是我们的动力。让我们携手共进，在新的一年里共同打造《中国地热能》的美好明天。

《中国地热能》编辑部

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中國地熱能
CHINA GEOTHERMAL ENERGY

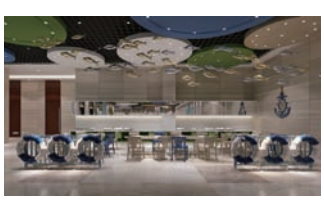
中国节能建筑·地能供热（冷）示范项目

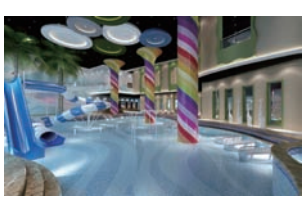
大连嘉乐比温泉度假酒店

▶ 酒店系中国节能环保集团公司旗下的中国地能产业集团有限公司（香港上市号 8128, 简称中国地能）的全资子公司－恒润丰置业（大连）有限公司投资建设，委托国内知名专业化酒店管理公司首旅建国酒店管理有限公司独家经营。以普及宣传水文化知识为主旨，以商务会议接待、家庭度假旅游为主营。采用产权式酒店方式管理运行。

▶ 酒店规划建设面积为 2.34 万平方米，开发投资 4 亿元。由中国建筑科学研究院、中国建筑技术集团有限公司以现代时尚的外观设计风格设计，以水文化在绿标建筑当中应用为概念，以地热（温泉）水、海水、淡水三种水的结合应用为展示。酒店的采暖、制冷及生活用水均由原创的恒有源地能热泵环境系统和地能热宝环境系统提供。

▶ 酒店拥有别墅 33 栋（66 套）、各类客房 237 间/套，大小会议室 4 个，SPA5 间，可以承接会议、团队及宴会；配有大型儿童娱乐设施，室内泳池、室外温泉泡池以及康乐设施，满足客户度假的不同需求。





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为推广地能热冷一体化新兴产业的发展，恒有源科技发展集团有限公司与四川长虹空调有限公司合资成立了宏源地能热宝技术有限公司。公司以智慧供热市场为导向，专注于地能热冷机各类产品的开发和各种形式的地能热宝系统的产品集成，推广地能无燃烧方式为建筑物智慧供热，满足人们舒适稳定的生活环境需求。

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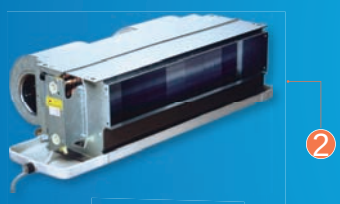

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